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Enhancing the Flight Time of Multirotors Using Solar Energy

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Abstract: *Multi rotors are devices that fly with the help of two or more rotor mechanisms. It is evidentiary that multi rotors have a very less flight time due to low power availability. If the size of the battery is increased to increase the discharge capacity, then AUW (All Up Weight) increases .Hence another solution to this problem is to be found. To increase the flight time, solar energy can be used. But the size of solar panel increases AUW. Therefore a circuit is proposed in this paper which increases flight time significantly by slightly increasing the weight. Secondary power system based on solar energy is used in the circuit. The secondary power system gains energy from solar panel on a continuous basis. An economical design of a hex copter was made that gave an average flight time of 7mins without deploying solar cells and around 9mins with solar cells. This design not only increases the flight time but also helps in charging the battery in substantially less time, without making the battery offline. This application can be useful in long distance flights.*
Keywords: *AUW, thrust, flight time, pitch, ESC.*

I. Introduction

Multi rotors are devices that fly by using two or more rotors. The principal of operation is to provide upward force twice or more than twice of its weight. Based on number of rotors they are differentiated as tri copter, quad copter, and hex copter. A multi rotor finds its application in surveillance where rotor has to monitor a scenario, as the flight time of multi rotors is less their use is not that extensive. They consist of six major Components:

1. Battery: These are portable power units which store electric energy and provide them when load is applied. In drones generally a lithium polymer battery is used due to its light weight characteristics.
2. Motors: These are rotary mechanisms that consist of a stator and rotor part. As name specifies stator is stationary unit and rotor is rotating unit. In drones a stationary core and a rotating out runner is used.
3. Propellers: Propellers are blades which when rotated generate thrust by pushing the air downwards. These are specified based on diameter and pitch.
4. ESC: Electronic Speed Control units are electronic chips that vary the speed of motors in accordance to the signal provided by changing the voltage of motor.
5. Flight Control: This is a major component in drones. It controls the degrees of freedom of a drone by controlling the motors in a synchronized way.
6. Receiver-Transmitter: These are used to control the drones by giving a signal. The receiver placed on drone receives the signal and transmitter transmits the signal.

These components are connected to each other and are fixed on a frame. Copters are VTOL rotorcraft with propellers/rotors for propulsion. Multirotor is a more general term encompassing not only quad copters but also tri copters, hex copters, octacopters and all other form of rotorcraft with more than 2 rotors. The early pioneers actually first attempted rotor flight using multicopters, because using more than one rotor seemed to be the natural solution to the problem of VTOL flight. The very first experimental attempts of taking off with a rotorcraft were mostly done with multirotors. Around 1907 Jacques and Louis Breguet, French brothers, built and tested Gyroplane No 1, a quad copter. They managed take-off, although the design proved to be very unstable and hence impractical.

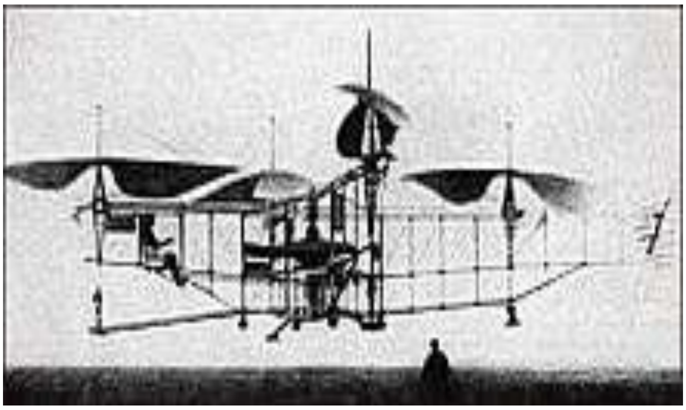

Fig 1.1 Oehmichen model

A Multi rotor uses energy from an energy bank known as battery. As long as current is provided to the motor the multi rotor flies. If a more discharge battery is used, then the large size of the battery will increase the total weight further increasing the requirement of upward force.

As we know solar energy is abundantly available it can be utilised to increase the flight time. But the problem with solar panel is that ,to charge main battery of high wattage large size panels are required which posses heavy weight, they will costs on the AUW further deceasing the flight time.

Hence a circuit that utilises secondary battery system can be used. The secondary battery acts as a charging unit for main battery. The paper is organised in the following manner: Section 2 describes the dual battery circuit in detail. The calculations for a hex copter model are shown in Section 3.

NOTE: the circuit can be extended for other type of copters as well.

