ELECTRONICS PROJECT

Submitted To:
Dr. Swati Arora
Cluster Innovation Centre
Submitted By:
Vaibhav Jain(11634)
B.Tech (IT & MI) - IIIrd Semester
Cluster Innovation Centre

This report is submitted as the fulfillment of the project of Electronics and Circuit Designing
In Semester III of B.Tech (IT & Mathematical Innovation)
at Cluster Innovation Center, University of Delhi

Table of Contents

Abstract

In this project, a design for power management of quadcopter is described. The design aims to extend the operating time of the battery. It employs a solar panel mounted on the quadcopter as a means of efficiently harvesting the ambient solar energy. The comparative study of a quadcopter with and without a solar panel is also done. The main aim is to increase the battery life by using a clean power source such as solar energy.

Introduction

As the name suggested quad means four and quad-copter is an unmanned aerial vehicle made up of four motors which are fixed in a frame structure. As the quadcopter has the advantage over agility and stability, they have become a good choice for applications that require unmanned aerial vehicle. Great tasks can be achieved easily within minutes using Quadcopters. However, most of the quadcopters which are available commercially have the disadvantage of limited power supply onboard which generally lasts upto 30 to 40 minutes (this is the maximum flying time achieved by any commercial quadcopter till now). This disadvantage restricts the usage of quadcopters in many areas where they could have been of great help. In this project, our objective is to design a quadcopter circuit which uses solar panel in order to supply power to the circuit (i.e, micro-controller) which would eventually reduce the power usage of the Lithium Polymer (Li-Po) batteries used in the drone and hence, prolong it's flight time.

The transition from fossil fuels to renewable energy sources is an ambition not just at the field of flight though. In the last decades, a considerable effort concentration towards that direction has led to an evolution of the renewable energy resources technologies. Therefore, specifically at the field of aeronautics, utilizing alternative energy sources, and mainly solar energy, for flight applications is becoming more feasible and realistic in the 21st century. The operation of a so-called "solar aircraft" is based on a rather simple procedure. Solar panels installed on the external surfaces of the aerial vehicle collect the power from the sun during daylight and transfer it to the aircraft's batteries, which in turn power the propulsion systems and the electro-optical equipment of the aircraft. The panels and the batteries have to be appropriately sized, in order to ensure that there is enough energy surplus available to power the vehicle during the night i.e. when the sunlight is absent. Therefore, it follows that the use of solar energy can help to dramatically increase flight endurance, and even unlock the potentiality of "eternal flight", thus adding to the aforementioned advantages of UAVs. In the present study, the conceptualization of an aircraft that will utilize both solar and conventional energy sources is attempted. Thus, the benefits of solar-powered flight are exploited, while the conventional power source provides the system with increased reliability and versatility, being for example less dependent on weather conditions.

Literature Review

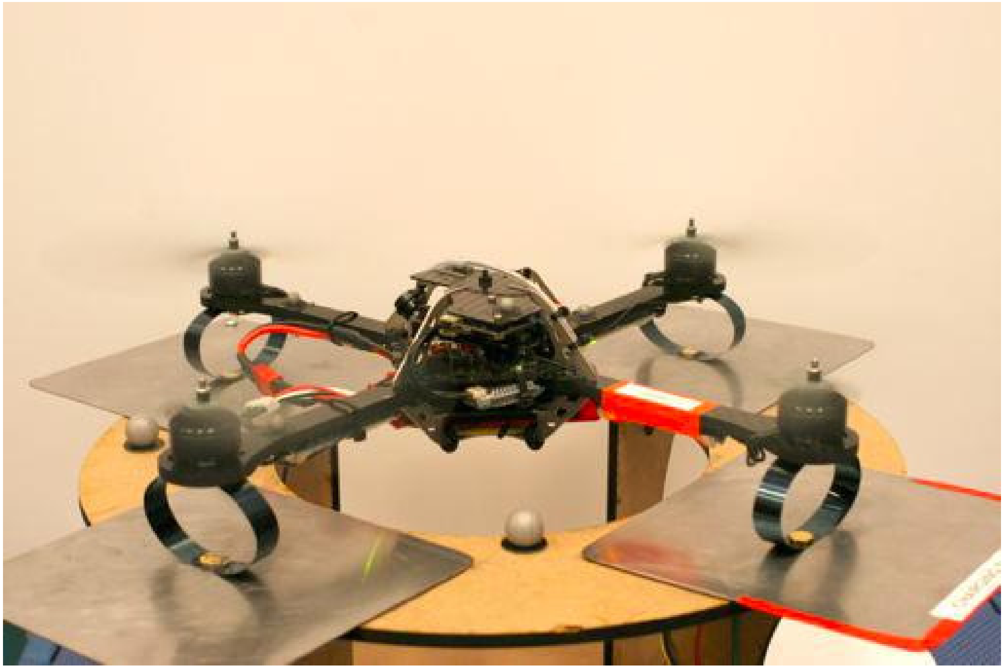
Published work relevant to this project is reviewed throughout this section in order to identify opportunities and limitations posed by existing technologies. The review process is also undertaken to identify gaps which can be addressed. System requirements and research questions are then in turn derived from this accumulated knowledge.

