DESIGN OF A SOLAR-POWERED LAPAN SURVEILLANCE UAVS-01 (LSU-01)

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Abstract

LSU-01 had accomplished many missions, to optimize a complete mission, extendable time flight is need to pursued with solar energy. This paper studies a conceptual design of a solar-powered LSU-01 that has the same specification and profile with LSU-01. It is expected that no significant changes to the airplane. Missions will be conductedfrom7 AM to5PM to get optimal sunlight. Comparative study to other similar airplane and calculation to solar cell requirement with the capability power of LSU-01 has been calculated, the solar cell need 0.9 m^2 to be assembled on wing. The components weight has been measured for about 1.5 kg addition mass for PV system. As a result, solar-powered LSU-01 is necessary to extend the time flight about ten hours.
Key Words :*solar energy, surveillance UAVs LSU-01*

1. Introduction

During 2011, LAPAN (Indonesian National Institute of Aeronautics and Space) project research in UAV especially for remote sensing is developed which it called LAPAN Surveillance UAV-01 (LSU-01), in 2012 LAPAN has applicate the effort on Merapi photoshoots to mitigate the disaster, monitoring flood in Jakarta and monitoring the paddy field to having survey agricultutal land in Java Island, along coorperation with other institutions.In it is progression it need to extend the time flight to optimize the mission. Motivated by the need to achieve the time flight extension and it is efficiencyin power consumptions, the concept of a solar powered LSU-01attend to pursued.

The objective for this paper is to design a solar-powered UAV that have the same specification as LSU-01. A comparative study of similar solar-powered LSU-01s and fundamental calculations of power that will be required for how many hours for the air vehicle to take a flight in a day will be discussed.Finally, there will be recommendation for solar cell specification and mass estimation to determine the solar-powered LSU-01 vary fixed or a new configuration on it is air vehicle that will be conceptual design for this UAV.

2. Mission Specification

2.1. LSU-01's Systems

This aircraft consists of the equipment used to monitor the ground with the same specifications with LSU-01. The components system includes[1)]:

- Autopilot
- Sensors: gyros, GPS, accelerometer, magnetometer, barometric pressure
- Engine: brushlessdcmotor
- An electronic speed controller with 40 A
- 9 x 6 propeller
- A telemetry communication in 900 MHz- 1 watt
- High-sensitivity 12.1 MP Canon
- Gymbal Camera
- Canon S100 camera

The maximum endurance for this aircraft will be at least ten hours at cruising altitude it needed to attain maximum power received by the solar cell at a day time. The maximum cruise speed for this aircraft is 60 km/hours. This was chosen based on a LSU-01 urban mapping mission.[1)]Maximum cruise altitude will be 2,000 meters. However, UAV will be able to cruise at lower altitudes depend on mission requirements. This aircraft is in to the small aircraft weight categories, the UAV will be hand-launched takeoff and belly landing.

