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NEW DEPLOYABLE SOLAR PANEL ARRAY FOR 1U NANOSATELLITES

Mohammed Chessab Mahdi[1], Adnan Falh Hassan[2] and Jaafer Sadiq Jaafer[3]
[1]Faculty of Engineering, University of Kufa, Iraq
[2]Faculty of Science, University of Kufa, Iraq
[3]Al-Furat Al-Awsat Technical University -Iraq
E-Mail: mchessab@yahoo.com

ABSTRACT

A new design for increased power extraction for NanoSatellites is proposed, which is used for KufaSat. This proposed design contains four expandable panels with additional sixteen solar cells, two solar cells on each side of panel. The proposed design with additional panels and how these additional panels are assembled to the body of KufaSat and how they are deployed after the launching are presented. Comparison between original design and proposed design in addition to discussion the increasing in power production and charge current are included.

Keyword: solar panel, deployment mechanism, nano satellite, KufaSat, electrical power system.

1. INTRODUCTION

Low power generation is a major factor limiting current CubeSat capabilities. Because of limited area of CubeSat's walls for solar cells assembling, so, a deployable structure with additional solar panels offers a solution to improve power generation. The concept of having additional solar panels on satellites is common practice to increase the power generation. KufaSat is a1U NanoSatellite which is according to the current CubeSat-Standard a cube shaped satellite with length of 10cm and a mass of maximum 1.33kg. It also contains 1.5 m long gravity gradient boom, which will be used for passive attitude stabilization. KufaSat has the mission to imaging purposes and designed for a low earth orbit (LEO) of about 600km.The original KufaSat design has solar cells on all faces.

In order to design efficient and flexible electrical power system (EPS) which meets the power requirements of a specific mission, and can then be used multiple times in different missions, without having to be redesigned for each mission, the power generation must be increase [1]. To increase power generation for KufaSat, four expandable panels for additional sixteen solar cells are proposed to add. Two solar cells on each side of panel. The expandable solar panels are mounted on the four sides of KufaSat and will be deploy by an angle of 90 degrees after the satellite is launched. The proposed design with additional panels and how these additional panels are assembled to the body of KufaSat is shown in Figure-1.

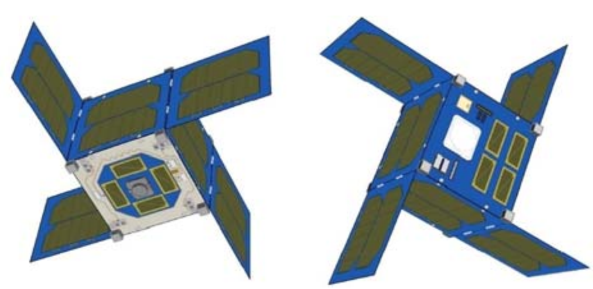

Figure-1. Proposed design.

All panels in opposite sides will be connected in parallel to form two groups (+X,-X) group and (+Y,-Y) group. All eight small panels in top and bottom sides will be connected in parallel to form (+Z,-Z) group. Figure-2 illustrates the connection of all solar cells. This configuration will allow for power to be produced on every face, and will also allow for the satellite to maximize the power produced with the exterior surface area.

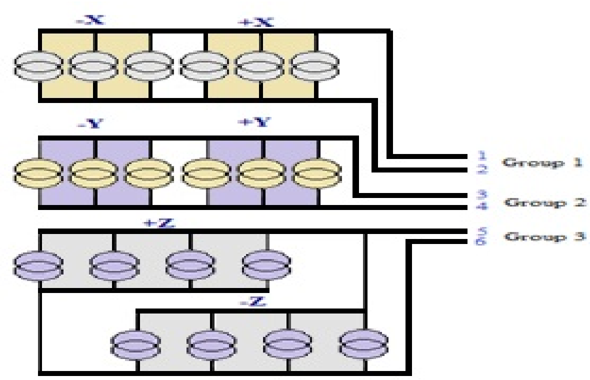

Figure-2. Solar cells connection.

2. POWER GENERATION

The amount of generated power available depends on solar power flux, efficiency of the solar cell [2] in addition to power supply unit efficiency, and effective area of the solar cells and can calculated using equation (1)

$$P=SK\varepsilon A \qquad (1)$$

Where S is the solar power flux, K is efficiency of the power supply unit, ε is solar cell efficiency and A is effective area of the solar cells. The generated power calculated with considering the following points:

The solar power flux (S) in the earth's vicinity varies between Smax = 1399W/m^2 in early January and

Smin = 1309W/m^2 in mid-summer. An average value of S = 1353W/m^2 is often assumed for design purposes [2].

The power supply system consists of components that dissipate energy such as the battery charger and power bus regulators which lead to reduce the efficiency of power supply unit. The calculated efficiency of the power supply unit is 90%.

Solar cell efficiency is considered as constant without dependencies and its value is obtained from manufacturer documentation [3].