3.1 THE ENERGY PROBLEM

Some of the greatest problems for robotics are energy-related, as the whole system may shut down if energy sources are depleted. High power consuming motors, flight systems, onboard computers and external equipment are all powered by the main battery and consequently flight times and range of operation are limited. It is important to consider that the physical design, including weight and any action taken by the robots increases energy consumption as stated by Seyfried et al. in [7]. It is therefore important to ensure that both the physical design of the robots and any activity taken by the robots are energy efficient. A requirement for an autonomous unmanned aerial vehicle (UAV) is the replenishment of its energy source. Automated energy recharging systems must be developed to satisfy the desire of fully autonomous systems. Such processes are often overseen and effectively reduce the operating range of the system. While it is unlikely that all ground based activities can be automated, the energy source is a possible target for automation. One research angle would be to try to harvest energy from the environment as stated by [10]: "The replenishment of the on-board energy resources must not be performed manually; ideally the robots harvest energy from the environment." Energy-harvesting techniques may even be better to use, as using batteries for the primary power source for sensor networks can be troublesome due to their limited lifetime. Simple solar power based systems has already been tested as demonstrated by [12] and [13]. But sources such as airflow, vibrations, thermoelectric and electromagnetic radiation can also be used to power wireless sensor networks. Another practice, as described by [14], refers to using wireless radio-frequency energy transmissions from a base station to power sensors over limited distance. However, the radio-frequency technique is severely limited by legal limits set by health and safety concerns. For tasks such as surveillance, monitoring and long-term sensing perching techniques can be used to conserve energy as the aircraft can remain at rest. Perching instead of hovering will prolong mission endurance and can provide images without motion blur using long exposure times. It can be concluded that the lack of sufficient energy sources is one of the main issues. If this issue can be solved the results would contribute to limiting the need for human interaction, and increasing the range of operation which is desirable. This issue will be addressed in the system requirements and research questions sections. It can also be concluded that keeping the weight of the system as low as possible will minimize the loss in flight time, so the total weight of the system should not be more than half of the rated quadcopter payload. An initial estimation is that no more than 20% loss in flight time could be acceptable as more would reduce the range of operations too much.

3.2 AUTONOMOUS RECHARGING

There has been quite a lot of research done about autonomous recharging of rotorcrafts, and there are some suggested practical applications. [15] uses a stationary charging station that is composed of four stainless steel landing pads, which also works as contact surface for charging. The magnets embedded in the charging ports on the quadrotor pull it toward the landing pads and ensures good contact. The pads of the charging station are connected to a LiPo charger that interfaces with the rotorcraft once it lands. The design is shown in Picture 1. This design requires that an on-board software monitor is used that determines when a vehicle must return to the charging station location for recharging. [18] suggests a similar solution where the rotorcraft will operate in an environment with one or more charging station locations. It is said that the units will be recharged wirelessly and in situ using an inductive charging platform. In the same manner there exists an idea of charging rotorcrafts by flying close to power lines.



Picture 1 – Charging station design [15].

