

PIR sensor-based automatic solar-powered UVC LED sterilizer lamp

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Received for publication
July 06, 2022.

Abstract

A PIR sensor-based automatic solar-powered UVC LED sterilizer lamp is UV-based air disinfection system that kills the microorganisms, including COVID-19 virus, floating freely in the air of a room. This lamp is designed using embedded system for automatic control of UV lamps based on the human presence. This is carefully designed to ensure that the end user is protected. The automatic detection unit shuts OFF the UV in case if a human is detected. The product is PV powered but also has an option with line 220 V mains supply. The bank of UV LEDS is completely enclosed. The battery is charged using a solar panel that has a backup of 8 h. This study includes the design and implementation of PIR sensor-based automatic solar-powered UVC LED sterilizer lamp using the components such as PIR sensor, DC-DC converter, Arduino board, PV panel, battery, charging circuit, and UV LED array.

Keywords

PIR sensor, PV panel, sterilizer, UVC LED, battery charging, DC-DC converter

1. Introduction

UV-based air disinfection involves killing the microorganisms floating freely in the air of a room using radiation. This is far more effective than the conventional means of disinfecting air which are generally ineffective. UV-C, the so-called short-wave UV, is a good air disinfectant that will inactivate the airborne organisms like CV-19 present within a room. The global pandemic COVID-19 has affected all of us in some way over the last few months, an uncertain period that has caused a degree of panic and/or desire for new equipment and methods to solve this problem. UV products for CV-19 protection as suggested by International Ultraviolet Association (IUA) minimize the effect of transmission of corona virus. UV irradiation and ozone are used in treating the virus but must be used with caution. Any useful UV is harmful to humans and animals unless they are completely protected from UVC irradiation. A global pandemic due

to COVID-19 affected more than 146 million people in 2019. The transmission of virus through air played a vital role in the spread of the disease. The viruses spread fast when the infected person sneezes. During the action of expiration, aerosols as well as respiratory droplets are created. The size of the aerosols during sneezing is $<5\ \mu\text{m}$. The size of the aerosols during talking and breathing is $<1\ \mu\text{m}$. The aerosols occur in different sizes in the respiratory tract and have corona virus in the infected persons. These viruses are influenced by the environmental conditions and physicochemical properties. When the virus is inhaled, it is deposited in the respiratory tract. Aerosols of larger size deposit in the upper airway, which control the quantity of medicines reaching lungs. Small-sized aerosols enter into the lungs. It has been proved through different case studies that the COVID-19 viruses spread through airborne transmission. The effect of virus is active when the distance between the persons is $<0.2\ \text{m}$. In 2021, WHO has officially

acknowledged that breathing in the aerosols containing virus will spread the virus. Low-pressure mercury vapor lamp and medium-pressure vapor lamp were used to produce light waves having short wave length. UV radiation does not help view the objects but it has the properties of visible light. Visible light that helps view objects has seven colors as it is seen in rainbow. UV radiation starts at the end of the visible radiation. Similar to visible light rays, UV radiation is an electromagnetic radiation. Similar to light rays, the UV radiation transmission takes place in the form of waves. These waves are measured in terms of their wavelength, which is the length of one cycle in the range of nanometers [1]. The intensity of the waves is measured in terms of their magnitude. The effects of different wavelengths of rays are different on human beings. Generally, cancer treatment uses high-energy gamma rays to destroy cancer cells. The wavelength of UV radiation lies between X-rays and visible light. The main source of UV radiation is sunlight. There are three ranges of wavelengths in UV radiation. Artificial UV radiation produced by human beings makes use of UV lamps. The exposure to UV radiation produces vitamin D in human beings [2].

At present, UVC sterilizer lamp uses UVC LED to produce light waves having short wave length. Generally, UV lamps make use of 20–200 mg mercury that produces adverse effects in the environment. The cost of mercury is high and its availability is less. The world environment has to be free from the usage of mercury products. The power consumed by these lamps is higher than LED lamps [3]. The heat produced by mercury lamps is higher than LED lamps. These disadvantages have led to the use of LED lamps instead of mercury lamps.

There is a great importance for the UVC radiation for killing the corona virus. UVC is one of the disinfectants to reduce the spread of corona virus in air. Therefore, the lamp developed using the UVC LED is named as germicidal lamp. The light rays of these lamps have the ability to inactivate the outer protein coating of the corona virus present in the air surface economically, efficiently, and quickly [4]. Even in case of closed rooms having air-conditioning facility, the different wave lengths of rays from UVC LED have the ability to kill the corona virus present in air. The transport department also needs an efficient method of killing corona virus in air in various transportations like bus, train, plane, etc. UVC LED lamps can be installed in these places to have a safe journey to people. The amount of energy required to kill the corona virus by the UVC LED lamps is very less.

By the proper installation of UVC LED lamps in the places where there is an exposure of the UVC radiation without direct exposure of the light to the human beings, corona virus can be killed. The direct exposure of UVC rays to the human beings has to be completely taken care when the lamp is installed [5]. The virus spreads from the human beings to the furniture through the infected person. It can be killed through the UVC LED lamps. The breath-in air should be free from corona virus. The spread of virus from the infected people to the uninfected people is very easy.

Corona virus in the air and the non-living things can be killed using UVC radiation from the UV LEDs. The health of the person depends on the surrounding air that the persons breath-in and also the drinking water quality. In crowded areas like shops, the virus can spread from one person to another easily through air by the contact with infected person. It has been found 40 years ago itself that the UVC radiation from UV LED lamps has the capacity to act as a disinfectant for killing the viruses in 6 s. This has been tested in the laboratory and the effects the UV LED radiation have been proved. Thus, the UVC radiation from the UV LED is useful to prevent the human beings living in an infected environment. There is a vast application of these UV LED lamps as a disinfectant practically [6]. The radiations from these lamps have the capacity to neutralize the virus and the spread of virus is completely prevented. The corona virus had a great impact in the daily life of human beings. Its effects reduce the global economy also. There were a great number of unexpected losses in the life of human beings due to the corona virus. There was a need to take many precautionary measures to safeguard the life of human beings. Some new ways like social distancing, wearing mask, and washing hand frequently were followed for safeguarding the human beings. There was a lockdown in countries to reduce the spread of the virus, and hence the production in industries was temporarily stopped.

The corona virus has a single-stranded protein capsid coating and RNA core. When the parts of the virus are deactivated, the virus becomes inactive in the surrounding area. The UV radiation from the UVC LED lamps could deactivate these viruses. The rays from the lamp have proper disinfection property. The design of these lamps is more flexible. The lamp can be operated as per the convenience of persons with less operating time. The voltage level for the operation of these lamps is less, which can be obtained from the PV panels. The UVC LED lamps are used for killing many types of pathogens. Due to the low

wavelength and narrow emission spectrum of UV LEDs, the output power is less. This led to the use of high-wavelength UV LEDs for the purpose of killing corona virus. This lamp operates using the power obtained from the PV panel.

The extraction of maximum power transfer for the PV-based battery storage system involves pulse width modulation (PWM) switching using the maximum power point tracking (MPPT) algorithm. This cannot be used in direct power transfer DC–DC converter. The perturb-and-observe (P&O) method is the commonly used MPPT algorithm for DC–DC power conversion [8–17]. At present, the use of three port converters for interfacing PV panel, battery, and load is highly recommended for renewable power system. The efficiency and the power density of these converters are high.

The organization of the paper is proposed UVC sterilizer lamp and is discussed in Section II. Block diagram of UV LED lamp with controller is discussed in Section III. UV sterilizer circuit is discussed in Section IV. Analysis of converter is discussed in Section V. PV power extraction is discussed in Section VI. Hardware is discussed in Section VII. The conclusion is dealt with in Section VIII.

II. Proposed UVC sterilizer

Figure 1 shows the block diagram of the proposed UV sterilizer. The solar panel is used as a power source in this circuit. The power collected from the solar panel is stored in the battery via charging circuit. Two sensors are employed for sensing the people in and people out. If in sensor senses count is increased to 1, then out sensor senses count is decreased to 1.

In this manner, the number of people inside the room is counted. Once the count becomes 0, Arduino insists the relay to switch on the UV sterilizer. The UVC sterilizer is made up of “n” number of UVC LEDs.