II. Circuit Description

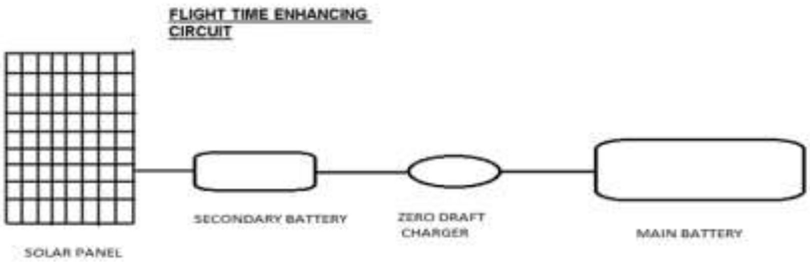

FIG 2.1 Flight Time Enhancing Circuit

The circuit consist of four major parts. They are as follows:

A. Main Battery: It is the primary battery that provides power to run the motor -propeller unit, which provides the upward thrust. Mostly a lithium polymer battery is used for flight applications. The battery is selected based on the current requirements of motors. The discharge of battery should be more than the current drawn by motors.

B. Secondary Battery: The connection from solar panel is extended to secondary battery and from secondary battery to primary through a zero draft charger. The secondary battery should contain a voltage more than primary battery as it facilitates the current flow. If the secondary battery contains a less voltage the secondary battery draws current from main battery reversing the flow.

Here in this design it was made sure that the DC battery to DC battery discharge will happen at the faster rate possible by increasing the potential difference.

C. Zero Draft Charger: This is basically a key mechanism located between main and secondary battery. It moderates the current flow from secondary to primary battery. It is embedded so as to start charging as soon as main battery discharges. The embedded chip continuously checks the voltage of main battery and provides the value as an input to a loop which checks continuously whether the charging initiation point has reached or not. If the discharge reaches the required value then the zero draft charger pulls the key between secondary and primary batteries closing the circuit and allowing current to flow.

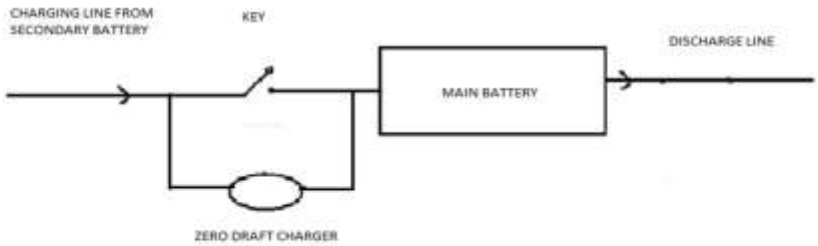

FIG 2.2 Zero Draft Charger

D. Solar panel: This is where solar energy is converted into electrical energy. The selection process of panel is in accordance with secondary battery. Hence small capacity panels can be selected as the wattage of secondary battery is less. The solar cells can be arranged in such a fashion that they occupy less space, as more space results in more drag force on copter. Each standard solar cell provides 0.5V and has wattage of 1 W with dimensions of 40 X 40 mm.

III. Calculations

In this section of paper, calculations for design of a hex copter (1kg model) are carried out.
Initially assuming total weight (AUW) = 1000g.
The next step is of calculating thrust needed to lift and hover the copter. As rule suggest thrust should be more than twice the weight of copter (Total thrust) = 2.4x1000=2400g.
Now to calculate thrust acting on each motor, divide the total thrust with number of motors (TOM) =2400/6=400g.
Once the thrust is determined the next step is to select a compatible motor and propeller configuration (most of manufacturers provide either charts or tables for this purpose). The following motor configure was selected.

Kv	2700 rpm/volt.
Max load current	7.5A
No load current	0.7A
Weight	20gx6=120g
Propeller	7x 4.7 (weight =20gx6=120g)

A motor and propeller combination is to be selected by taking thrust into consideration. For this purpose thrust formula can be used.
Thrust (Newton) = $((\text{etaxW})^2 \text{ x } 2 \text{ x } 3.14 \text{ x } R^2 \text{ x } A_{\text{air density}})^{0.3333}$
Eta = motor efficiency.
W= motor wattage
R= propeller radius (meters)
A=air density = 1.22 kg/ m^3
For converting thrust from Newton into Kgs divide the obtained value by acceleration due to gravity (g =9.81m/s^2) and further to convert Kgs into grams multiply with 1000.
T= $((0.8\text{x } 89)^2 \text{x2x3.14x } (7\text{x } 2.53)^2 \text{x } 1.22)^{0.3333}$= 9.8Newton