[18] presents three different service station solutions. The Rollin' Mat is a rollable mat where the three different sections are connected to the different terminals on the battery charger. The corresponding terminals of the on-board battery of the UAV are also connected to locations on the UAV so that they match the areas of the mat when it lands. The design is shown in Figure 7. The Concentric Circles is a very similar platform but requires lower precision in the landing. The terminals on the UAV are deployed in such a way as to guarantee that the terminal match is independent of the helicopter orientation. This design is shown in Picture 2. The third suggestion is a Honeycomb station where an IR emitter signals to the platform that the vehicle has arrived.

The platform controller can then connect the terminals of its battery charger to the appropriate hexagon cells, and thus the battery terminals.

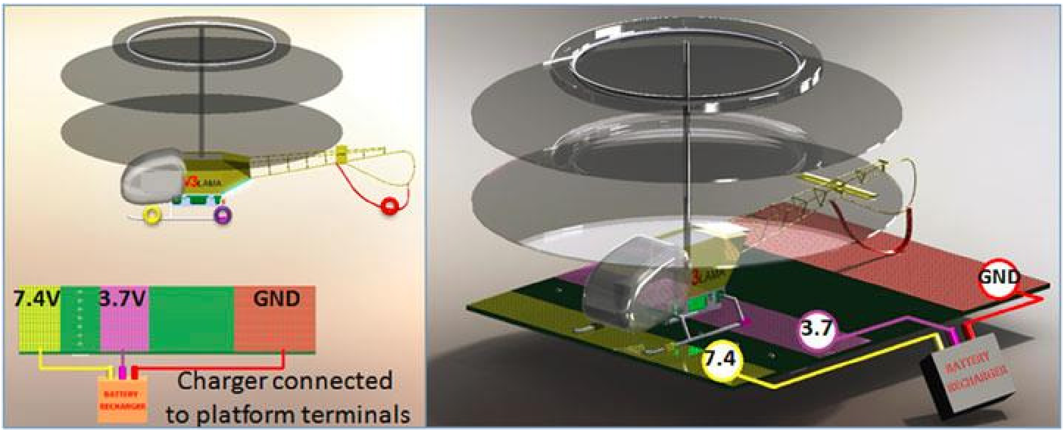
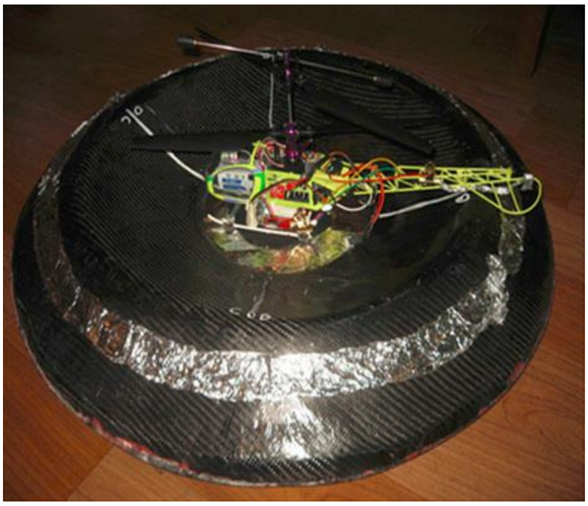


Figure 7 – Rollin' Mat station [9].



Picture 2 – Concentric Circles station [9].

All these suggestions has in common that they solve the problem of autonomous charging, but as they are all stationary charging station solutions they do not solve the problem of long range operation. For a UAV to be truly autonomous it must be able to recharge regardless of the distance to the base or any field station. A solution of an on-board recharging system which would make the

