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Solar Based Drive System For Aerial Vehicles

[1]AMRETHA.A ME(PED), & [2]KRISHNAKUMARM.Tech.

[1]Department of Electrical and Electronic Engineering,
Meenakshi Engineering College,
Chennai, India.

[2]Asst. Professor,
Department of Electrical and Electronic Engineering,
Meenakshi Engineering College,
Chennai, India.

Abstract

The Unmanned Aircraft Systems (UAS) is used for many applications these days,both in military and civil applications. The use of UAS is increasing rapidly due to the reduced production and operating cost compared to the large conventional aircraft. The problem faced by the most UAS is their non-stop time of flight (endurance) which is typically around 5 hours for most UAS. The above problem can be overcome by using solar energy in the UAS, called solar powered UAS. The solar energy is readily available (in India) for most part of the year and can be utilized effectively to power the aircraft and its sub systems. They can have long endurance with a backup battery power. This paper deals with the design consideration and development of solar power system capable of providing endurance of more than 12hours.The power management system mainly consists of the maximum power point tracking (MPPT), the battery management, and the power conversion stages. The MPPT stage attempts to obtain the maximum power available from the solar cell panels. The battery management stage monitors and controls the charge and discharge processes of the Li-Ion polymer battery modules. The simulation is done MATLAB/SIMULINK of version (R2012a).

***Index Terms*— UAV,MPPT,Battery Management System**

I. INTRODUCTION

Solar power is the cleanest energy in the world. Usages of solar energy are widespread in industry, commercial, and military applications. The solar energy has unlimited reserves, hence can be used in aircraft as a primary source of power This paper discusses the design of a solar power management system (SPMS) for an unmanned aerial vehicle (UAV).Solar-powered UAV possesses broad research value for technology development and commercial applications. A solar-powered UAV could in principle stay overhead indefinitely as long as it had a proper energy-storage system to keep it flying at night. The design of the power management system for such aircraft is challenging due to possible rapid attitude changes during manoeuvres.It is also used to charge the battery, used as a backup source when sunlight is not sufficient to produce enough power.

The major problem faced by the use of solar cells is the added weight, which is of main concern in the aircraft design. With the advancements in the design of solar cells, thin, flexible, light weight and high efficiency solar cells of more than 40 % are developed. These advancements in solar cell design reduced the weight concern. The most important consideration for using the solar power is to maximize the utility of the solar power while it is available. To ensure that the maximum available power is received from the solar panel, a certain type of maximum power point tracking (MPPT) algorithm[1] is usually incorporated into the SPMS. A comparative study of MPPT algorithms that could be easily implemented in a low-cost microcontroller is reported in [3].The perturb and observe algorithm [6] can efficiently track the maximum power point under rapidly changing atmospheric conditions. In this paper, we are implementing perturb and observe algorithm and use the natural sunlight as the irradiance source.

The most common form of the energy storage for the stand alone solar power system is battery technology. The basic functions of the battery management are to control the charge/discharge of the battery, to protect the battery from damage, to prolong the life of the battery, and to maintain the battery in a state to fulfil the functional requirements. The lithium-ion polymer battery is selected for this UAV application study. The microcontroller-based charge controller is designed to control the auto-ranging power converter to maximize the utility of the solar power. Two battery modules with one serving as the charging module and the other as the discharging module are used in this design.

II. SOLAR POWER MANAGEMENT SYSTEM

The solar power management system incorporates a DC-DC converter, an MPPT in microcontroller and a Battery Management System (BMS).The microcontroller is used to sense the input and output power to perform MPPT operation and to generate gate pulse for DC-DC converter. The purpose of BMS is to monitor each cell and to avoid over charging of battery, hence increasing the battery life. The first step in the design of solar power system is to identify the power demand and the maximum power that can be generated with the available surface area.

The solar power management system is to be incorporated into UAV is shown in figure 1.

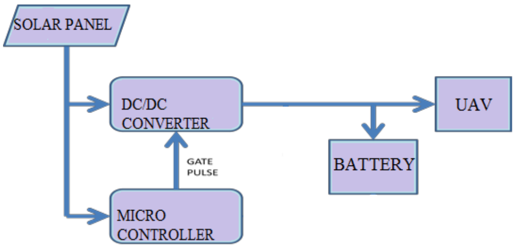


Fig. 1 Diagram of solar power management system

III. POWER ESTIMATION

Power estimation is made to match the total power demand of the UAS. Power requirements broadly depend on the power required to generate aircraft thrust and the power required to operate subsystem and payload. The four forces acting on the aircraft is shown in figure 2.

