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Smart Drone with Renewable Smart System

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Abstract

In order to lessen its negative effects on the environment and to maintain its future operations in a clear, renewable, and sustainable manner, the aviation industry has begun developing designs that are dependent on alternative energy sources but also friendly to the environment and conventional energy. Solar energy has been suggested as a potential remedy. Aerial vehicles driven by solar energy are viewed as essential to limiting the consequences of global warming. In this study, a MATLAB/Simulink environment is used to simulate a mathematical model of a solar-powered BLDC motor of a UAV. under photovoltaic (PV) array systems, the phrase "maximum power point tracking" (MPPT) is crucial to ensuring that, under specific circumstances, the connected systems receive the greatest power output. This study simulates "fuzzy logic control," one of the preferred MPPT methods, using a solar-powered BLDC motor for an unmanned aerial vehicle (UAV) design. The PV cell, MPPT, buck-boost converter, and BLDC motor models in the cascade structure are simulated, tested, and the results are compared to the DC motor technical data. As a result, despite changes in irradiance, the results of mathematical model simulation overlap with motor technical reference values. A mathematical model of a solar-powered BLDC motor for a UAV is created and simulated using the MATLAB/Simulink environment, in contrast to prior solar-powered BLDC motor literature efforts. The fuzzy logic control MPPT technique is preferred for adjusting the maximum power output at the solar cell, and a buck-boost converter structure is connected between the MPPT and the BLDC motor mathematical model. It is recommended for usage in solar-powered UAV designs in the future.

Keywords: Buck-BOOST Converter; Unmanned Aerial Vehicle; MPPT; BLDC Motor; FLC; Solar Power.

1. Introduction

Given that it is a source of plentiful and clean energy, solar panels have received a lot of attention recently. Solar cells are a type of clean, renewable energy source that work by converting light energy into electrical energy. Solar energy may lower the emissions from conventional vehicles by 92% [1].

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Since the solar cell has a distinctive voltage, power, and current graph, the voltage of a solar panel must be controlled to get the most power. Power conditioning often employs a regulated converter that uses the Maximum Power Point Tracking (MPPT) algorithm. To maintain the panel operating at its best, MPPT will condition the panel voltage. The Perturb and Observation technique (P&O), which is simple to regulate but time inefficient and has significant loss, is the most widely used form of MPPT algorithm. P&O's tracking stride has an impact on tracking precision and speed. Peak tracking accuracy will rise if the tracking step is reduced, but peak tracking speed will fall, and vice versa.

The Hill Climbing algorithm is one of the most frequently used algorithms for power optimization. The Hill Climbing algorithm operates by varying the converter's duty cycle while monitoring how it affects the output power of the solar panel. greater duty cycles result from greater power and current levels, whereas lower duty cycles result from lower power and current levels [2].

Fuzzy logic control is used to address these drawbacks. Fuzzy logic outperforms the P&O method in terms of maximum power point detection time and fluctuations [3].

The maximum power tracking time is accelerated, and power oscillations are decreased, using fuzzy logic control. When the weather changes nonlinearly, fuzzy logic can make wise judgements [4].

Since the output of fuzzy logic is neither 0 or 1, but rather the accumulation of the input variable's membership in the membership functions, the output value depends on the rule that links the input and the weighting of each membership function. In this study, an MPPT is created utilizing fuzzy logic control to provide a switching duty cycle that changes according on the load and solar panel conditions. The tracking time of solar electricity is found to be quicker by using this approach.

A. Solar Powered UAV

primary energy source is solar energy, Solar irradiance and plane position determine how much power is generated by solar panels, and this fluctuation is constant. Solar panel power will have an effect on the brushless dc motor's (BLDC) speed and torque. In order to sustain the speed and thrust of the BLDC motor, MPPT must maximize and track quickly.

The goal of this study is still to create an MPPT solar controller that will power a BLDC motor. This approach's efficacy is contrasted with that of traditional MPPT solar controller.

B. Photovoltaic Model

A substance known as a photovoltaic may transform the energy of photons into electrical energy. When photons have short enough wavelengths, they have the power to liberate electrons from atoms. On a conductor, the electrons can flow and transform into an electric current. The sun provides the energy needed to break the bonds. Given that the earth's surface gets energy at a rate of 6000 times the planet's daily energy needs, this is a significant potential [3].