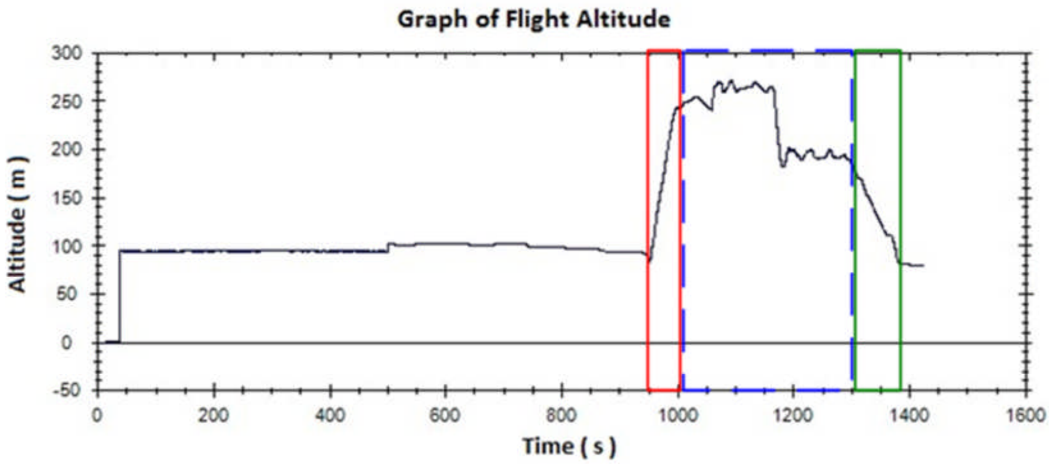

Fig. 1.LSU-01 flight altitude

These data was taken from flight testing of LSU-01 at PUSTEKBANG, in Rumpin, Bogor. Figure 1is the graphic LSU-01 flight test, at 0 until 950 second was the process for autopilot module GPS to initialize the altitude. Then the aircraft take off for 50 second (red line), after that cruising from 1000 second to 1300 second (blue line), then landing for about 90 second (green line).Power requirement of the system will be define below, see table 1. Maximum current was 16 ampere and power needed for takeoff is 268.8 watt, and air vehicle require power between 0 until 50.4 watt for landing and cruising. To comply the maximum power of the aircraft, it full filled by the batteries as specification below;

Battery type	:	Lipo
Cell	:	4
Voltage	:	16.8 V
Current	:	5800 mAh
Constant discharge	:	40 C

A solar-powered LSU-01 power source need batteries for take-off conditions, and for landing and cruising position the power requirement will sufficient directly from PV (photovoltaic) system's. There must be maximum power point tracking (MPPT) to transfer the most energy from the solar panels to the batteries. MPPT is a high efficiency DC-DC converter with an adjustable gain between the input voltage (the solar cells) and the output voltage[7].

Table 1.Power consumption

No	Flight condition	Time (second)	Current (Ampere)	Power (Watt)
1.	Take Off / Climb	50	16	268.8
2.	Cruise	300	2 s/d 3	33.6 s/d 50.4
3.	Landing	60	2 s/d 0	33.6 s/d 0

Fig. 2 for electric control system illustration a solar-powered LSU-01.The power generated by solar cell, which it depend on the temperature, sun irradiance and the inclination of the rays. A converter or MPPT ensures the maximum amount of power is obtained from solar panels. This power is used firstly to power the propulsion group and the onboard electronics, and secondly to charge the battery with surplus energy[8].

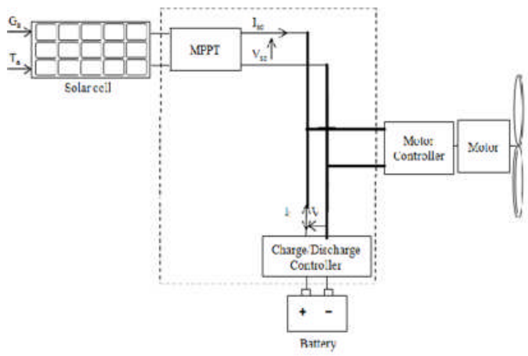

Fig. 2.Electric control system of a solar-powered LSU-01

2.2. Mission Profile

The mission profile are as follows:

- Phase 1: UAV will be hand-launched and will ideally begin to climb at 7 AM in particular altitude as mission requirement. After cruise in certain altitude, aircraft will be switch to autonomous flights.
- Phase 2: the UAV will cruise about 10 hours.
- Phase 3: At 5 PM, the UAV will switch to manual control by operator in a ground and begin to landing.

2.3. Critical Mission Requirements

The critical mission requirements that will drive the design of this aircraft are as follows:

- Total mass must be less than 2.5 kg
- Must be capable of carrying a payload no more than 0.5 kg (500 gram)

3. Comparative Study of Similar Airplanes

Comparative study that will be studied are So Long, QinetiQ Zephyr and Sun sailor 1 and 2. See Table 1.