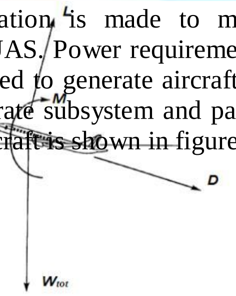


Fig .2 Forces acting on an airplane at level flight

For a level equilibrium flight,
Lift force= Weight
Drag force= Thrust
The power required for level flight is

$$P_{LEV} = T.V = \frac{C_D}{C_L^{3/2}}\sqrt{\frac{2ARg^3m^{3/2}}{\rho b}} \quad (1)$$

Where T = Thrust

V=velocity

C_D,C_L= Drag and Lift coefficient

AR= aspect ratio

m= mass of the system

ρ = air density

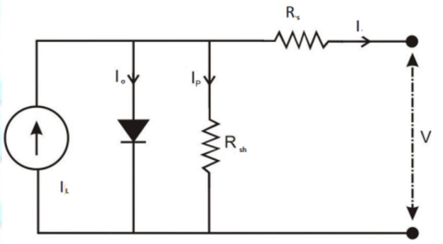
b =wing span

IV. MAXIMUM POWER POINT TRACKING

The electric power generated from the solar cells depends on the temperature and the solar radiation conditions and the load electric characteristics. MPPT is often used in photovoltaic systems to maximize the solar panel output power, irrespective of the temperature and irradiation conditions and of the load electrical characteristics. The solar cell is a nonlinear device and can be represented as a current source model as shown in Fig.3[21] where I is the equivalent current source, R_{sh} and R are the shunt and series resistance of the material and D is the P-N junction diode.
From figure 3 the current from the panel is given as

$$I_L = I_{ph} - I_D = I_{ph} - I_O\left[\exp\left(\frac{qV_L}{KTA}\right) - 1\right] \quad (2)$$

where q is the charge of an electron, K is Boltzmann constant, A is the ideality factor of the P-N junction, T is the solar cell temperature (K),and I_0



is the reverse saturation current

Fig.3 Equivalent circuit of Solar Cell

The light generated current source I_{ph}

$$I_{ph} = [I_{sso} + K_i(T - T_r)]\frac{S_i}{100} \quad (3)$$

where I_{sso} is the short-circuit current at reference temperature , K is the short-circuit current temperature coefficient, S_i is the insolation in mW/cm2 .So the output power from the solar cell can be expressed as

$$P = I_L V_L = I_{ph} V_L - I_o V_L\left[\exp\left(\frac{qV_L}{KTA}\right) - 1\right] \quad (4)$$

Output current and power for the particular solar power panel are shown in figure.4.Each curve has a maximum power point as indicated in figure.4, which is the optimal operating point for the efficient use of the solar cells at that particular operating condition. In order to efficiently use the solar cells, we attempt to force the solar cells to operate at the maximum power point through some mechanism called the MPPT.At maximum power point ΔP=ΔV =0. We decrease the output voltage if ΔP=ΔV < 0, and increase output voltage while ΔP=ΔV > 0.

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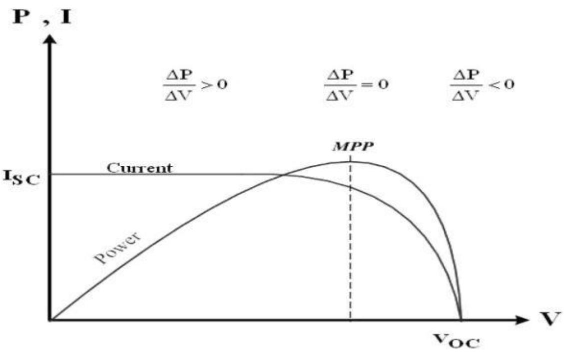

Fig.4 Characteristics of Solar Panel

The flow chart of the MPPT algorithm used in the simulation is shown in figure.5. The MPPT system consists of a pulse width modulator (PWM), a MOSFET driver, a dc/dc buck power converter, and a micro-controller. A commonly used MPPT algorithm includes perturbation and observation method [3], incremental conductance technique and fuzzy logics. In this design, we use perturb and observe technique to implement the MPPT function.