III. Block diagram of UV LED lamp with controller

In this UVC sterilizer lamp, lead acid batteries are used. These batteries are charged from a solar panel and the extra energy is stored for future usage. Solar energy can be converted into electrical energy using the PV panel. This can be done during the daytime and be stored in the battery.

The voltage obtained from the solar panel is fluctuating in nature. To change the voltage level of the panel output, DC–DC converter with controller is used. The converter output is stored in the battery. The battery voltage is regulated using a switch control to supply the required voltage to the UV LED lamp. Figure 2 shows the block diagram of the UVC sterilizer lamp along with its controller.

IV. UV sterilizer circuit

The UV sterilizer is made up of UV LEDs. The use of mercury in UV lamps led to environmental issues and the cost of these lamps is high. This has led the researchers around the globe to have mercury-free lamps for sterilization. While a traditional UV lamp has around 20–200 mg of mercury, UV LED lights are free from mercury. Additionally, as compared with traditional lamps, the energy consumption and heat generation of UV LED bulbs are significantly less.

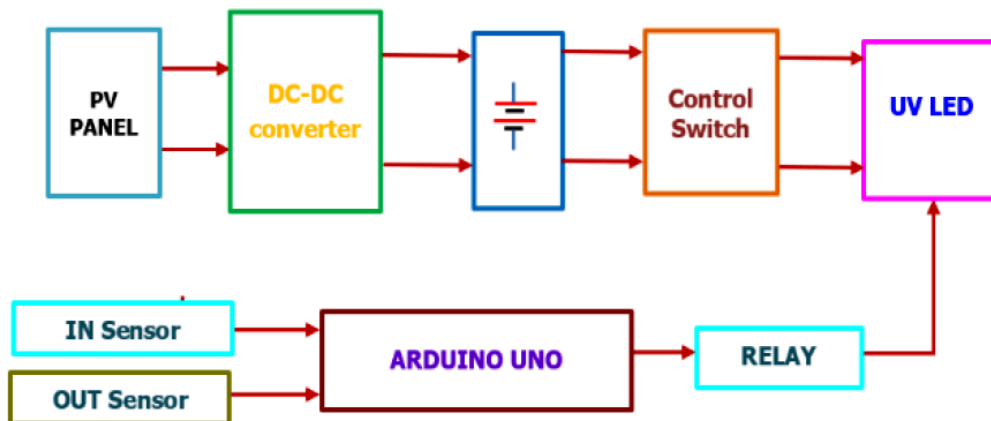


Figure 1: Block diagram of UV LED with sensor.

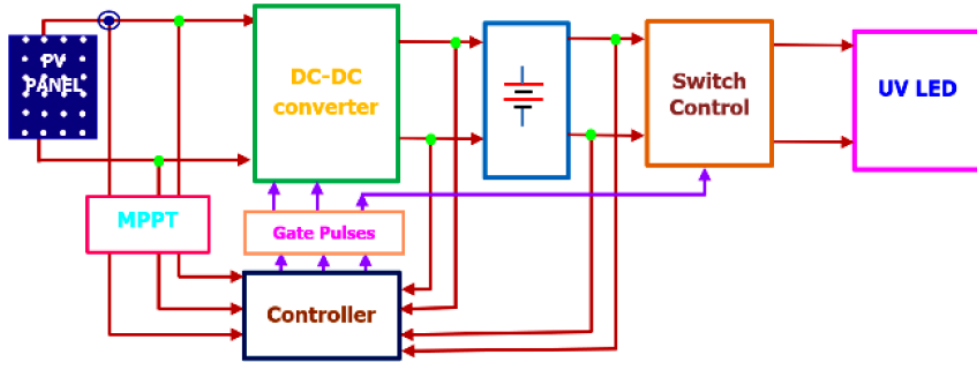


Figure 2: Block diagram of UV LED lamp with controller.

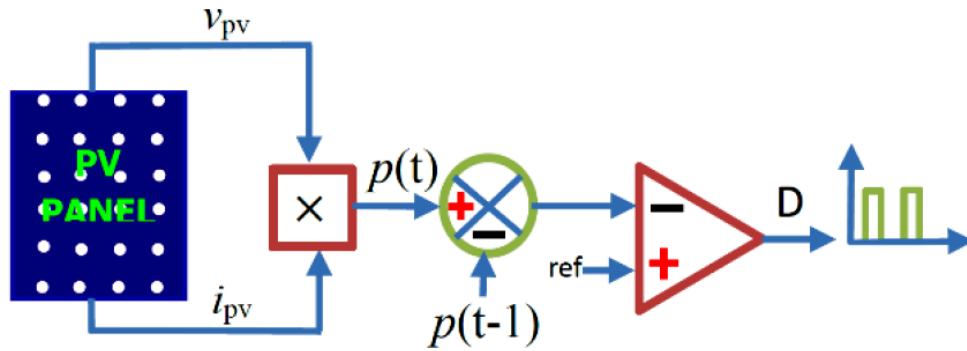


Figure 3: Functional block diagram of P&O method. P&O, perturb-and-observe.

The different components used for modeling of UV sterilizer are discussed. The hardware setup is modeled and the output is taken to show the working model of the UV sterilizer.

There are different types of UV sterilizer used for disinfection. Here, UV LEDs are used for disinfecting COVID-19. The main source of power is solar panel. It gives an output of around 13–15 V. There are two solar panels used for charging the battery. The purpose of DC-DC converter in the voltage control circuit is to provide a constant voltage and also to obtain maximum power extraction from the solar cells. The functional block diagram of conventional P&O method is shown in Figure 3. The conventional buck boost converters are simple in construction and control, but these converters provide voltage conversion over small ranges. In case of CUK DC-DC converter and SEPIC DC-DC converter, the two-stage power conversion provides low efficiency.

The non-isolated DC-DC converter can provide large conversion ratio with high efficiency. The voltage gain of these converters is high. But these converters use large capacitor at the input side of the converter which reduces the lifespan of the converter.

To replace large capacitor, filter elements can be used. But filter circuit reduces the efficiency, and the performance under transient condition is affected. Therefore, a novel buck boost converter is designed to obtain a constant current. The topology and the modes of operations are discussed. Figure 3 shows the topology of the proposed converter which consists of two switches Q_A and Q_B , two inductors L_A and L_B , and three capacitors C_A , C_B , and C_O .

In the analysis of the converter, the capacitors, inductors, switches are assumed to be ideal elements. The circuit diagram of the DC-DC converter under step-down mode of operation is shown in Figure 4. In this mode, the source is connected in series with inductor L_A to provide a constant current.

V. PV power extraction

The PV panel is used as the input source for energy supply to the lamps. To extract maximum amount of power from the solar panel, converters are connected between PV panel and load and control techniques are used to extract maximum power.

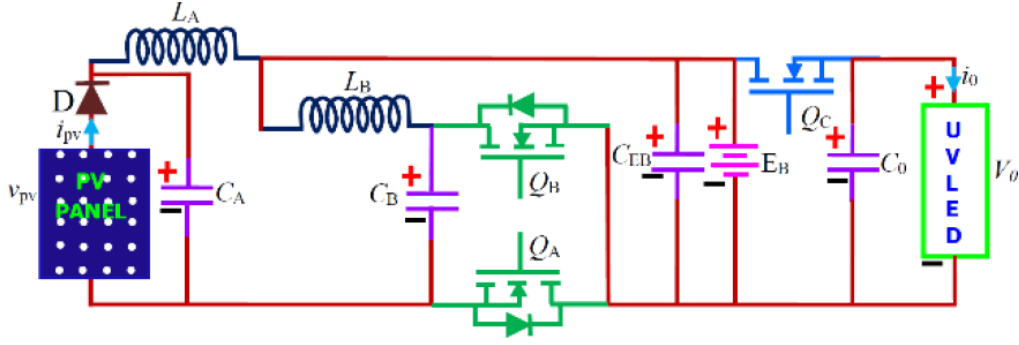


Figure 4: Proposed converter circuit.