Fig. 3.SoLong, QinetiQ Zhephyr and Sunsailor2

Table2.Mission Capabilities for So Long, QinetiQ Zephyr and Sun sailor 1 and 2. [4)]

	So Long	QinetiQ Zephyr	SunSailor 1	SunSailor 2
Capabilities	Minimal capabilities. Flew continuously for 48 hours using solar cells and electric motor	Endurance flight 336 hours 22 minutes. Payload 5 lb	Minimal capabilities. Used to break range world record for F5-SOL category (still has not been broken)	Same as SunSailor1.
Configuration	Single propeller conventional configuration with v-tail	Zephyr, which weighs in at just over 50 kilograms, has a wingspan of 22.5 meters that is covered with paper-thin amorphous silicon solar arrays.	Single propeller conventional configuration with v-tail	Same as SunSailor1.
Solar Cell Configuration	120 Sanyo 1850 Li-Ion cells, 76 Sunpower A300 solar cells, nominal power = 225 W, battery mass = 5.5 kg		Sunpower A300 solar cells with 21% efficiency, 0.943 m^2 area weighs 0.66 kg total.	Sunpower A300 solar cells with 21% efficiency, 1.097 m^2 area weighs 0.77 kg total.
Power Output	Maximum motor power 800 W	-	PV's max power is 100 W	PV's max power is 140 W

The mission capability is shown in Table 2 and several a solar powered UAVs are seen in Fig 3. Mostly consist of a single engine propeller propulsion system. The system powered by electric motors. Since wing has photo voltaic cells and sometimes batteries the air vehicle toward to the conventional configuration.
Sun Sailor 1 has similar power requirement with LSU-01, and the solar cell configuration on a wings need area of 0.943 m^2. Even though Sun Sailor 1 did not succeed brake the world record, this note will be the consideration to a solar-powered LSU-01 will be changes on it air vehicle configurations.

4. DesignSolar-Powered for LSU-01

The energy needed for the aircraft from the power source of batteries LSU-01 specification[2)] is more less than 100 W.The solar cell type must be known before the solar panel is calculated.

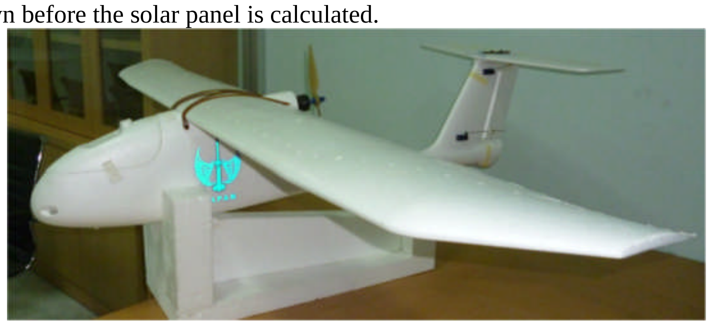

Fig. 4.LAPAN Surveillance UAV - 01

There are many solar cell type manufacturer are available in the market, some used for household electrical resources, satellite and also UAV. In this design there were two type solar cell manufacturer that reliable for UAV; mostly SunPower were used in solar UAV, see Table 1, and Azurspace's solar cell was recommendation in Hartney solar UAV design[4)]. On table 3represent solar cellsmanufacturer for a solar powered LSU-01, the Azurspace's solar cell will be choose and used for solar LSU-01 because of it is high efficiency and fairly flexible to be connected to other component in the aircraft[4)]. The maximum number of solar cell that can be installed onto the wing, can be calculated:

$$d = d_{sc} \times P_{req} = 30.18\ \frac{cm^2}{W} x\ 100W\ = 3018\ cm^2 = 0.3\ m^2 \quad (1)$$

Knowing 34% solar cell efficiency, then the total solar cell would be:

$$P = 0.34\ x\ 100 = 34\ Watt \quad (2)$$

With the result, then total solar cell can be calculated:

$$d_{total} = d \times 3 = 0.3\ \times 3 = 0.9\ m^2 \quad (3)$$

Wing span of LSU-01 is 0.45 m^2,there will be not enough space for solar cell to be assembled.