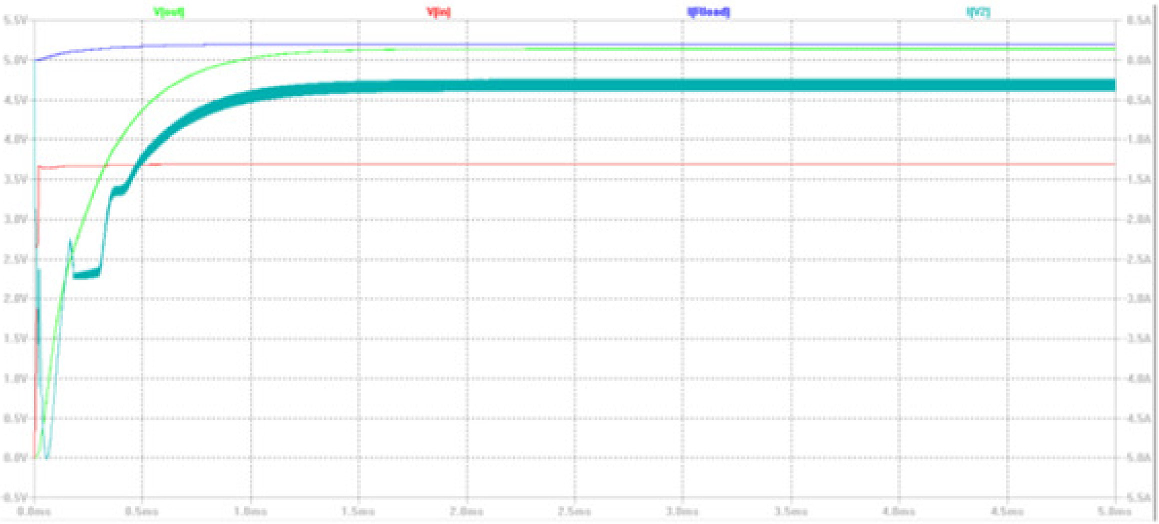
vehicle more autonomous than the suggestions presented above would be preferable.

Methodology

The project aimed for increasing the efficiency of a quadcopter using solar cells as another source of energy. Thus, we carried out some experiments to show the effect of solar cells onboard a quadcopter. This is to note that most of the experiments shown in this work are simulated results gained through an open source quadcopter simulator library in Robot Operating System (ROS) environment. The experiments and their results are as follows:

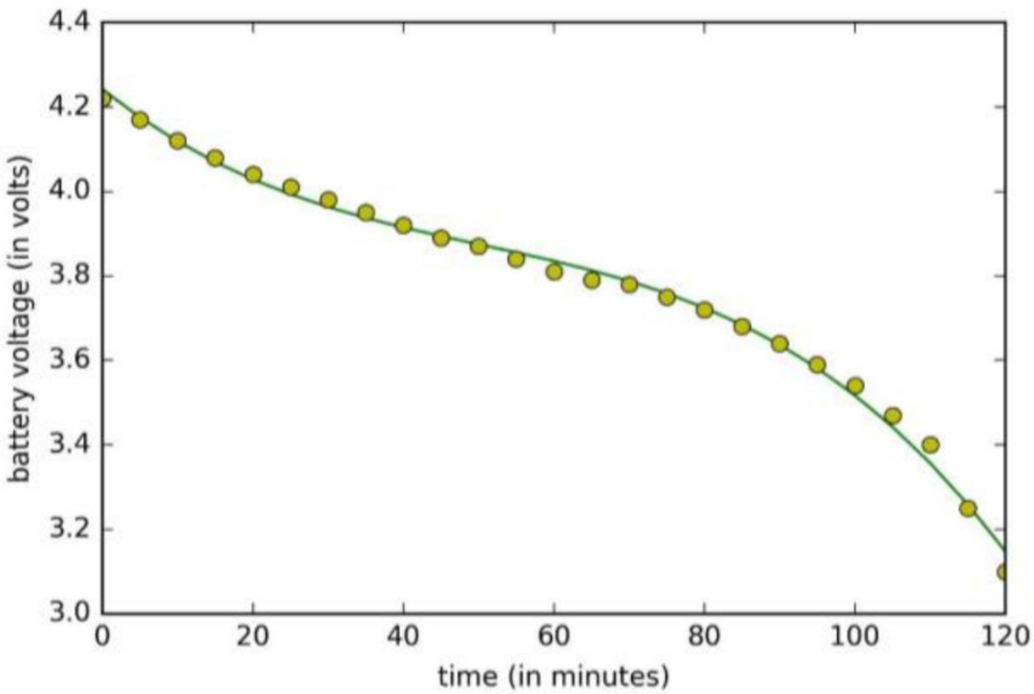
- Effect of solar panel on response time of quadcopter

The simulation shows the response of the circuit showing the input power given by the source voltage (red) and the input current (cyan) drawn from the battery while it is simultaneously charged by the solar cells and discharged to the load, and the output power represented by the output voltage (green) which satisfies the requirements of the load circuit and the output current (blue).