A PV module may be represented by an equivalent circuit made up of a current source, a diode, and a resistor to represent the internal resistance. When the solar cell is exposed to sunlight, current is produced as:

$$Iph = \frac{I_{sc} + K_i(T-298)\times Ir}{1000}$$

Where :

I_{sc} = Short circuit current

K_i = Temperature constant

Ir = Irradiance

T = Ambient temperature

The internal resistance Ish and the current flowing through the diode ID determine the solar cell's output current. The equation then becomes: -

The equation below must be used to determine current flows in the diode.

$$I_D = I_o[\exp\left(\frac{q(V+IR_s)}{nkT}\right) - 1]$$

Where :

I_o = diode saturation current

V = solar cell voltage

R_s = Series resistance

k = Boltzmann constant

q = electron charge

n = diode ideality factor (1 for an ideal diode)

Then total equivalent circuit of solar cell become as Fig (1):

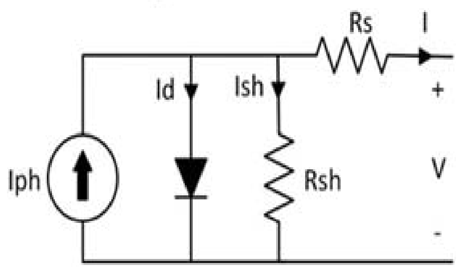

Figure 1: equivalent circuit of solar cell

The relationship between a PV module's output of current and voltage may be calculated using Figure 2.

$$I = I_{ph} - I_o[\exp\left(\frac{V+IR_s}{nkT}\right) - 1] - \frac{V+IR_s}{R_{sh}}$$

The functioning of the solar panel will produce the I-V characteristic curve, in accordance with equation above. The solar panel's operational point occurs when the I-V characteristic curve and the load characteristics cross at constant irradiance and temperature. The operational point of the panel switches from the zero resistance, which results in the *Isc*, to the infinite resistance, which results in the appearance of the *Voc* [5] as shown in figure (2).

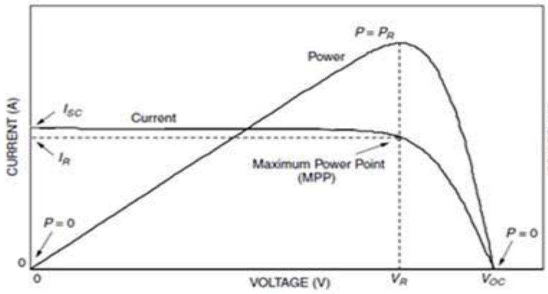

Figure 2: characteristic curve of a PV module

C- THE BUCK-BOOST CONVERTER

The buck-boost converter transforms uncontrolled source voltages into desired output voltage levels that are greater or lower. In Figure 3, a common buck-boost model is displayed. In this diagram, Vs represents the input voltage, MI a switch, VL represents the voltage across the inductance, Vo represents the output voltage across the load, Vref represents the reference voltage, and L, C, D1 and D2, and RL represent, respectively, inductance, capacitance, diodes, and load resistance [6, 7].

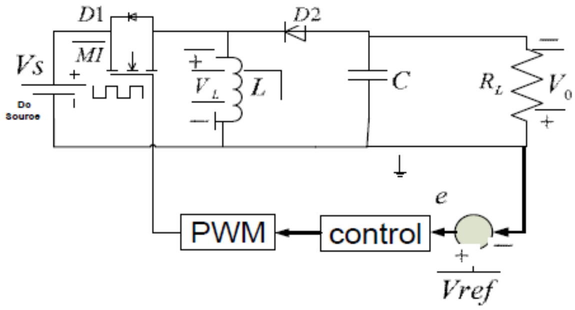

Figure 3: DC-DC Buck Boost Converter System used in simulations.

The circuit works in two modes, as seen in Figure 3. When the transistor is turned on and diode D2 is reverse biased, the first thing happens. The input current IL passes via the transistor MI and inductor L in this mode. The voltage across the inductor is determined by:

$$V_L = V_S = L\frac{di_L}{dt}$$

whereas equation bellow calculates the current flowing via the inductor:

$$i = \frac{1}{L}\int_{0}^{t} V_S dt + io \,..$$

If the transistor MI is off, the current passes from L via C, the diode D2, and to the load in the second mode. Equation bellow provides the voltage across the inductor in this scenario.

$$V_L = V_S - V_0 = L\frac{di_L}{dt}$$

When the energy stored in inductor L is transmitted to the load and the inductor current decreases, as illustrated in Figure 4 [8, 9], the transistor is turned back on in the following cycle.