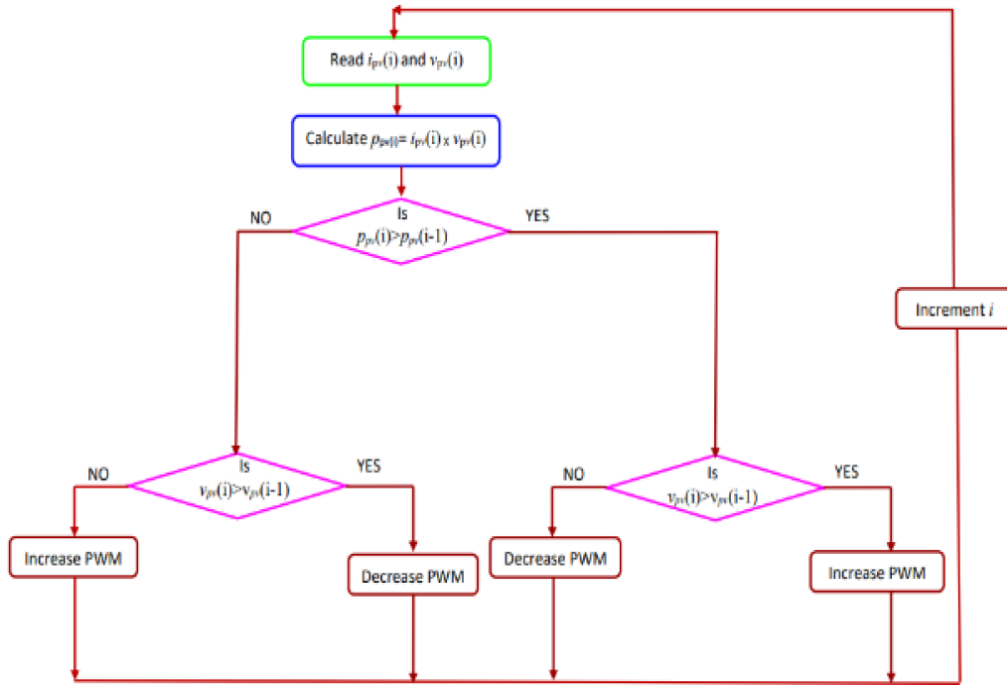


Figure 5: MPPT algorithm. MPPT, maximum power point tracking.

Various control techniques used for MPPT are constant voltage, lookup table-based MPPT, ripple correlation control, hill climbing, short circuit current, open circuit voltage, adaptive reference voltage, P&O method, and incremental conductance method. In this paper, P&O technique is implemented. This algorithm is one of the simplest and easy algorithms to use and implement using microcontroller. Since this algorithm is user-friendly, it is easy and widely used in MPPT.

This algorithm uses trial-and-error method to reach the maximum value. This method calculates the power at two points of power voltage curve. Then the voltage value is checked and shifted to left or right till

it reaches the maximum. The algorithm implemented for tracking maximum power is shown in Figure 5.

VI. Analysis of converter

There are two modes of operation of the converter. They are step-down mode as shown in Figure 6 and step-up mode as shown in Figure 7.

In the step-down mode, there are two modes of operation based on the switching condition. As shown in Figure 8, switch Q_A is initially in ON condition during the interval t_0 to t_1 . This is the mode 1 operation of the step-down operation. During this interval, switch Q_B is turned OFF. Inductor L_A is energized by

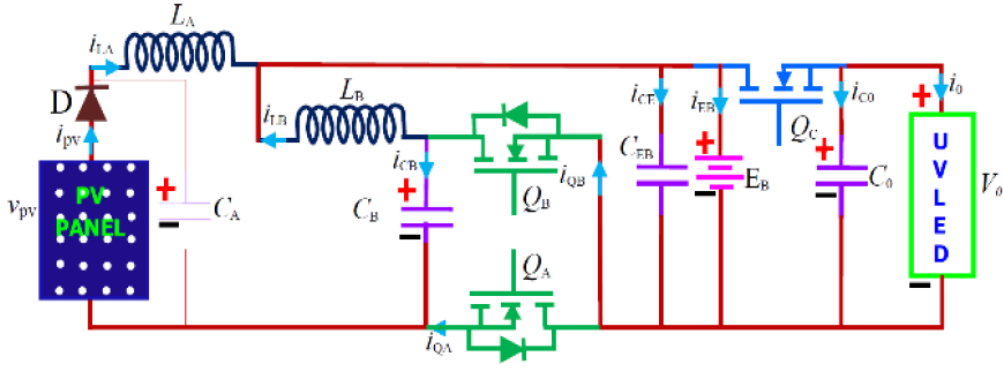


Figure 6: Equivalent circuit for step-down mode.

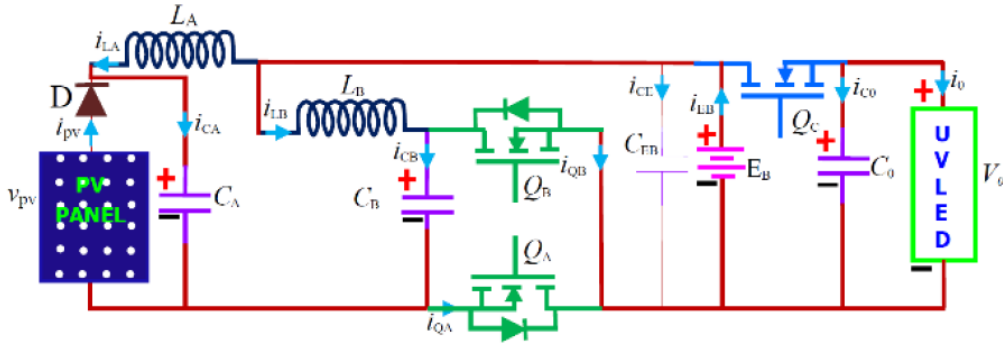


Figure 7: Equivalent circuit for step-up mode.

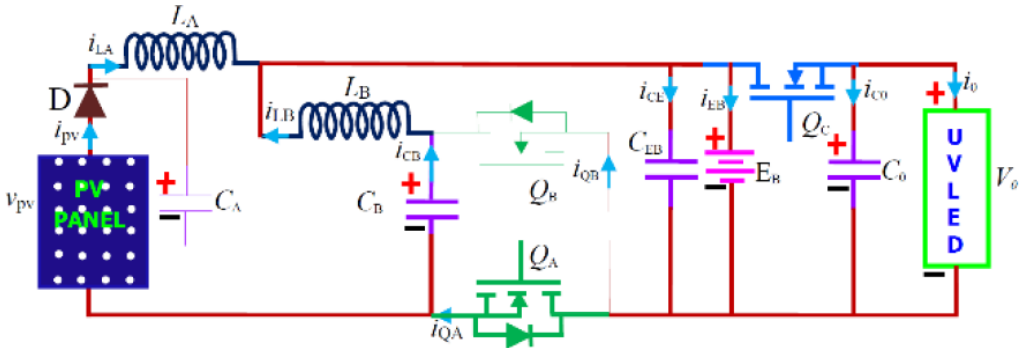


Figure 8: Step-down mode 1.

the input source. This steadily increases inductor current i_{LA} . The energy stored in capacitor C_B supplies power to the load and also energizes inductor L_B . The equations under this mode are given as follows.

$$i_{LA}(t) = I_{LAMIN} + \frac{V_{PV} - V_{EB}}{L_A} t \quad (1)$$

$$i_{LB}(t) = I_{LBMIN} + \frac{V_{CB} - V_{EB}}{L_B} t \quad (2)$$

$$i_{CB}(t) = -I_{LBMIN} - \frac{V_{CB} - V_{EB}}{L_B} t \quad (3)$$

$$i_{CA}(t) = I_{LAMIN} + I_{LBMIN} + \left(\frac{V_{PV} - V_{EB}}{L_A} + \frac{V_{CB} - V_{EB}}{L_B} \right) t - i_{EB} \quad (4)$$

During the step-down mode, switch Q_B is in ON condition during the interval t_1 to t_2 . This is the mode 2 operation of the step-down operation as shown in Figure 10. During this interval, switch Q_A is turned

OFF. The input source and the energy in inductors L_A and L_B supply power to the load. This results in a decrease in current through inductors L_A and L_B . The waveform for the step-down operation is shown in Figure 9. The equations under this mode are given as follows.