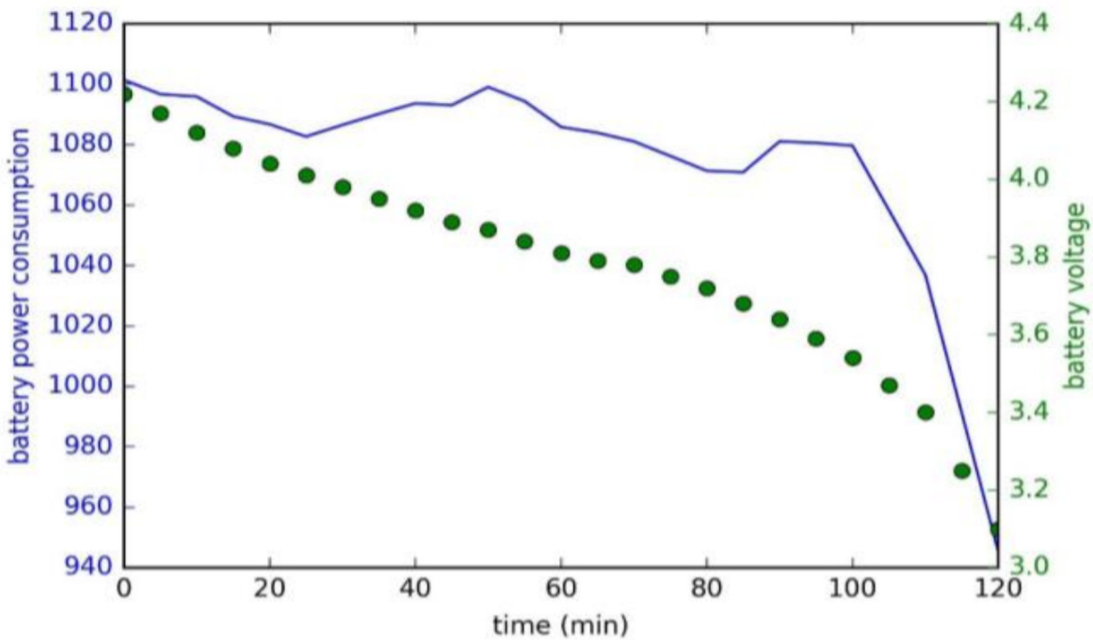


All the parameters achieve a stable condition at 1ms which suggests that constant supply is given to the load at the nominal battery voltage (3.7V) which is the average lithium battery state and the load circuit is drawing constant current at a maximum of 200mA