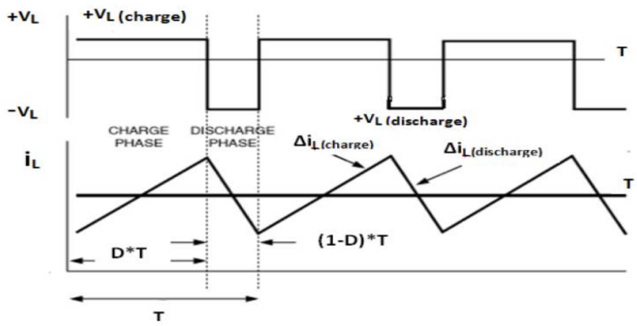

Figure 4: Waveforms of Buck-Boost converter

Figure 5 depicts the controller's physical layout in a DC-DC Buck boost converter. The graphic makes it obvious that the duty cycle value affects the buck-boost converter's output voltage. The duty cycle's value ranges from 0 to 1. According to the duty cycle and voltage relationship indicated in equation 4, if the duty cycle value is more than 0.5, the output voltage will be greater than the input voltage. Therefore, we may get the desired output voltage by adjusting the buck-boost converter's duty cycle.

$$D = \left(\frac{V_o}{V_o + V_S}\right).$$

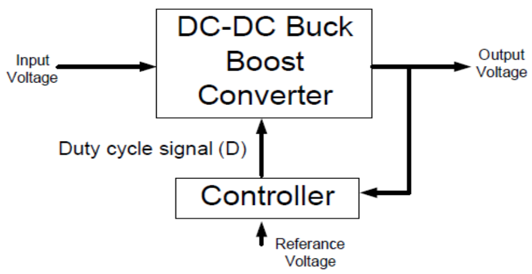

Figure 5: General block diagram for the control of DC-DC Buck-boost converter

D. FUZZY LOGIC CONTROLLER

The Fuzzy-based MPPT system of solar panel consists of two inputs and one output, which are the magnitude of error and error changes from power tracking respectively. Fuzzy logic output is a duty cycle change which is used for MOSFET switching.

$$Error = \frac{P(t)-P(t-1)}{V(t)-V(t-1)}$$
$$\Delta Error = Error(t) - Error(t-1)$$

errors and changes in errors. The error value will be near to zero when the power is at its highest, and the direction of the error change corresponds to the power change. The duty cycle change will increase with distance from the maximum point. Fuzzy logic's membership function receives these input-output parameters, which causes the duty cycle to change in response to the power situation rather than remain constant.

The range of values for the membership function, which represents the input-output values, is defined through experiment.

The system's reaction to the duty cycle modification determines how the duty cycle will be changed. Figure 6-8 shows how the system's membership features work.

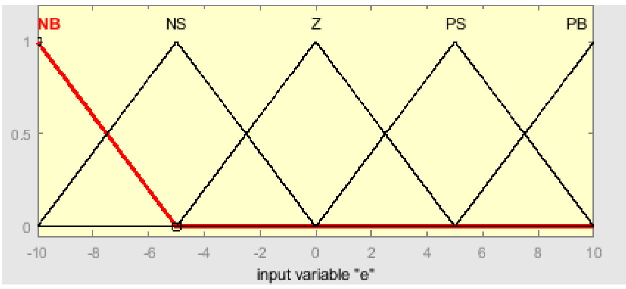

Figure 6: Membership function of error.

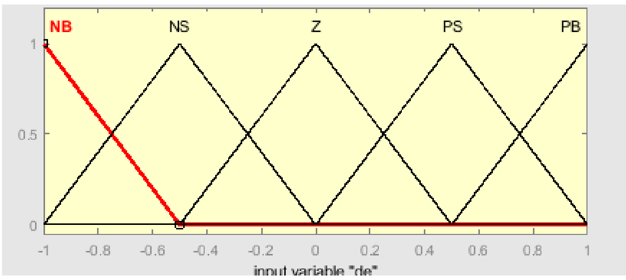

Figure 7: Membership function of error change..

