AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electronics Engineering and Electrical Communications

Design of Photovoltaic System for Satellites Using High Efficiency Cells

A Thesis submitted in partial fulfilment of the requirements of the degree of

Master of Science in Electrical Engineering

Electronics Department and Electrical Communications

By

Ahmed Lotfy Ali Mostafa

Bachelor of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

Faculty of Engineering, Alexandria University, 2002

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Statement

This thesis is submitted as a partial fulfilment of Master of Science in Electrical Engineering Engineering, Faculty of Engineering, Ain shams University.
The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Date: 20 March 2019

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Faculty of Engineering-Ain Shams University

Electronics and Communication Engineering

Department

Thesis title "**Design of Photovoltaic System for Satellites Using High Efficiency Cells**"

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Degree: **Master of Science in Electrical Engineering**

SUMMARY

In the current modern era, artificial satellites are considered as one of the greatest mankind creations. Satellites are used for several services and applications like remote sensing and earth observation services, meteorological and navigation services, search and rescue operations in addition to the space telescopes and the military purposes.

Satellite orbits are greatly varying, depending on the required mission of the satellite, and they are classified into a number of ways. In this thesis, the designed PV system will be applied on Geostationary Earth Orbit (GEO) satellites and small satellites like CubeSat.

Satellites are usually constructed from semi-independent computer-controlled subsystems, which attend many tasks such as power generation, thermal control, telemetry and command, attitude control and orbital control.

The power generation source is always one of the most sensitive and complicated issues in the field of satellite science due to several issues:

- The challenge of the area limitation constraints for the solar panels versus the required power capacity forces the satellite technology to develop solar cells with high efficiencies.
- High advanced technology for batteries is required to efficiently supply the satellite subsystems during the periodic eclipse durations. This is, in addition to fulfill the requirement of batteries long lifetime due to the impossibility of their replacement and maintenance.
- The cost of the main components is very high, which lead to many theoretical and technical researches for decreasing the financial budget while preserving the same technical requirements.

Design for the satellite solar arrays will be presented and discussed with several technical considerations. The thesis consists of five chapters including lists of contents, figures, and tables as well as a list of references.

Chapter 1: contains a thesis introduction, as well as literature review, covering satellite types and their applications.

Chapter 2: discusses satellites size, altitude classifications, defining the satellite orbital period.

Chapter 3: discusses Design of an Optimum PV System for the GEO Satellites, small GEO and the impact of the types of propulsion on the sizing of a solar array. Identifying the optimum solar cell type to fit with the available solar panels area and the power demands for CubeSat.

Calculating the optimum sizing of the battery bank storage and selecting the type of batteries that copes.

Chapter 4: discusses the economic analysis of the effect of various types of propulsion on solar array and thus reduces the weight of the satellite, an economic analysis is demonstrated and investigated in two different plans. The first option fixes the satellite weight and offers the revenue due to the increase in the satellite payload. However, the second option evaluates the saving profits due to the reduction in the satellite weight using the same number of satellite transponders

Chapter 5: contains conclusions and recommended for future work.

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Abstract

This thesis presents the design of a photovoltaic (PV) power system for the satellite market using high-efficiency solar cells. This is to enhance the power capabilities of the satellite solar arrays without extra challenges in area, weight and budget constraints. In this way, the designed power system can efficiently fulfill the power requirements of the satellite subsystems, either in daylight or eclipse periods.

The presented design is applied on GEO satellites, we use triple junction as an approved technology for the solar array. The required area and mass of the solar array are calculated. This is in addition to estimating the required number of assembled cells in the designed solar array. The optimum size of the satellite batteries, used in eclipse periods, is also determined.

Also presents an optimum design of the solar Photovoltaic (PV) power system for small Geostationary Earth Orbit (GEO) satellites using triple-junction solar cells and advanced (Li-ion) batteries. The thesis applies the proposed system to various propulsion technologies; full chemical, full electrical and hybrid propulsions. This research work studies the capability to fulfill efficiently all the satellite power requirements during both the launching and the on-station phases while reducing the high-cost challenge. Since the propulsion type is a key factor for the satellite cost, an economic analysis is demonstrated and investigated in two different strategies. The first scenario fixes the satellite weight and offers the revenue due to the increase in the satellite payload. However, the second scenario evaluates the saving profits due to the reduction in the satellite weight using the same number of satellite transponders. The analytical comparison among the different propulsion techniques shows the superior advantages of using the full electrical satellites.

The power source is a crucial parameter in the field of micro-satellites. This work aims to investigate the effect of using the solar power source of different technologies and configurations on the economic side including the economic

income return of the satellite from increasing the payloads or by reducing the thrust required for launching or whether by increasing its lifetime.

Considering a typical LEO micro-satellite, this thesis illustrates the main design of solar and battery (EPS) with different orbits parameters such as its period, duration of eclipse and incident solar irradiance for different types of solar cells. Furthermore, the integration of solar power in the electric propulsion, rather than the usage of fuel in chemical propulsion. It is shown with concluding its positive impacts on the economic side by reducing the satellite's weight and hence the launching cost and increasing its lifetime.

Finally, a brief discussion on the usage of deployed wings for solar modules that can increase its lifetime without affecting its standard volume.

The conclusion is summarized to show all the different results of this research and development.

Key words: Multi-junction Solar cell, GEO, LEO, Satellite Orbit, Batteries, Lithium Ion Batteries, Design PV, Efficiency, Electric Propulsion, Solar Deployed Wings, Economics.