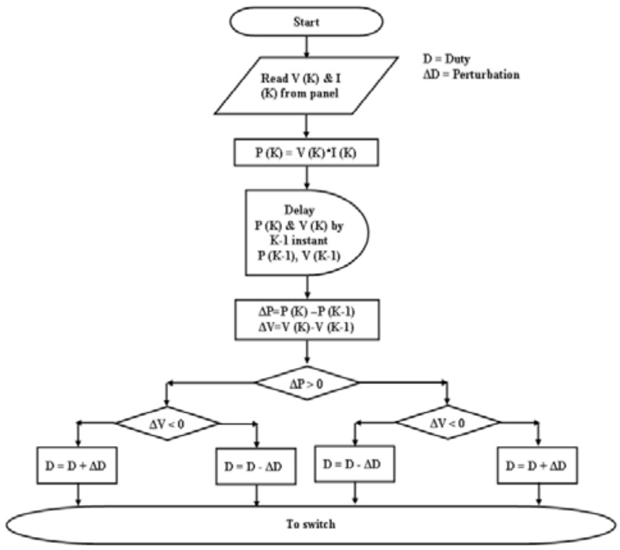

Fig.5 Flow Chart of Modified Perturb and Observe Algorithm

V. BATTERY AND LOAD

Energy storage is necessary in case of decrease in solar irradiance due to clouds and also to increase the reliability of the system. Rechargeable batteries are the most preferred choice of energy storage medium. Commercially available batteries and their specifications are given in table -1.

Table 1: BATTERIES AND SPECIFICATION

Battery	Energy density (Wh/kg)	Power (W/kg)	Efficiency (%)
Lead – acid	30 – 40	180	70 – 92 %
Nickel cadmium	40 – 60	150	70 – 90 %
Lithium – ion	150 – 250	1800	99 %
Lithium – ion polymer	130 – 200	3000+	99.8 %

Lithium – ion polymer battery is preferred as it has high efficiency, power and considerably high energy density. The primary load connected to the solar panel is the electric motor, used to propel the aircraft. The battery and load is connected directly to the output of DC/DC converter. The battery gets charged when the power available from the PV module is higher than the power required by the load and vice-versa for discharging.

VI.BATTERY MANAGEMENT SYSTEM

The battery management system monitors and controls the storage and delivery of the energy drawn from the solar panels. Lithium –ion polymer (Li-Po) batteries are less tolerant to overcharging. Battery Management System (BMS) is used to avoid overcharging of the individual cells. Commercially available Li-Po batteries have individual cells connected in series to provide the required voltage, 3-cell and 4-cell batteries are commonly used, as shown in figure -6.

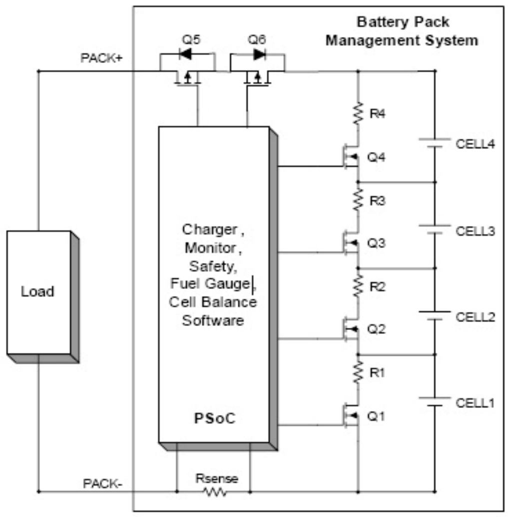

Fig .6 Battery management system

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VII.SIMULATION AND RESULTS

The simulation of the power management system was done in "MATLAB – SIMULINK". The buck converter is designed and simulated for Continuous Current Mode (CCM) operation. The SIMULINK model used for the simulation is shown in figure 7.