Two public types of solar cells used in Nanosatellites EPS are Azur Space TJ Solar Cell with efficiency 29.5% and Spectrolab's Triangular Advanced Solar Cells (TASC) with efficiency 27.0%. The effective area of the solar panels is the total area of the solar panels exposed to the Sun. The area is minimum when axis of rotation of the satellite is pointing always to the Sun, thus, only one side of the satellite is exposed. The area is maximum when the corner between 3 faces points towards the Sun In this case the effective area is equal to the area of three faces [4]. Figure-3 shows the two cases.

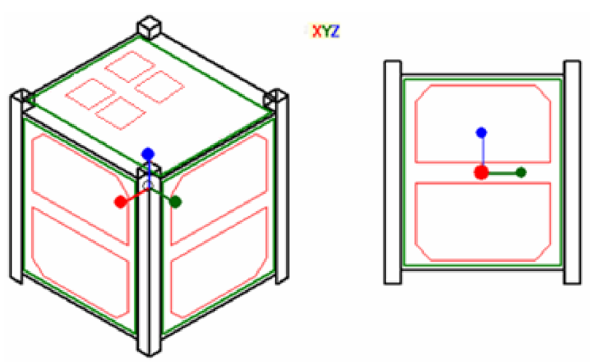

Figure-3. (A) Max-exposed area (B) Mini-exposed area.

3. ORIGINAL DESIGN

Azur Space TJ Solar Cell 3G30C - Advanced and Spectrolab UTJ TASC used as a hybrid design for the flight model of KufaSat. The Azur Space TJ Solar Cell used on all four side faces. Each cell has an efficiency of 30%, with an output of 2.4 V and 504 mA when maximum power point is achieved. Each panel of these side faces of the CubeSat has two solar cells (4x8 cm) connected in series to form large panel.

The Spectrolab UTJ TASC cells used on the top and bottom faces. Each cell has an efficiency of 27%, with an output of 2.19V and 28 mA when maximum power point is achieved. Each two solar cells arranged within a rectangular area of 1.55 x 3.18 cm and connected in series to form small panel. Four small panels are mounted on each of top and bottom sides as shown in Figure-4. All large panels in opposite sides connected in parallel to form two groups and all eight small panels in top and bottom sides connected in parallel to form one group [4].

There are two cases of the effective area of the solar panels exposed to the Sun, maximum when the corner between 3 faces points towards the Sun, and minimum when axis of rotation of the satellite is pointing always to the Sun. Table-1 explains the power generated in two cases Using equation (1) .

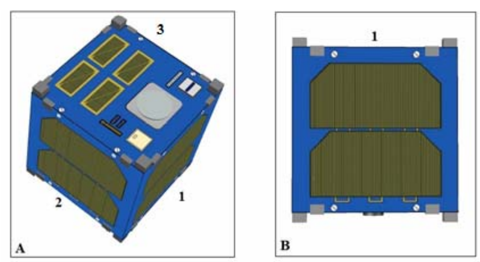

Figure-4. (A) Maximum effective area (B) Minimum effective area.

Table-1. The power generated in two cases (original design).

Maximum exposed area to the sun		
Solar power flux (φ)	(Wm^{-2})	1353
Power supply unit efficiency (K)		90%
Solar cell efficiency (ε)		29.5% and 27.0%
Effective area of the solar cells(A)	(m^2)	0.01477
Power production	(W)	5.248
Power production averaged over the period	(W)	3.323
Minimum exposed area to the sun		
Solar power flux (φ)	(Wm^{-2})	1353
Power supply unit efficiency (K)		90%
Solar cell efficiency (ε)		29.5% and 27.0%
Effective area of the solar cells(A)	(m^2)	0.0064
Power production	(W)	2.3
Power production averaged over the period	(W)	1.456

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4. PROPOSED DESIGN

Additional solar panels are proposed for KufaSat. It has four expandable panels for additional sixteen solar cells. Two solar cells are mounted on each side of expandable panel. One expandable panel is mounted on each face of satellite and will be deploy by an angle of 90 degrees after launching in order to increase the effective area of the solar panels exposed to the Sun. Azur Space TJ Solar Cell 3G30C - Advanced which is the same type of solar cells used in original design will be used in expandable panels.

As in original design of KufaSat, there are two cases can be considered: The first case is when the corner between 3 faces of satellite points towards the Sun the effective area of the solar panels exposed to the Sun will be maximum and equal to six faces in addition to top or bottom side as shown in Figure-5(A). The second case is when axis of rotation of the satellite is pointing always to the Sun, the effective area of the solar panels exposed to the Sun will be minimum and equal to three faces as shown in Figure-5(B).

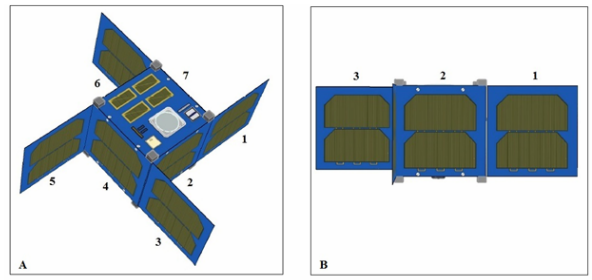

Figure-5. (A) Maximum effective area (B) Minimum effective area.