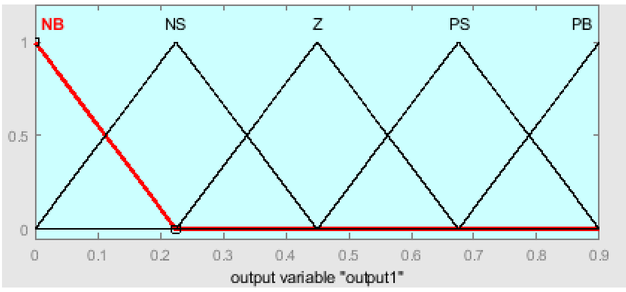

Figure 8: Membership function of duty cycle change.

Rules are used to link the two inputs in order to establish the relationship between them and the output of the MPPT. Rules are used to govern the duty cycle so that the error of input-output power in solar panels is always zero. These rules describe according to different input situations. Table (1) lists the rules applied in this MPPT system.

Table 1: rules of fuzzy logic controller for mppt system

Δt \ ΔP	NB	NS	Z	PS	PB
NB	PB	PB	PB	PS	PS
NS	PS	PS	PS	Z	Z
Z	PS	Z	Z	Z	NS
PS	Z	Z	NS	NS	NS
PB	NB	NB	NB	NB	NB

E. BLDC MOTOR

Due to its advantages over conventional DC brushed motors, as well as the faster development, efficiency assessment of control electronics, and control semi-conductor power technology, brushless DC motors (BLDCMs) are widely utilized [10]. The BLDC motor is a permanent magnet synchronized machine (PMSM) that has six transistors and an electrical system that determines (on/off) switching based on the position of the device's rotor. BLDCM works in the same way as a DC motor, but because it lacks brushes, maintenance costs are lower. Additionally, it is known as an electronically commutated motor (ECM), is powered by DC energy, and operates with a great deal of reliability [11] . BLDC motors are frequently used for a variety of applications in industries including automation and medical solutions for a variety of equipment [12]. The BLDCM is becoming more popular as performance increases. These motors have several appealing qualities, including high instantaneous torque, longer life, the ability to regulate speed over a wide range with little maintenance required, less inertia, a higher power to volume ratio, and lower friction [13] . The main problem with this engine is its expensive design and development costs, as well as the fact that the BLDC motor controller is far more difficult to use than a conventional motor controller [14] . BLDCMs have a higher energy density than other types of motors (such as induction machines (IM)), and they appear to have no loss and no commutation inside the copper of the rotor, making them perfect for high-performance applications [15,16].

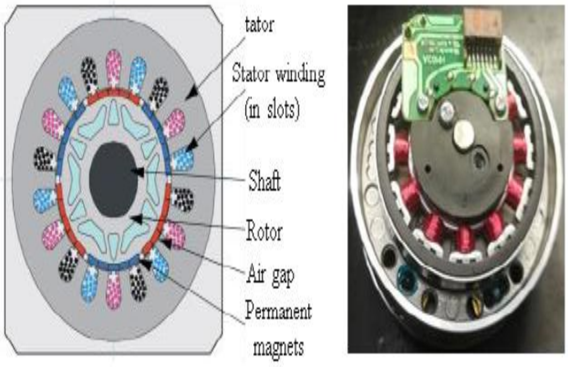

Figure 9: Basic BLDC motor construction[17]

I. *PROPOSED SYSTEM*

In order to manage the voltage obtained from the PV cell and supply it to the BLDC motor of UAV at a consistent level, we constructed and simulated a buck-boost converter using fuzzy logic controller in this paper. The drone's BLDC motor requires electricity, which is produced by the PV array. The BLDC motor receives this electrical energy via a buck-boost converter. The primary issues with PV systems are their relatively poor energy conversion efficiency and the clear climate dependency of their energy characteristics. The maximum power point tracking method was created utilizing a fuzzy logic controller to improve the effectiveness of power conversion and achieve the necessary voltage for the BLDC motor.

II. *DESIGN OF PROPOSED SYSTEM*

The following provides a full description of the design of several stages, including a PV array, buck-boost converter, and BLDC motor which was simulated by using MATLAB/Simulink.