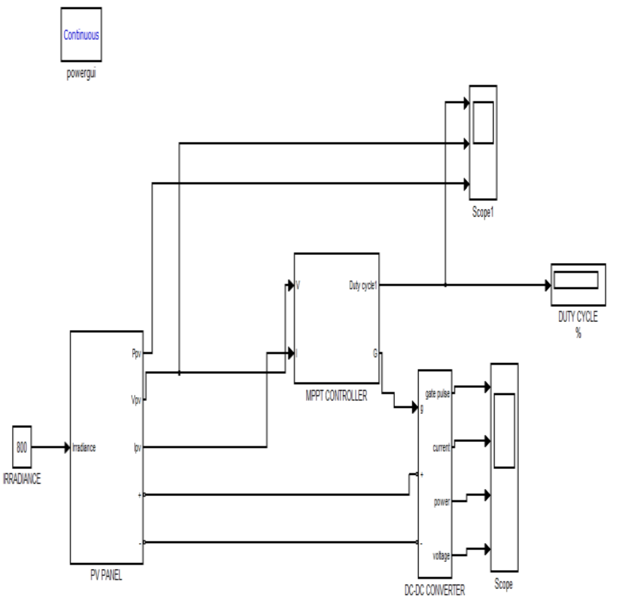

Fig 7 Simulation Diagram of the Power Management System

Table 2: DESIGN PARAMETERS

Parameter	Value
Input voltage (max)	21 V
Nominal output voltage	12.5 V
Output current (max)	4 A
Frequency	10 KHz
Load resistance	5 Ω

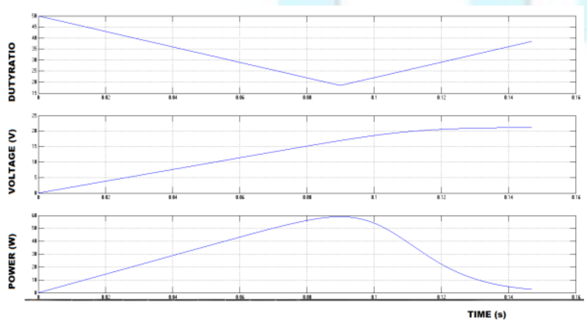

Fig 8. Variation of Duty Ratio, Panel Voltage, Panel Power

The figure 8 shows the panel output power and voltage and duty cycle. It can be seen that as the power and voltage increases duty ratio is decreasing till a value of 19%. When the maximum power is reached the duty ratio starts to increase to maintain that power of 60W.

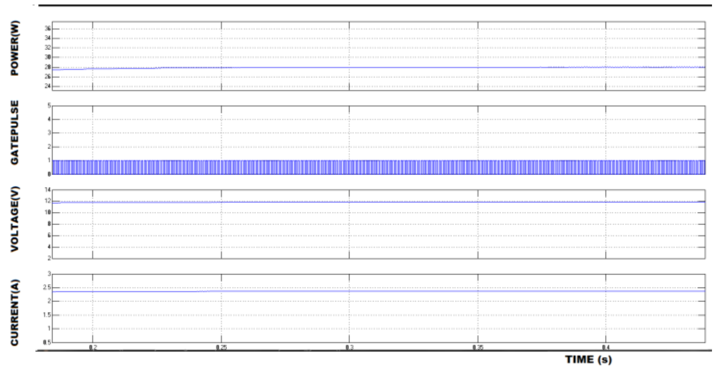

Fig 9 Simulation output of the converter system

Simulation output of the converter system is shown in Fig 9. It can be clearly seen that the output voltage is maintained at the level of nearly 12 V with a current of 2.4 A and the power of 28.8 W.

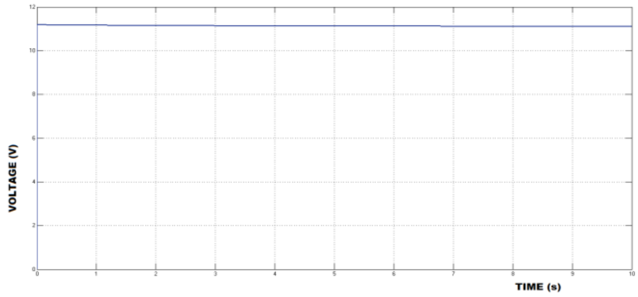

Fig 10 Output voltage at the R-load

Figure 10 gives the output voltage at the resistive load. The voltage across the resistive load is at nearly 11.2 V.

VIII.CONCLUSION

This paper discusses the design of an SPMS. The system consists of solar power panels shaped to accommodate aircraft configuration, an MPPT system to increase operating efficiency of the solar cells, a battery management system to monitor and control the energy storage. MPPT algorithm improves energy efficiency of the system in comparison to the systems without MPPT reducing the size and cost of the panel. An experiment system for MPPT evaluation has to be developed to support the system design. The results will be used to improve the solar powered UAV configuration, propulsion and performance designs. The endurance of the flight is the main consideration of electric powered UAS.It can be overcome with the help of solar power with battery .With

proper selection of components and power system design the aircraft can be kept in flight for weeks and months.

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