$$i_{LA}(t) = I_{LMAX} - \frac{V_{pv} - V_{CB} - V_{EB}}{L_A} t \quad (5)$$

$$i_{LB}(t) = I_{LMAX} - \frac{V_{EB}}{L_B} t \quad (6)$$

$$i_{CB}(t) = -I_{LMIN} - \frac{V_{pv} - V_{CB} - V_{EB}}{L_A} t \quad (7)$$

$$i_{CA}(t) = I_{LMAX} + I_{LMAX} + \left(\frac{V_{pv} - V_{CB} - V_{EB}}{L_A} + \frac{V_{EB}}{L_B} \right) t - i_{EB} \quad (8)$$

The analysis of the step-down mode of operation of the converter is used to obtain relation between the input voltage, output voltage, and capacitor voltage. The voltage-second balance equation for the inductors can also be derived from the analysis of the converter for the modes of operation.

$$D(V_{pv} - V_{EB}) + (1-D)(V_{pv} - V_{EB} - V_{CB}) = 0 \quad (9)$$

$$D(V_{CB} - V_{EB}) - (1-D)V_{EB} = 0 \quad (10)$$

From the above equations, the gain of the converter is derived as below:

$$\text{Voltage gain } G_V = \frac{V_{EB}}{V_{pv}} = D \quad (11)$$

To derive the current expression, current-second balance equation is used during the step-down operation. Since the average current in capacitor is 0 over a switching period "T," it can be written as follows:

$$\int_0^T i_{CB}(t) dt = 0 \quad (12)$$

Based on the above equations, the inductor currents are derived as below. The expression for minimum inductor current through L_A and L_B is given as follows:

$$I_{LMIN} = DI_{EB} - \frac{V_{pv} - V_{EB}}{2L_A} DT \quad (13)$$

$$I_{LMIN} = (1-D)I_{EB} - \frac{V_{pv} - V_{EB}}{2L_B} DT \quad (14)$$

The expression for maximum inductor current through inductors L_A and L_B is given as follows:

$$I_{LMAX} = DI_{EB} + \frac{V_{pv} - V_{EB}}{2L_A} DT \quad (15)$$

$$I_{LMAX} = (1-D)I_{EB} + \frac{V_{pv} - V_{EB}}{2L_B} DT \quad (16)$$

The average value of battery current is considered I_{EB} . The average current of inductor A is $I_{LA} = DI_{EB}$ and the average current of inductor B is $I_{LB} = (1-D)I_{EB}$. The expression for maximum current through inductors during step down is derived as follows:

$$I_{LMAX} = I_{EB} + \frac{(V_{pv} - V_{EB}) \times V_{EB} \times L_B}{2L_A \times V_{pv}} DT \quad (17)$$

The circuit diagram of the DC-DC converter under step-up mode 1 operation is shown in Figure 11. In this mode, the source is connected across capacitor C_A . The waveform for the step-up operation is shown in Figure 10. During the step up, switch Q_A is in ON condition during the interval t_0 to t_1 . During this interval, switch Q_B is turned OFF. Inductor L_A and the input source supply energy to the load. This steadily decreases the inductor current I_{LA} . The energy stored in capacitor C_B and inductor L_B supply power to the load. The equations under this mode are given as follows:

$$i_{LA}(t) = I_{LMAX} - \frac{V_s - V_L}{L_A} t \quad (18)$$

$$i_{LB}(t) = I_{LMAX} - \frac{V_L}{L_B} t \quad (19)$$

$$i_{CB}(t) = -I_{LMAX} - \frac{V_{CB} - V_L}{L_B} t \quad (20)$$

$$i_{CC}(t) = I_{LMAX} - \left(\frac{V_s - V_L}{L_A} \right) t - i_{EB} \quad (21)$$

The circuit diagram of the DC-DC converter under step-up mode 2 operation is shown in Figure 13. In this mode, the source is connected across capacitor C_A . The waveform for the step-up operation is shown in Figure 10. During the step up, switch Q_B is in ON condition during the interval t_0 to t_1 . During this interval, switch Q_A is turned OFF. The input source supplies energy to inductors L_A and L_B . This steadily decreases the inductor current I_{LA} .

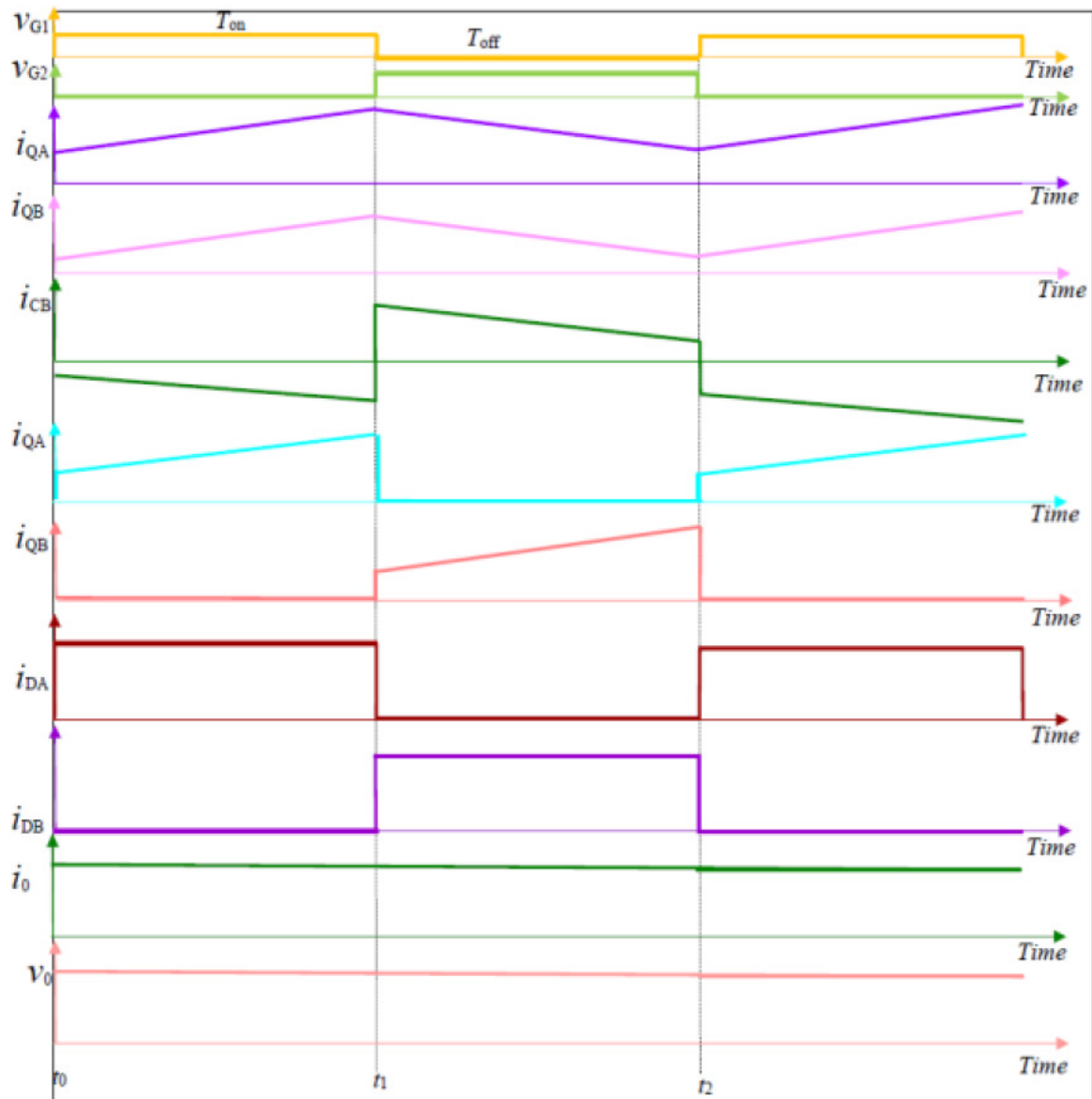


Figure 9: Waveform for step down.