⇨ T=9.8/9.8 kg= 1kg=1000gms

Hence this combination can generate a maximum thrust of 1kg; the required thrust is of 0.4kg.
The maximum altitude that can be reached with this combination = 4.7’ x 2.53 x maximum rpm.
The maximum rpm of motor at 7V = 7 x 2700=18900rpm.
Hence the maximum altitude is = 4.7 x 2.53 x 18900=224739.9 cm =2247.4m
By taking max current drawn from motor into account an ESC is to be selected.
From motor current unit Lithium-polymer battery can be selected by satisfying the following condition:

$$\text{C- Rating of battery} = \frac{\text{(current drawn by each motor x no. of motors)}}{\text{(Ah reading of battery)}}$$

In this case 2S 3000mAh li-po battery was selected (weight=249g).
Now by taking into account the primary battery mAh capacity select secondary battery , say around 20% mAh of primary battery 500mAh,3S li-po (weight=92g) battery was selected. The wattage of secondary battery = working voltage x mAh =5.5watts.
Taking in account wattage of secondary battery, select a solar panel. Make sure that the voltage of solar panel is more than secondary battery voltage.
As discussed earlier solar cell specifications:

Required voltage = 11.1V ~ 12V
Each Cell voltage = 0.5 V => Total number of cells = 24 cells.
Each cell area = 40 X 40 = 1600 mm^2 => Total area coverage = 24 X 1600 = 38400 mm^2 = 0.0384 m^2.
Weight of each cell = 4grams => Total solar cell weight = 96 grams.
These 24 cells will charge the secondary battery in 15 mins as battery amperage is 0.5 and solar panel amperage 2. For more swift charging an additional 24 cell can be attached in parallel decreasing the time to 7 mins.
Once all the components are selected a cross check is to be performed to determine whether the total weight is below the limit or exceeding it. If it's exceeding the limit, repeat the process from beginning by taking new weight into consideration and check whether the components can withstand new load.
Total weight = weight of (main battery + secondary battery + solar panel +frame +motors + propellers + miscellaneous for wires, ESC, etc) = 249+92+100+150+120+120+150 =1000g (approx).
In this scenario as it is falling below the limit, the design is preferable.
In the end to determine the flight time, divide Ah of battery with average ampere drawn by 6 motors and multiply with 60 (for answer in min).

$$\text{Flight time} = \frac{\text{(Ah of battery x 60)}}{\text{(Average current drawn)}}$$

Calculation of Average current drawn can be carried out in three ways. First knowing the current drawn at the known thrust (can be determined only after testing) and second method is interpolating the current value with the help of min. current of motor and max current of motor from the motor chart. The last method include running simulation on various e-sites available, here E-calc site was used. In this case second method and third method was used which gave an approximate value to be 3.85amps.
Initially calculating the flight time without secondary battery unit, we get
Flight time = (3 x 60)/ (3.85 x 6) = 7.79min
Now calculating with secondary battery, here the solar panel charges the battery as long as it has solar incidence and as soon as the point of charging main battery is reached, secondary battery keeps discharging continuously. In this case calculating flight time becomes difficult. Hence calculation of flight time for worst case scenario was made by assuming that in this case secondary battery will be charged only once (+500mAh).
Flight time = (3.5 x 60) / (3.85 x 6) =9.09

$$\text{Percentage increase in flight time for worst case scenario} = \frac{(9.09-7.79) \times 100}{7.79}$$

= 16.69%.
While working of model a percentage increase in flight time up to 30% and above is possible.

IV. Conclusion

A new design utilising solar energy for increasing flight time of multi rotors was presented in this paper with design calculations of an enhanced hex copter. It is evident that flight time majorly depends on battery discharge; hence by increasing the discharge capacity for the same battery size, more flight time can be attained. With the work carried out in this paper it was estimated that a multi rotor with this circuit in worst case scenario had more flight time than a model without this circuit.

To prove the above data a prototype was developed and flight time was determined. The flight time of prototype without solar panel was 5mins and with solar panel was around 7mins at an altitude of five meters, increasing the flight time by 40%. If the altitude is increased, the flight time of the copter decreases. A large increase in flight time can be attained by using large capacity of secondary battery or directly charging main battery. Hence it was determined that this circuit helps in increasing the flight time of multi rotors with small addition of weight.

The continuous charging of the battery without its removal from frame was found to be very helpful while making a long distance run. The only problem faced was over heating of the batteries. This problem can be overcome with proper ventilation for cooling is provided for battery. Hence in this paper it is being concluded that this circuit helps in increasing flight time of multi rotor and also eases the charging procedure this application was found crucial in long distance runs.

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