- Effect of solar panel on flight time

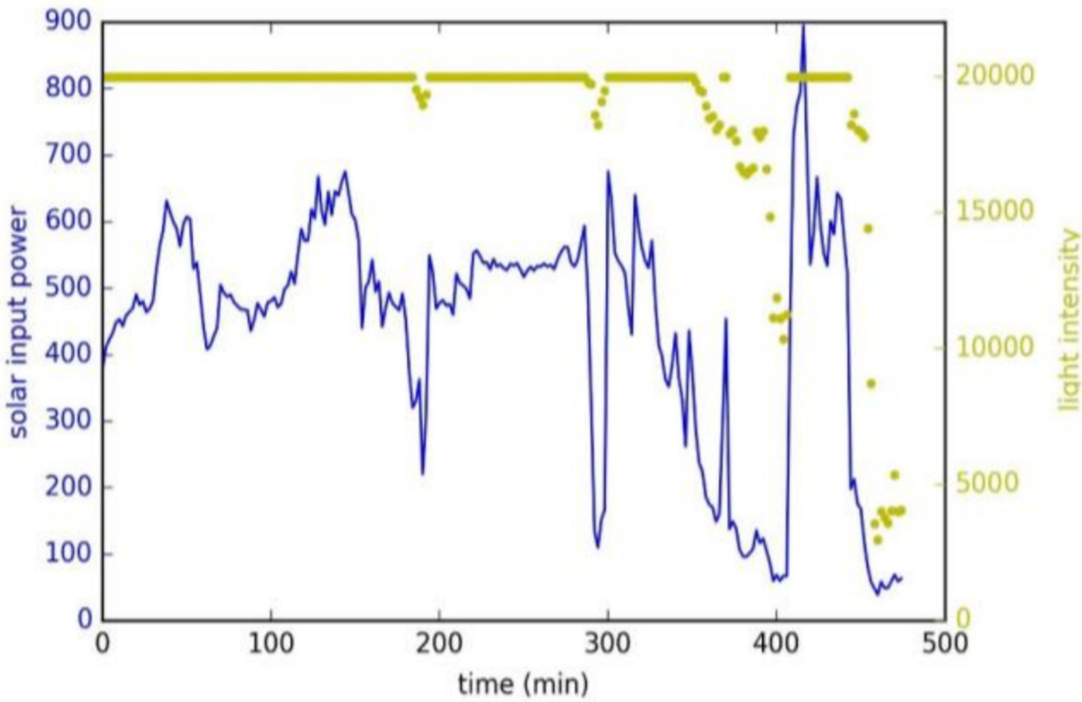


The above figure shows drop in battery voltage as the time passes. Clearly the drop if more when battery voltage is low. After using solar cells for charging the the battery the flight time increases. This can be illustrated by the simulation below

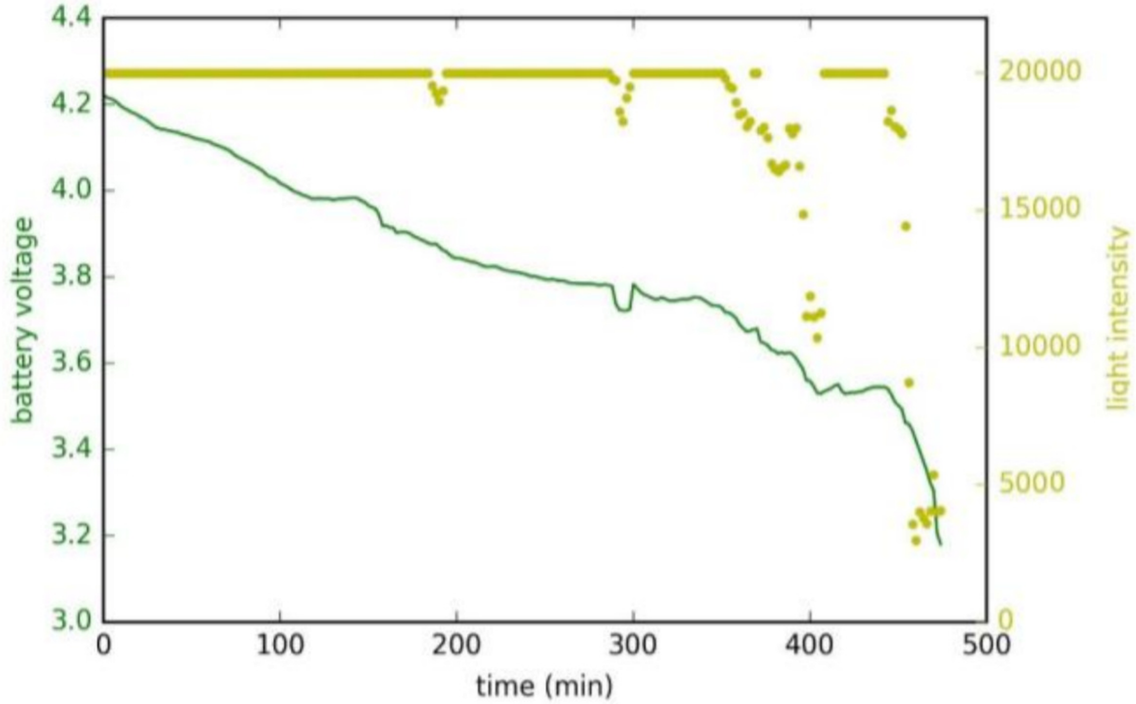


- Effect of solar intensity

More sunlight falling on the solar panel makes it more more efficient. The input current produced by the solar cell increases. As a result the battery gets charged quickly and the voltage of the battery rises. The parameters we are looking into for the testing are the light intensity using a lux meter, the voltage at the maximum power point tracked by the design reflected in the terminals of the solar panel, the charging current produced by the solar panel and the battery voltage which is monitored while the system load is connected. The same is shown in the simulation below:

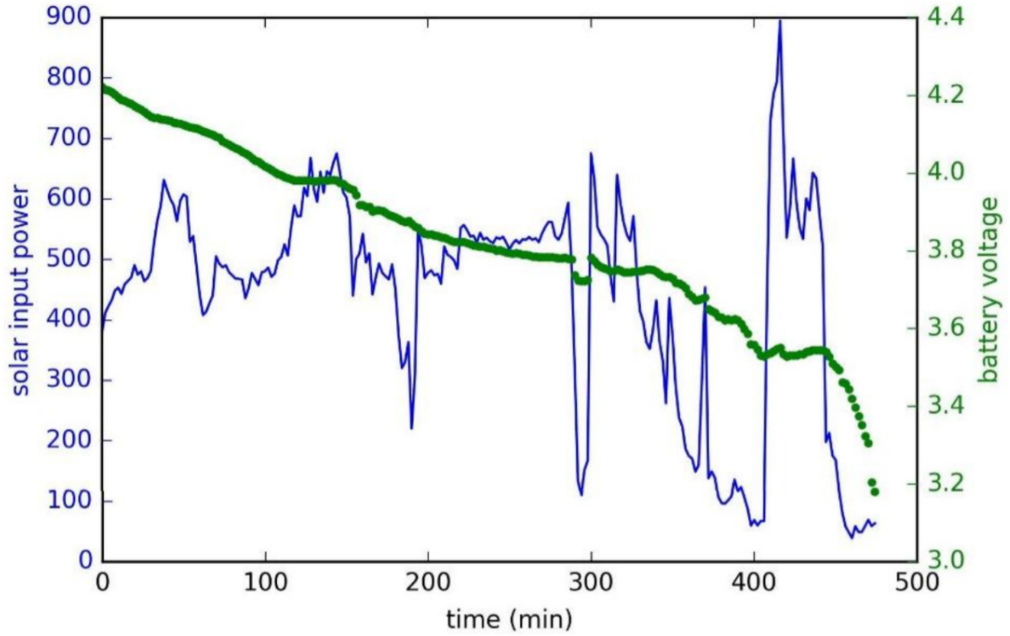


The figure shows how the input power of the solar cell varies with light intensity. The input power is used to charge the battery and the charge rate depends on the input power of the solar cell which in turn depends on the solar intensity. Thus it is fitting to simulate battery voltage and solar intensity. This simulations fulfils this:

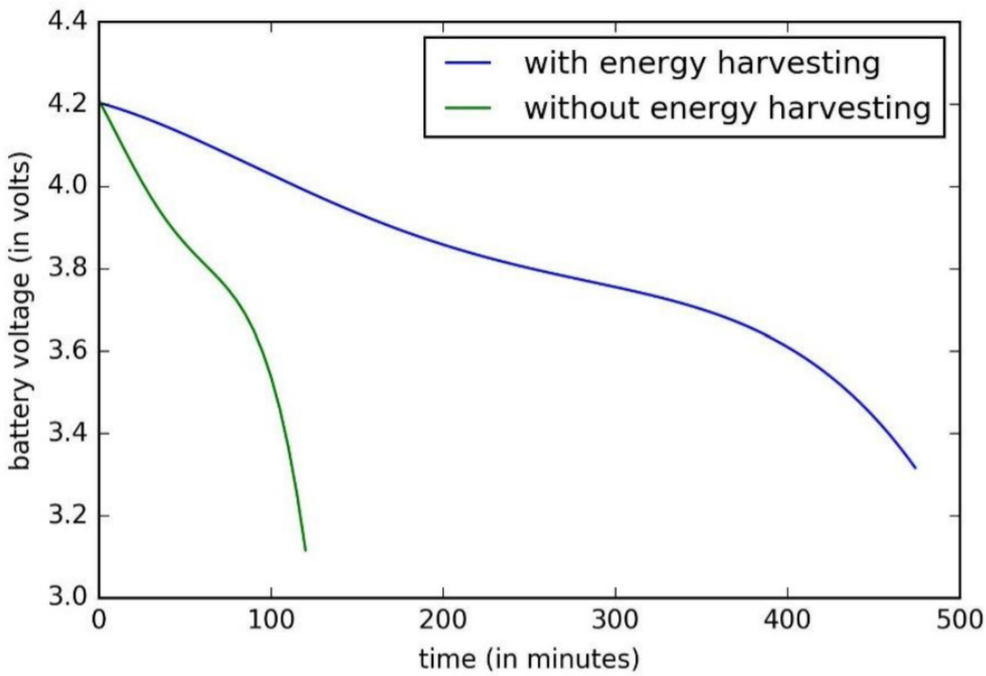


The variations in the light intensity can also be seen in effect to the rate of discharge of the battery causing steeper slopes at times when illumination is low and this can be observed more in the rightmost part of the plot shown below which corresponds to the time approaching sunset where the daylight intensity is getting lower.

The next plot describes how the solar input power aids in extending the battery life showing the flattening of the downward slope as solar input power increases in level at some intervals along the testing data.



At last we find out what is the effect of all the parameters on the flight time of the quadcopter with and without the energy harvesting,



As we can clearly see that the flight time is significantly increased by using a clean energy resource i.e. solar energy.

Conclusion

The purpose of this study was to design a power management system for solar powered quadcopter. The design focused on power management solution through extending battery life of the system and efficient power conversion from the source to the loads of the system. The objective of extending the battery life of the system was achieved by employing energy harvesting schemes using solar panels. The results show that the battery life of the system was extended significantly with the use of solar panels under normal daylight condition. A graphical analysis on parameters that affected the design in attaining this objective was also presented such as light intensity and equivalent solar input power. The objective of efficiently converting power from the source to the loads of the system was achieved by first, modelling the design based on target specifications of conversion efficiency, line regulation and load regulation, choosing the components wisely based on the model, simulating the design using available simulation software, trading off between designs, prototyping and evaluation through experimentation. The results showed the target specifications of the project being met.

References

[1] Gur O, Rosen A. Optimizing electric propulsion systems for unmanned aerial vehicles. J Aircr 2009;46:1340e53.

[2] Shin Y, Chang S-H, Koo S-O. Performance test and simulation of a reciprocating engine for long endurance miniature unmanned aerial vehicles. Proc Inst Mech Eng Part D J Automob Eng 2005;219:573e81.

[3] Bradley TH, Moffitt BA, Fuller TF, Mavris DN, Parekh DE. Comparison of design methods for fuel-cell-powered unmanned aerial vehicles. J Aircr 2009;46:1945e56.

[4] Bradley TH, Moffitt BA, Mavris DN, Fuller TF, Parekh DE. Hardware-in-the-loop testing of a fuel cell aircraft powerplant. J Propul Power 2009;25:1336e44.

[5] Seyfried, J. et al. (2005). The I-SWARM Project: Intelligent Small World Autonomous Robots for Micro-Manipulation. Swarm Robotics, LNCS 3342, pp 70–83.
[6] Kernbach, S. (2013). Handbook of Collective Robotics: Fundamentals and Challenges. Stanford: Pan Stanford Publishing.
[7] Akyildiz, I.F. et al. (2007). A survey on wireless multimedia sensor networks. Computer Networks, 51(4), pp 921–960.
[8] Jiang, J. et al. (2005). Perpetual environmentally powered sensor networks. Proc. IEEE SPOTS, pp 463–468.
[9] Visser, H.J., Vullers, R.J.M. (2013). RF Energy Harvesting and Transport for Wireless Sensor Network Applications: Principles and Requirements. Proceedings of the IEEE, 101(6), pp 1410-1423. REFERENCES 77
[10] Mulgaonkar, Y. (2012). Automated Recharging For Persistance Missions With Multiple Micro Aerial Vehicles. Master thesis, University of Pennsylvania.
[11] Mullins, J. (2011). Autonomous Recharging of Swarm Robots. Master thesis, Monash University.
[12] Brown, W.C. (1996). The History of Wireless Power Transmission. Solar Energy, 56(1), pp 3-21.
[13] Queen Mary, University of London. (2013). SolarCopter students soar to new heights with TV appearance. Retrieved November 12, 2014, from http://my.qmul.ac.uk/news_and_events/2013/95068.html