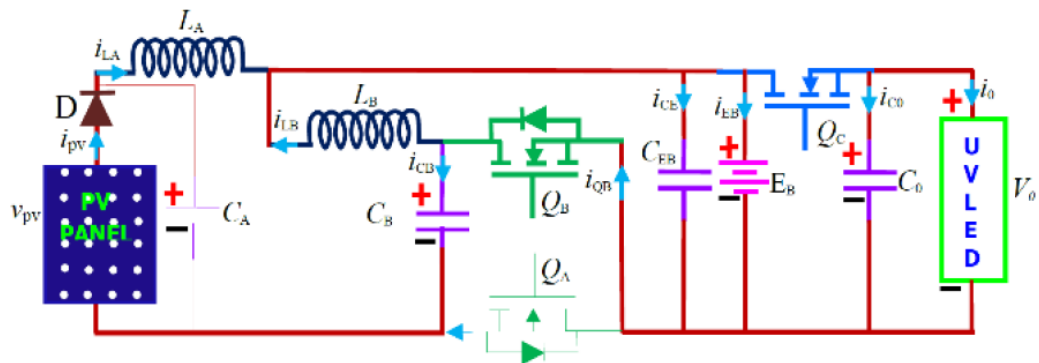


Figure 10: Step-down mode 2.

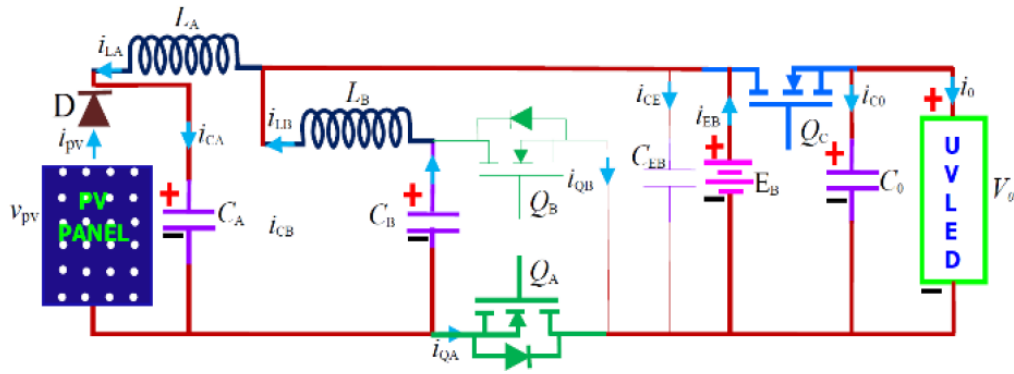


Figure 11: Step-up mode 1.

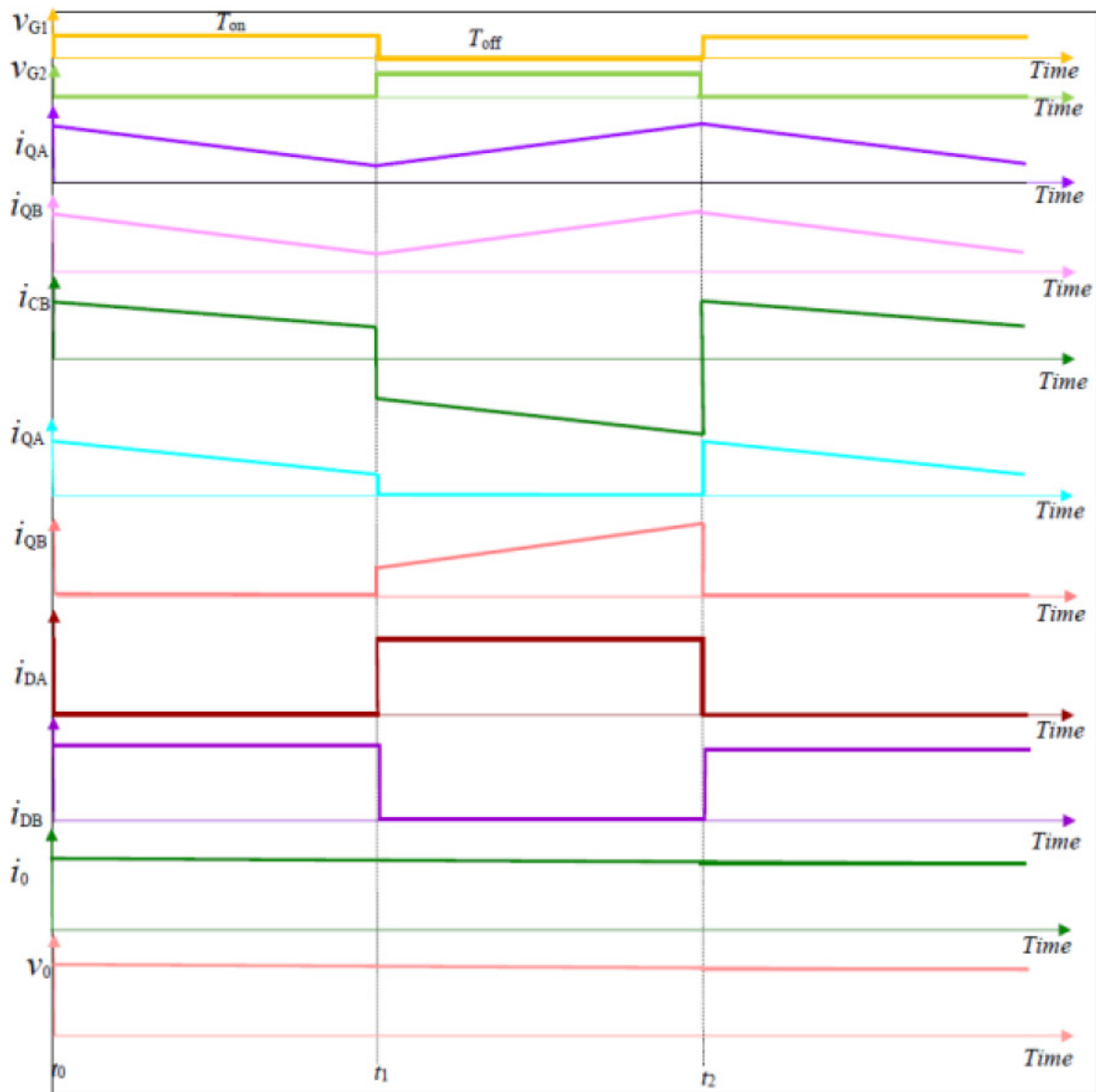


Figure 12: Waveform for step-up operation.

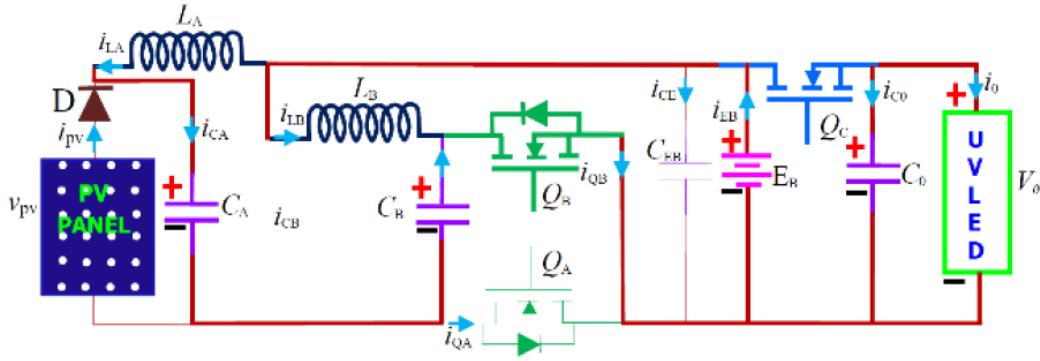


Figure 13: Step-up mode 2.