Table 3.Solar cell specification for UAV[5&6)]

Manufacture	Efficiency	Active cell area	Cell Thickness	Standard Test Conditions (STC)
Sunpower A300	Min 20%	1.25 cm^2	250±30 µm	1.5 Amd – 1000W/m2
Azurspace 3T34A	34 %	30.18 cm^2	280±25 µm	1.5 Amd – 1000W/m2

5. Weight and Balance

5.1. Component Weight Breakdown

For each part on the airplane, a mass is necessary in order to calculate the total mass. There will be configuration for component weight that will impact the balance of the aircraft. From the LSU-01 specification the weight component can be seen on table 4, solar cell weight will be added on the solar-powered UAV column.Refer to section 4 and average weight per solar cell type 3T34A[5)], the total weight of solar cell needed to be assembled on to solar LSU-01 wing is 1.044 kg. Total weight of a solar powered LSU-01 is out of weight to mission specification of LSU-01.There for it necessary to find motor electric and MPPT which the weight will carry major influence to the total mass of solar UAV requirement.

Table4.Weight components

No.	Component	Mass (kg) LSU-01	Mass (kg) A solar-powered LSU-01
1	Camera	0.178	0.178
2	RadioTelemetri	0.0467	0.0467
3	BrushlessMotor	0.1223	0.1223
4	ReceiverRC	0.0136	0.0136
5	Autopilot	0.0177	0.0177
6	ESC	0.0462	0.0462
7	GPS	0.0112	0.0112
8	Camera Batteries	0.1172	0.1172
9	Gymbal	0.0851	0.0851
10	Batteries 4 s 5000mAh	0.533	0.533
11	Fuselage	0.2941	0.2941
12	Cable	0.05	0.05
13	HTP	0.0555	0.0555
14	Small components	0.062	0.062
15	Wing	0.5815	0.5815
16	Servo	0.06	0.06
17	Glue	0.02	0.02
18	Ubec	0.042	0.042
19	Solar cells	-	1.044
	Total	2.3361	3.3801

4.3. Motor Electric

The motor electric of SunSailor 1 was chosen as initial design especially because the similar power requirement and it will be mass estimation for solar powered LSU-01. SunSailor 1 used Hacker B50-13S with 6.7:1 gearbox brushless electric motor with following properties, see table 5:

Table 5. Hacker B50-13S Electric Properties

Motor constant Kv (RPM)	2800
Max power (W)	900 W
Max Ampere	50 A
No load current (A)	2.1A
Resistance (Ω)	0.015 Ω
Weight	256 gram

4.4. MPPT

In the case of high altitude long endurance solar UAV (HALE-SPUAV) it would feasible to have a MPPT. For this solar UAV, GV-10/140W 10 A MPPT charge controller is capable of working between -40 ºC until 85 ºC with an average efficiency of 96 % – 98 %. The device weighs is 185 grams, which add more number of a mass since motor electric weight is 256, the total mass will be about 1.5 kg for the PV systems (solar cell, motor electric and MPPT).

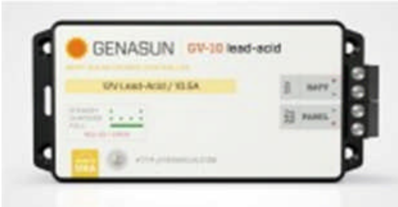

Fig. 5.Genasun GV-10/140W 10 A MPPT charge controller

5. Conclusions

A solar powered LSU-01 system has been recommended for initial design especially for the PV systems. Time flight will take about 10 hours to attain maximum power received by the solar cell at a day time.The comparison result,solar UAV need area of 0.9 m^2 to be assembled with solar cell configuration on it wing, it proven by a number of solar cell calculations and aircraft study withSunSailor 1. As well as the addition weighs, up to 1.5 kg from solar cell, motor electric and MPPT. In conclusion, redesign or a new air vehicle configuration will be necessary to a solar-powered LSU-01 to extend the time flight.

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Discussion

Question:
How efficient to change power plant with solar power?

Answer:
The efficiency to replace the gasoline as un renewable energy source is very important and very efficient in cost and safe for our environment, because gasoline produce CO2. Airplanes account for at least 3 % of greenhouse gas and 2 % of CO2 emissions and environmental damage by CO2 emissions at altitude of 30,000 feet is more than twice the damage at ground level. Therefore, CAEP (Committee on Aviation Environment Protection) in ICAO (International Civil Aviation Organization) is developing a CO2 standard for commercial aircraft that includes 2%/year of improvement in fuel efficiency until 2050 to achieve a significant reduction in aviation CO2 emissions. That is one of our reasons to develop the UAV based on solar energy.