A. Design of PV Array

Table 2: The design parameters regarding the PV system

Electrical characteristic	
Rated maximum power	100 W
Power tolerance range	0 5 W
Open circuit voltage (Voc)	21.90 V
Peak voltage (Vmp)	17.90 V
Short circuit current (Isc)	6.03 A
Peak current (Imp)	5.59 A
Max. system voltage	1000 V
Max. system Fuse Rating	15 A

B. Design of buck-boost converter

Table 3: The design parameters of buck-boost converter

System Variables	**Values**
PV Input Voltage	Volt- Volt
Output Voltage	21 Volt
Filter Inductance	133e-5H
Filter Capacitance	100.67e-3F
Output Resistance	10 Ohm

C. Design of BLDC motor

Table 3 : The design parameters of BLDC motor

Physical quaintly	**Numerical value**	**Suitable unit**
Rated speed	3,000	(rpm)
Rating voltage	500	(Vdc)
Rating (P)	1.00	(kW)
Number of phases (connection)	3 (star)	
Stator phase resistance Rs	2.8750	(ohm)
Stator phase inductance Ls	8.5e-3	(H)
Flux linkage stablished by magnets (V.s):	0.175	
Voltage constant	146.6077	(V_peak L-L/krpm)
Torque constant	1.4	(N.m/A_peak)
Back EMF flat area	120	(degrees)
Inertia, friction factor, pole pairs	[0.8e-3, 1e-3 4]	[J(kg.m^2) F(N.m.s) p()]:
Initial conditions	[0,0, 0,0]	[wm(rad/s) the tam(deg) ia,ib(A)]:

III. SIMULATION AND RESULTS OF PROPOSED SYSTEM

Using MATLAB/Simulink, a photovoltaic array is simulated as the necessary power source from a BLDC motor for the drone. To demonstrate the stability of the system under dynamic conditions, the solar radiation level is instantly reduced from 1000 W/m2 to 100 W/m2, and that power passes through a converter buck-boost, which regulates it to suit the needs of the BLDC motor. This process is done by designing one of the MPPT (FLC) technologies that controls the duty cycle of the switch in the buck-boost converter depending on the reference voltage of the BLDC motor.