The energy stored in capacitor C_B supplies power to the load. The equations under this mode are given as follows:

$$i_{LA}(t) = I_{LAMIN} - \frac{V_s - V_{CB} - V_L}{L_A} t \quad (22)$$

$$i_{LB}(t) = I_{LBMIN} + \frac{V_L}{L_B}t \quad (23)$$

$$i_{CB}(t) = -I_{LBMAX} - \frac{V_S - V_L}{L_A} t \quad (24)$$

$$i_{CA}(t) = I_{LAMIN} - \left(\frac{V_s - V_L}{L_A} \right) t - i_{EB} \quad (25)$$

The analysis of the step-up modes of operation of the converter is used to obtain relation between the input voltage, output voltage, and capacitor voltage. The voltage-second balance equation for the inductors can also be derived from the analysis of the converter for the modes of operation. The gain of the converter can be derived using the below equations. Considering the critical conditions for each mode of operation, the design of the converter is done. The ratio of input voltage to input current gives the value of the input resistance R_i .

$$D(V_L - V_S) + (1 - D)(V_L - V_S - V_{CB}) = 0 \quad (26)$$

$$D(V_{CB} - V_L) - (1 - D)V_L = 0 \quad (27)$$

From the above equations, the gain of the converter is derived as follows:

$$\text{Voltage gain } G_V = \frac{V_L}{V_s} = \frac{1}{D} \quad (28)$$

To derive the current expression, current-second balance equation is used during the step-down operation. Since the average current in capacitor is 0 over a switching period " T_s ," it can be written as follows:

$$\int_0^T i_{CB}(t) dt = 0 \quad (29)$$

Based on the above equations, the inductor currents are derived as below. The expression for minimum inductor current through L_A and L_B is given as follows:

$$I_{LAMIN} = I_{EB} - \frac{V_{pv} - V_{EB}}{2L_A} (1-D)T \quad (30)$$

$$I_{LBMIN} = \frac{(1-D)}{D} I_{EB} - \frac{V_{pv} - V_{EB}}{2L_B} (1-D)T \quad (31)$$

The expression for maximum inductor current through inductors L_A and L_B is given as follows:

$$I_{LMAX} = I_{EB} + \frac{V_{pv} - V_{EB}}{2L_A}(1-D)T \quad (32)$$

$$I_{LBMAX} = \frac{(1-D)}{D} I_{EB} + \frac{V_{pv} - V_{EB}}{2L_R} (1-D) T \quad (33)$$

The average value of battery current is considered I_{EB} . The average current of inductor A is $I_{LA} = I_{LB}$ and average current of inductor B is $I_{LB} = (1 - D)I_{EB}/D$. The expression for maximum current through inductors during step-up is derived as follows:

$$I_{LMAX} = \frac{I_{EB}}{D} + \frac{(V_{pv} - V_{EB})^2 \times V_{EB} \times L_B}{2L_A \times V_{pv}} T \quad (34)$$

When the inductor current reaches 0, the critical condition is obtained. Under this condition, the expression for inductor values is derived as follows:

$$L_A = \frac{R_i (V_s - V_L) T}{2V_L} \quad (35)$$

$$L_B = \frac{R_i V_L T}{2V_s} \quad (36)$$

The resultant inductor L_R is found out using the values L_A and L_B . The resonant capacitor C_B is calculated using the following resonant frequency expression:

$$\omega_r = \frac{1}{L_R \times C_B} \quad (37)$$

The capacitor has voltage changes that cause ripples in the capacitor voltage. The capacitor is designed on the basis of ripple voltage variation. The time period T of a cycle can be written in terms of frequency f as follows:

$$T = \frac{1}{f} = t_{on} + t_{off} \quad (38)$$

t_{on} can be calculated using from the energizing and de-energizing voltages across the inductor. During the energizing period, switch Q_A is ON and switch Q_B is OFF. In general, the voltage equation for the resultant inductor L_R during this period is written as follows:

$$V_{pv} - V_{EB} = L_R \times \frac{\Delta I}{T_{on}} \quad (39)$$

During the de-energizing period, switch Q_A is ON and switch Q_B is OFF. In general, the voltage equation for inductor L_R during this period is written as follows:

$$-V_{EB} = -L_R \times \frac{\Delta I}{T_{off}} \quad (40)$$

Equating the current variations in current flowing through the inductor L_R is written as follows:

$$\Delta I = \frac{V_{pv} - V_{EB} \times T_{on}}{L_R} = \frac{V_{EB} \times T_{off}}{L_R} \quad (41)$$

Using Eqs. (37)–(39), the current variation is written as follows:

$$\Delta I = \frac{V_{EB} \times (V_{pv} - V_{EB})}{f \times L_R \times V_{pv}} \quad (42)$$

The average current flowing through the capacitor is the given as follows:

$$I_C = \frac{\Delta I}{4} \quad (43)$$

The ripple voltage across capacitor C_{EB} using the above equations is written as follows:

$$\Delta V_C = \frac{V_{EB} \times (V_{pv} - V_{EB})}{8 \times f^2 \times L_R \times V_{pv} \times C_{EB}} \quad (45)$$

The critical value of capacitor C_{EB} is given as follows:

$$C_{EB} = \frac{1 - D}{16 \times L_R \times f^2} \quad (46)$$

The filter capacitor used in the PV and the lamp is calculated using the general expression given below

VII. Hardware

Using the analysis, the converter elements are designed. The values of the converter elements are listed below. The design of the converter elements is calculated using the equations derived from the analysis of the converter. The rating of solar panel used for charging the battery is 40 W 12 V with open circuit voltage of 22 V and total short circuit current of 2.53 A. The solar panel is used to charge battery of rating 12 V and 26 Ah. The voltage applied to the battery is regulated by varying the duty cycle. The designs of inductors L_A and L_B are calculated using Eqs. (35) and (36). The equivalent inductance is calculated, followed by the calculation of resonant capacitor C_B using Eq. (37). The filter capacitor is calculated using Eq. (46). The component values are listed below. The circuit diagram of the converter along with the controller is shown in Figure 14.

S. No.	Component	Value
1	Inductor L_A	0.1 mH
2	Inductor L_B	0.1 mH
3	Capacitor C_A	100 μ C
4	Capacitor C_B	10 μ C
5	Capacitor C_{EB}	100 μ C
6	Capacitor C_0	470 μ C

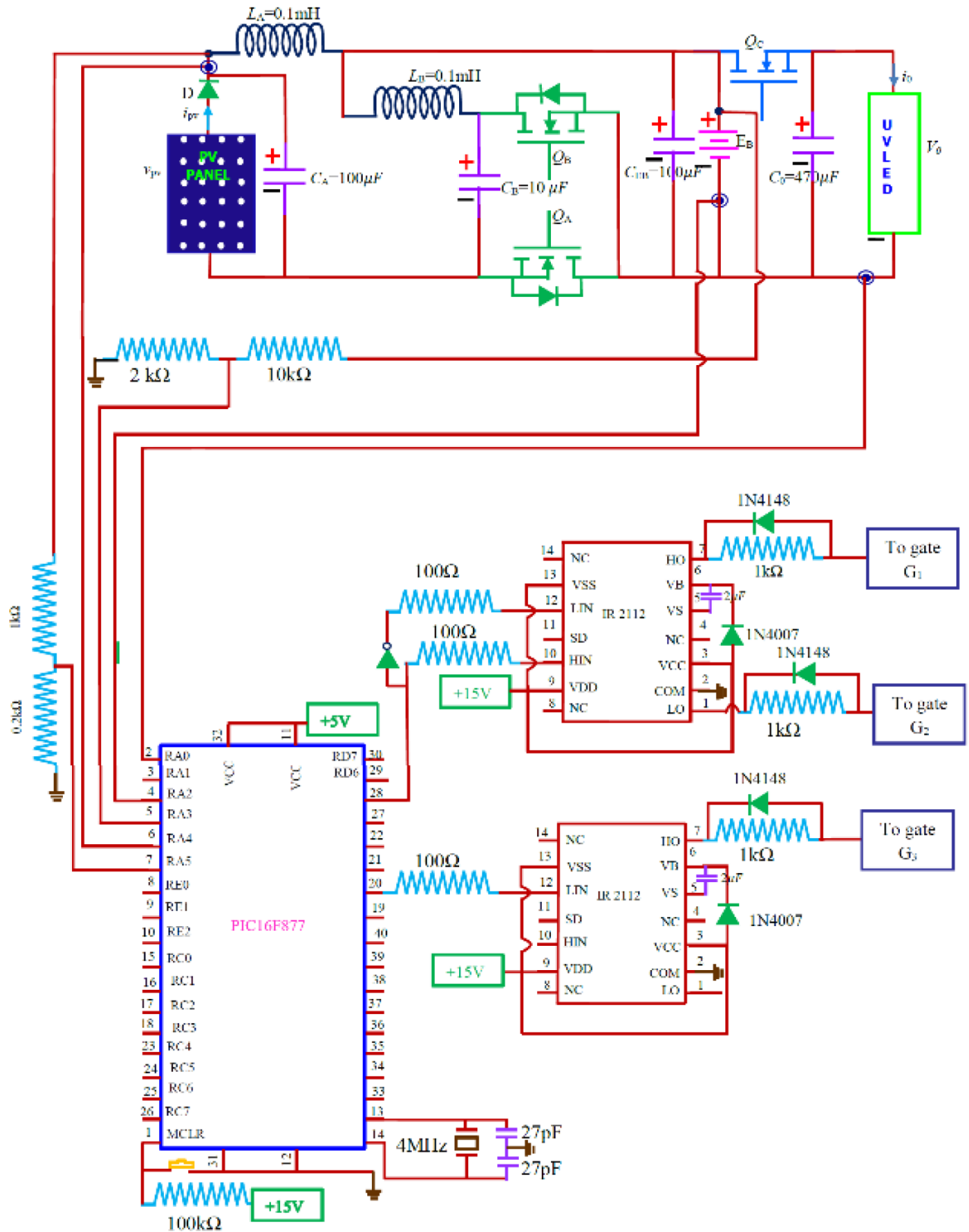


Figure 14: Proposed UVC sterilizer lamp circuit.