Table-2 explains the power generated in two cases of proposed design using equation (1).

Table-2. The power generated in two cases (proposed design).

Maximum exposed area to the sun		
Solar power flux (φ)	(Wm^{-2})	1353
Power supply unit efficiency (K)		90%
Solar cell efficiency (ε)		29.5% & 27.0%
Effective area of the solar cells(A)	(m^2)	0.0403
Power production	(W)	14.208
Power production averaged over the period	(W)	8.997
Minimum exposed area to the sun		
Solar power flux (φ)	(Wm^{-2})	1353
Power supply unit efficiency (K)		90%
Solar cell efficiency (ε)		29.5% & 27.0%
Effective area of the solar cells(A)	(m^2)	0.0192
Power production	(W)	6.78
Power production averaged over the period	(W)	4.293

5. DEPLOYMENT MECHANISM

The deployment mechanism for the additional panels is based on construction which is depending on a Pumpkin CSK deployable solar panel hinge. A hinge has three principal functions: deployment of the solar panel, latching the solar panel after deployment with a required stiffness for its final use and providing a delay mechanism to avoid locking shock and collision among the satellite body and solar panel. The solar panel deployment activated electrically by using the burn circuit .The burn circuit breaks the thread keeping the panel folded at the moment of deployment. This releases the hinge-spring mechanism, effectively deploying the solar panel. Pumpkin CSK Hinge and its components shown in Figure-6.

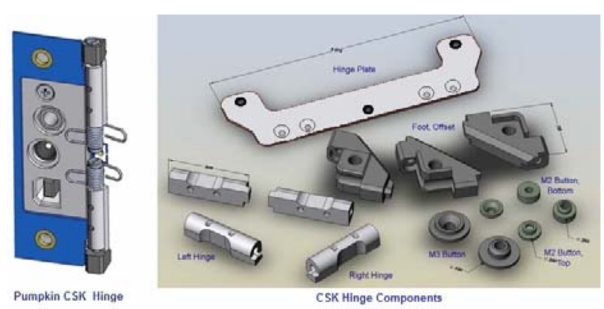

Figure-6. (A) Pumpkin CSK hinge (B) CSK hinge components.

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6. COMPARING THE PROPOSED DESIGN WITH THE ORIGINAL DESIGN

For a comparison between the proposed design and original design of KufaSat the same two cases can be considered, maximum and minimum effective area of the solar panels exposed to the Sun. The same type of solar cells used in the side faces of cube in the original design will be used in expandable panels. Azur Space is space proved gallium arsenide solar cells, called GaAs triple junction solar cells [5]. The type "TJ Solar Cell 3G30C" is a solar cell with an average efficiency of 30% with a cell area of 30.18cm² the solar cells have a mass of less than 2.6g. The average open circuit voltage is 2.669V and the maximum short circuit current is 525mA. At the maximum power point the voltage have a maximum of 2.379V and the current have a maximum of 505mA. Two solar cells are coupled in series to increase the maximum voltage from 2,379V to 4.785V.The comparison can be summarized in Table-3.

Table-3.

Specifications	Original design	Proposed design	Units	Increase %
Max exposed area	0.01477	0.0403	m^2	272
Min exposed area	0.0064	0.0192	m^2	300
Max power production	5.248	14.208	W	270
Min power production	2.3	6.78	W	294
Current at max exposed area	1.12	3.136	A	280
Current at min exposed area	0.504	1.512	A	300
Solar cell mass	14.144	35	g	247

7. BATTERY

Two batteries type Kokam SLPB 554374H was selected for original design of Kufasat. It is a Lithium Polymer Battery and was chosen for its good specifications which listed in Table-4.

Table-4. Kokam SLPB 554374H Specifications [6].

Nominal voltage	3.7	V
Typical capacity	1.25	Ah
Charge voltage	4.2	V
Width	42.5	mm
Length	73.5	mm
Thickness	5.4	mm
Typical weight	32	g
Max. charge current	2.5	A

The maximum charge current of this battery is 2.5 A and because of using two batteries connected in parallel ,the maximum charge current will be 5A.The current at max exposed area in original design is 1.12A,this current represent 22.4% from maximum charge current of batteries. In proposed design the current at max exposed area is 3.136A and this current represent 62.7% from maximum charge current of batteries therefore the batteries charger in proposed design will be more active than original design.

8. CONCLUSIONS

NanoSatellite missions can be succeeding if the solar panel array and energy power storage systems can generate and store more energy for payload use. A new structure, four expandable panels with sixteen solar cells, deployment mechanism for the additional solar cells achieved an increasing in power generation to 270% of power generation in original design at maximum exposed area to the Sun and to 294% at minimum exposed area to the Sun in addition to increasing the charge current of batteries to 280% of the charge current batteries in original design at maximum exposed area to the Sun and to 300% at minimum exposed area to the Sun. This makes the electrical power system (EPS) meets the power requirements of NanoSatellite , more robust and reliable in spite of increasing about 35 g in mass of original design.

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