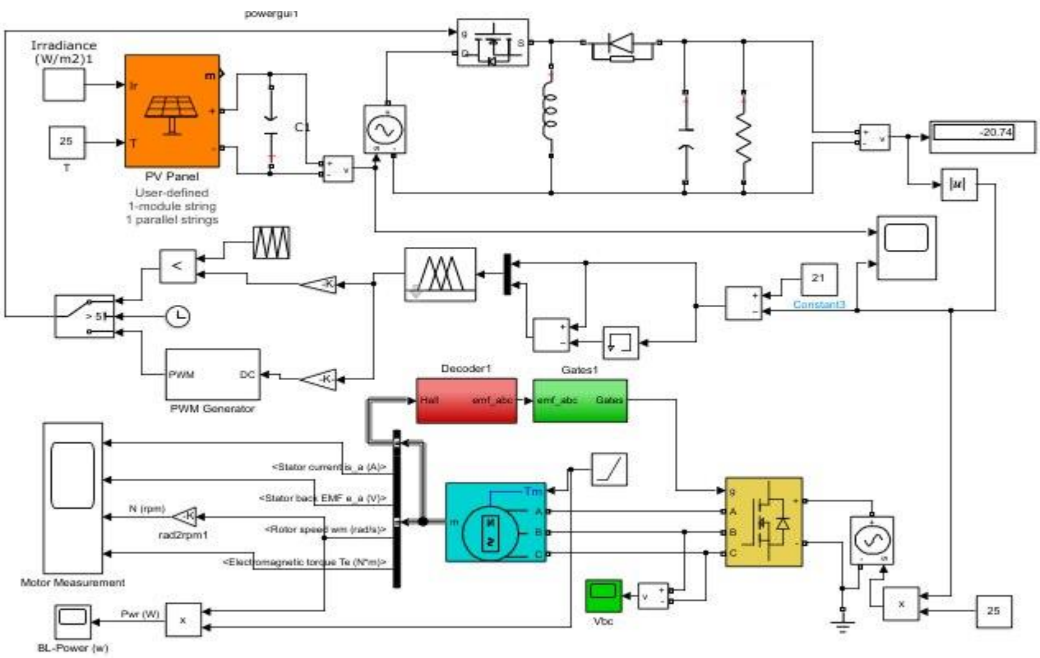

Figure 10

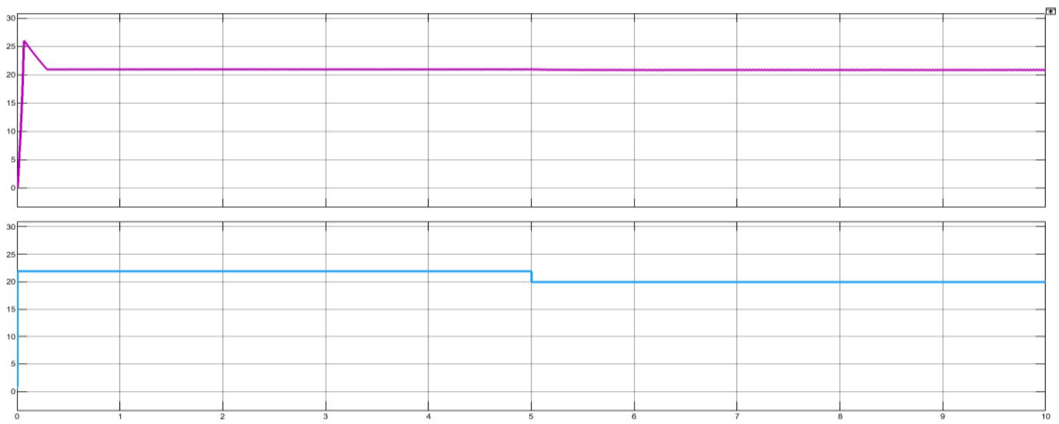

Figure 11

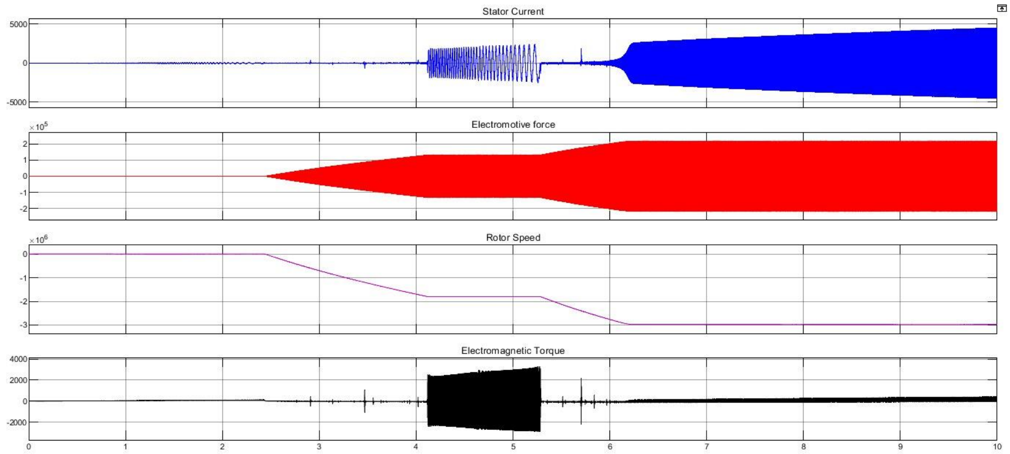

Figure 12

I.V Conclusion and discusion

The term "maximum power point tracking" (MPPT) under photovoltaic (PV) array systems is essential to guarantee that, under specified conditions, the linked systems receive the greatest power production. In this work, a solar-powered BLDC motor is used in the construction of an unmanned aerial vehicle (UAV) to replicate "fuzzy logic control," one of the popular MPPT techniques.

The cascade structure's PV cell, MPPT, buck-boost converter, and BLDC motor models are simulated, put to the test, and the results are contrasted with the technical information for DC motors. As a result, the outcomes of mathematical model simulation overlap with motor technical reference values despite variations in irradiance.

A mathematical model of a solar-powered BLDC motor for a drone was created and simulated using the MATLAB/Simulink environment.

The motor requires a voltage of 21 volts to operate, and a solar cell is used to provide this value. The solar cell gives off different levels of energy as a result of its influence on changing solar radiation. The voltage range produced by the solar cell ranges between 21.9 volts when the solar radiation value is 1000 W/m2 and 20 volts when the radiation value is 100 W/m2, so it is best to use MPPT fuzzy logic control technology to adjust the maximum output. For energy in the solar cell, the boost converter structure is connected between the solar cell and the mathematical model of the BLDC motor, which adjusts the voltage fluctuation to a constant level value according to the needs of the BLDC.

It is recommended for use in future solar-powered drone designs.

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