It is necessary to find out the performance of the converter under practical conditions. The solar panel power rating is 40 W. In this application, the panel charges the battery continuously during daytime. The lamp is not operated continuously. Intermittent loading is done on the lamp.

In this circuit, a 12 V and 26 Ah battery is used to store the energy supplied by the solar panel. The hardware developed is shown in Figure 15. The presence of persons inside the room is detected and the LED glows red to show that all the persons have gone out of the hall (Figure 15). The presence of persons inside the room is detected and the LED glows red to show that no one has entered inside the hall (Figure 15). The count of the persons is indicated in the laptop screen. The hardware developed is shown in Figure 16 for ON condition of the lamp. The charging current required is calculated

by dividing the solar panel power by the solar panel voltage. The amount of current is calculated as follows:

$$\text{Current required to charge the battery} = \frac{40W}{12V} = 3.33A$$

The controller used in the converter circuit is used to control the current in the circuit. If the amount of load connected in the output is increased, the panel rating should be changed based on the load. The time required to charge the battery is calculated by dividing the Ah rating of the battery by current. Thus, the time required to charge the battery is calculated as follows:

$$\text{Time required to charge the battery} = \frac{26}{3.33} = 7.8h$$

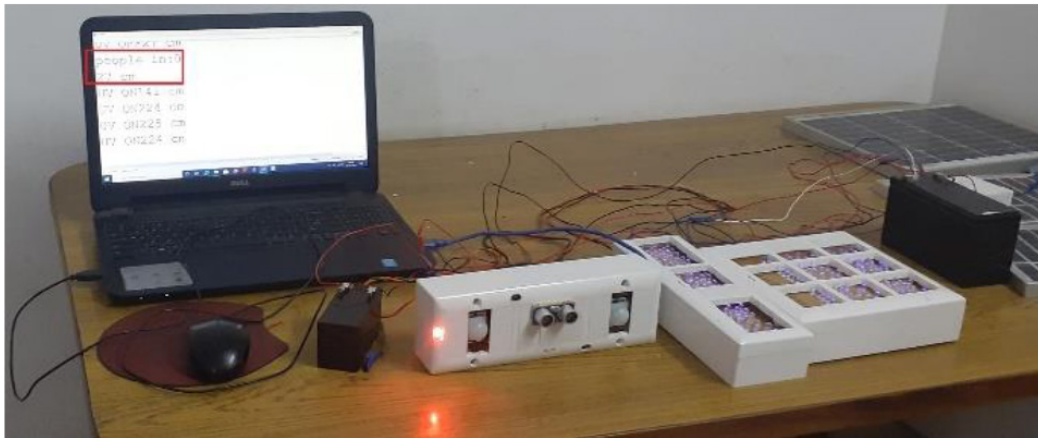


Figure 15: UV array ON condition.

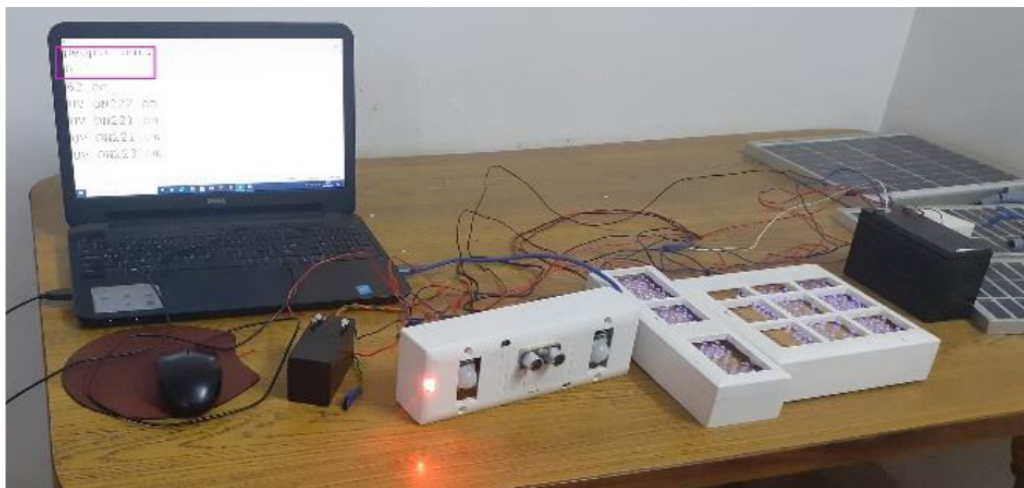


Figure 16: UV array ON condition.

The 40 W power supplied by the solar panel is controlled using the controller with MPPT algorithm. These parameters are considered while the battery is charged using the solar panel. There are two modes of charging the battery, namely, constant current mode and constant voltage mode. Based on the charges available in the battery, the mode of charging is selected to improve the charging rate. To supply power from the battery to the UV LED lamp, a MOSFET switch Q_c is used to control the power supplied to the lamp. Whenever the switch Q_c is turned on, power is transferred to the UV LED lamp.

Since the UV LED sterilizer lamp is harmful to the human skin, it is required to turn OFF the lamp in the presence of a person. The lamp will glow for 30 min when there is no person available in the room. The presence of persons inside the room is detected and

the LED indicator does not glow red to show that 12 persons have entered inside hall (Figure 17). The count of the persons is indicated in the laptop screen. The presence of persons inside the room is detected and the LED indicator does not glow red to show that out of the 12 persons who have entered inside hall, one person has gone out (Figure 18). The count of the persons is indicated in the laptop screen.

When the presence of a person is detected, it has to be switched OFF. This is done using a counter used in the smart sensor. Microcontroller-based charging is used. The controller is used to vary the input voltage to provide a constant voltage. Some of the hardware results are taken to validate the performance of the converter. The input voltage supplied by the solar panel and the input current is shown in Figure 19. The inductor current and the input voltage

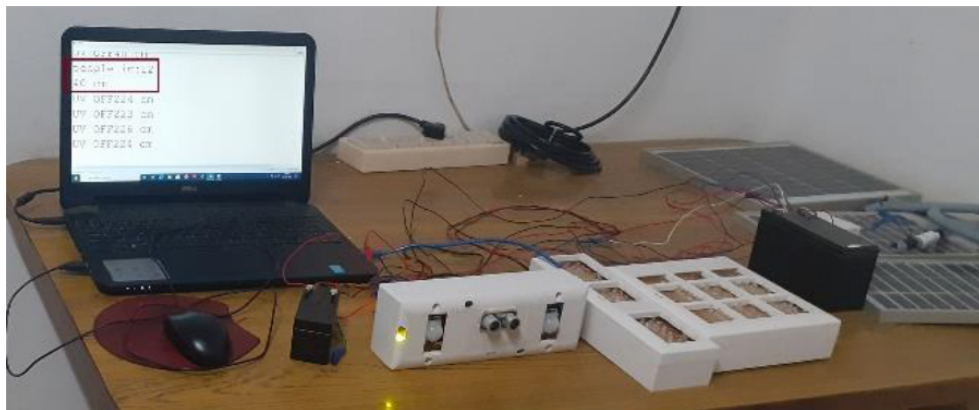


Figure 17: UV array OFF condition.



Figure 18: UV array OFF condition.

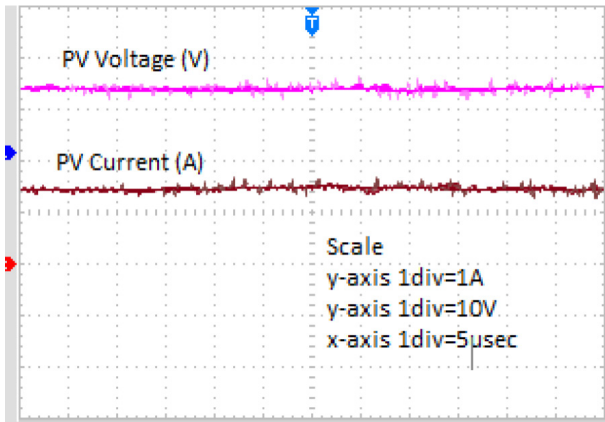


Figure 19: PV voltage and PV current.

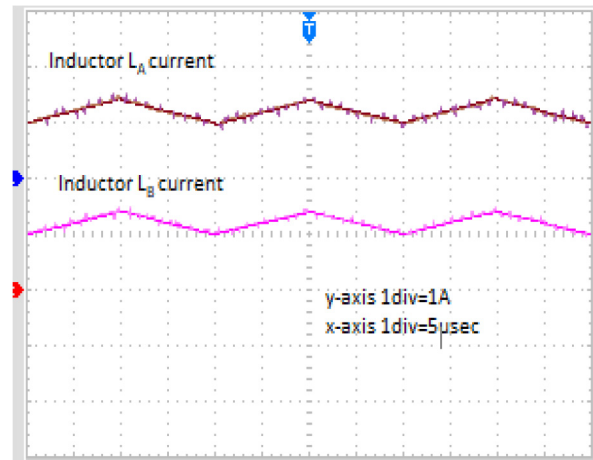
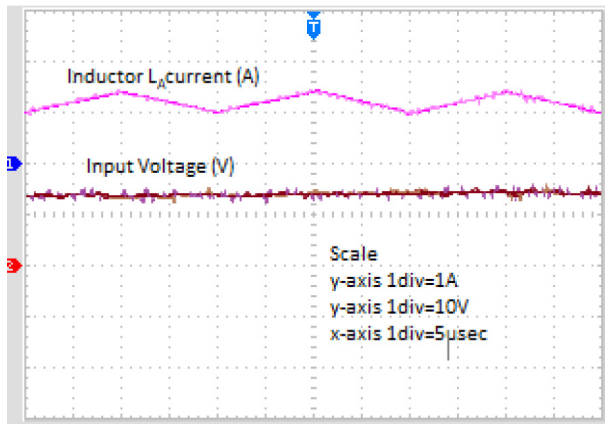
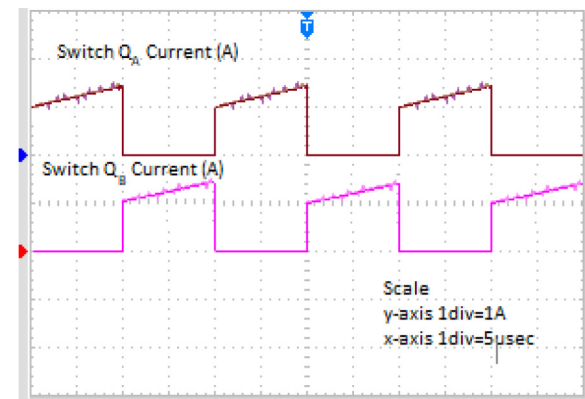
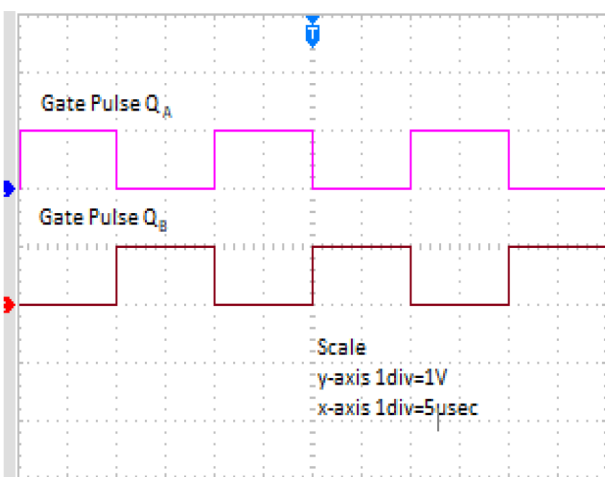
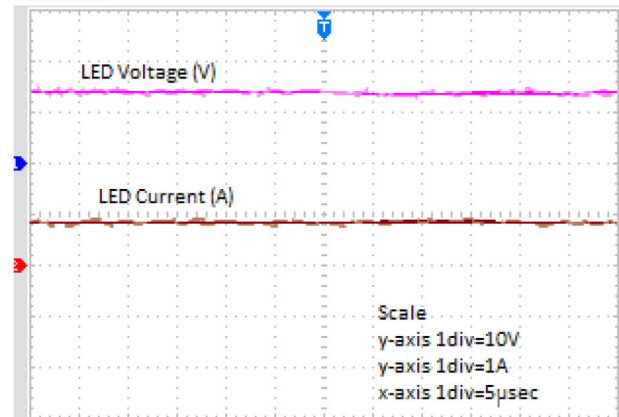
Figure 22: Inductor currents (L_A and L_B).Figure 20: Input current and inductor L_A current.Figure 23: Switch currents (Q_A and Q_B).Figure 21: Gate pulses (Q_A and Q_B).

Figure 24: LED current and LED voltage.

are shown in Figure 20. The gate voltage applied to the switches is shown in Figure 21.

The inductor currents are shown in Figure 22. The switch currents are shown in Figure 23. The output voltage and the current are shown in Figure 24. The

converter along with the controller regulates the varying input voltage to constant voltage. The circuit consists of PV panel to supply power to the battery. The power is supplied to the battery through the charge controller. The charge controller controls the voltage to 12 V.

VIII. Conclusion

This study presents the UV-based air disinfection device that involves killing the microorganisms floating freely in the air of a room using radiation. UV products for CV-19 protection as suggested by IUVA reduce the transmission of the virus causing COVID-19 and SARS CoV-2. UV irradiation and ozone are used in treating the virus but must be used with caution. Any useful UV is harmful to humans and animals unless they are completely protected from UVC irradiation. The PV-based rechargeable LED UV sterilizer lamp is UV-based air disinfection system that kills the microorganisms, including COVID 19 virus, floating freely in the air of a room. The product is designed using embedded system for automatic control of UV lamps based on the human presence. This is carefully designed to ensure that the end user is protected. The automatic detection unit shuts OFF the UV in case if a human is detected. The product is PV powered from the PV panel. The bank of UV LEDS is completely enclosed. The battery is charged using a solar panel which has a backup of 8 h. Various components included in the study are PIR sensor, Arduino board, PV panel, battery, charging circuit, and UV LED array.

Acknowledgment

We are thankful to Unnat Bharat Abhian, MHRD, Government of India for the funding provided to complete the project.

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Annexure

Embedded C coding

```
int irPin1 = 2;//out sensor
int irPin2 = 3;//in sensor
int count = 0;
int UVpin = 9;//relay control
void setup() {
  Serial.begin(9600);
  pinMode(irPin1, INPUT);
  pinMode(irPin2, INPUT);
  pinMode(UVpin, OUTPUT);
}
void loop() {
  while (1)
  {
    if ((digitalRead (irPin1)==HIGH))
    {
      digitalWrite(UVpin,LOW);
      Serial.println("UV OFF");
      count++;
      Serial.print("No of persons inside the room: ");
```

```
Serial.println(count);
      delay(2000);
    }
    if ((digitalRead (irPin2)==HIGH))
    {
      count – ;
      Serial.print("No of persons inside the room: ");
      Serial.println(count);
      if ((count==0))
      {
        digitalWrite(UVpin,HIGH);
        Serial.println("UV ON ROOM EMPTY");
        delay(2000);
      }
      if ((count==0))
        digitalWrite(UVpin,HIGH);
        Serial.println("UV ON ROOM EMPTY");
      }
    }
  }
```