Implementation of Intelligent – Based Uninterrupted Power Supply and Management Control System (UPSMCS) For Spacecraft

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Abstract
The need for reliable and un-interrupted Electrical Power Supply is Primary for spacecraft operations i.e. for satellites to navigate their orbits and achieve their varied mission objectives. The satellites Electrical Power Subsystem (EPS) generates, stores, conditions, control and distributes power for satellites housekeeping operations. The paper is ostensibly aimed at implementing an Intelligent-based Un-Interrupted Power (UPSMCS) for application in the stable coordination of power supply, power saving, load switching and battery temperature control in the EPS of a satellite. The application program implemented here as intelligent function to develop UPSMCS is VISUAL BASIC programming language to be implemented in INTEL 886 microcontroller (Toshiba) for software-based intelligence. Moreover, assembly language subroutine programming was considered to achieve a simulation model for virtual test for systems reliability and efficiency. The UPSMCS provided intelligence for real time stable power supply. It managed power load shedding and power cycling and actuated fault protection mechanism during eclipse and sunlight orbit periods. The UPSMCS monitored the solar source outputs to determine orbit periods. The monitored battery charge and discharge processes to determine threshold levels for battery state of charge (SOC) and depth of discharge (DOD) and actuated suitable battery charge rate regime for reliable system performance. The UPSMCS also monitored the battery temperature threshold levels to control destructive exothermic reaction. This enhances the service delivery of the battery and consequently prolong its lifespan.

Keywords: application packages, battery, solar energy, spaceflight, satellite, EPS.

INTRODUCTION
Levees are built to protect the floodplain from flooding water during high flow through a river. A satellite is used to describe a spacecraft manufactured on the Earth and sent into orbit on a launch vehicle to perform some specific missions or purposes. Example of these spacecrafts are navigation satellites, weather satellites, scientific satellites and communication satellites. The need for uninterrupted and reliable electrical power supply is very primary for satellites to navigate their orbits and achieve their mission objectives in accordance with Okoro, Okafor and Ejimaya; (2007), which is the focus of this paper. The satellite Electrical power system (EPS) is responsible for electrical power generation, energy storage for peak-power demands and eclipse periods, power regulation to prevent overheating and undesired spacecraft heating, power switching ad distribution to other subsystem as well as power management (Ulrich Cote and Culbin; 2006). Inadequate or erratic power supply has resulted to many unsavouries spaceflight development in recent times such as the ill-fated Nigerian communication satellite (Nigcomsat) launched by china got missing in action after two years was reported to have suffered a failure due to power related technical hitches (Nkanga; 2008). This unpleasant development is a proof that in the event of system and environment emergencies in the outer-space, the satellite’s is EPS is most vulnerable. Therefore, spacecraft power system must be developed with some level of intelligence. This will enable the satellite to sense undesirable system and environmental changes more quickly and efficiently and as well taken suitable corrective actions in order for it to fulfill its mission lifetime (Pratt and Bustian; 1986). Hence, electrical power supply with intelligent background will automatically endure the availability of electrical energy to the mass of satellite throughout its mission cycle of operation and consequently improves the system reliability.

SATELLITE ELECTRICAL POWER SYSTEM (EPS) DEVELOPMENT
The Satellite Electrical Power Subsystem (EPS) is the most critical system on any spacecraft because nearly every other subsystem needs power. Hence, the reason for this paper as the most important and
complex task facing spacecraft world as illustrated by Angawal; (1986). The operation of the satellite components are energized by the EPS. Therefore, the EPS must be developed to function optimally and reliably throughout the period of satellite mission.

The EPS is responsible for electrical power generation, energy storage for peak-power demands and eclipse periods, power regulation to prevent overcharging and undesired spacecraft heating, power switching and distribution to other subsystems as well as power management (Ulrich, Corbin and Cote; 2006).

EPS COMPONENTS
The EPS functions of guarantying and ensuring uninterrupted and stable electricity for satellite operation was achieved only by incorporating both solar panels for power supply while the satellite is in sunlight and batteries for storing and providing power when the spacecraft may be in shadow. A control circuit was studied to be developed along with power generation through solar panel to handle the situation when the satellite may be in the dark and power system must be responsible for determining the power levels of the batteries and maintaining them at an adequately charged level. Effective EPS performance are also determining by the choice of suitable panels at any given time for altitude control analysis and cycling of switchable communications subsystems ON or OFF to conserve power by Obland and Klunpar (2002). The figure 1.0 below shows functions to be provided by the EPS.

OVERVIEW OF ELECTRICAL POWER GENERATION
There are five major space power generation sources; solar power, fuel cells, batteries, nuclear and microwave. The choice of an appropriate power generation system depends on the amount of power required, the duration of the mission, constraints on mass and volume, the impact of the system’s hardware on the spacecraft development. In this research, renewable energy source from the sun such as the solar arrays distinguishes itself as the energy source of preference in the solar space Narty, Otting and Kudija; 1993).

SOLAR ARRAYS
The choice of an appropriate power generation system depends on the amount of power required, the duration of the mission, stability, constraints on mass and volume, and impact of the system’s hardware on the spacecraft specification. Renewable energy source from the sun as the solar arrays distinguishes itself as the energy source of preference in the solar space with stability assurances (Harty, Otting and Kudiga; 1993). Solar arrays consist of a large number of individual solar cells arranged on a substrate which convert solar energy into electric power by photovoltaic conversion. Deployable paddle-like arrays evolved from the need for increased power outputs is considered in this paper.

Fig. 1.0: EPS Functions Requirements

![Fig. 1.0: EPS Functions Requirements](image-url)
SOLAR CELLS
Solar cell design is rated by its ability to convert a certain percentage of the solar energy into electric power which is known as the solar cell efficiency defined as:

\[ \mu = \frac{P_{out}}{P_{in}} \]

Where \( P_{out} \) is the electrical power output and \( P_{in} \) is the solar energy input. The cell development depends largely on some factors such as I – V characteristics, temperature, distance from sun, incidence angle and radiation degradation.

I – V CHARACTERISTICS
The current – voltage (I – V) characteristics of solar cells are of great importance in the development of solar arrays. The Plot of the I – V characteristics is as shown in figure 1.1, an array can be developed for minimum mass and maximum efficiency at the maximum point (MPP).

![I-V Characteristics](image)

The MPP is determined where the product of I and V is at maximum which is described by the maximum area of rectangle within the plot. The point falls at the knee of the curve as represented in figure 1.1.

TEMPERATURE
Solar cell efficiencies are usually obtained at 25°C to 30°C. A decrease in temperature results in an increase of voltage which can be estimated at 2mV/°C. It was observed that as voltage increases, the current drops. This may likely have an adverse effect during the exit of an eclipse, when the panels are initially very cold. The initial power surge must be carefully considered as the temperature is building up.

SOLAR DISTANCE
It was discovered that as the distance from the sun increases, the available current drops with the voltage remaining constant or may increase due to decreasing temperature. In the development of a planetary vehicle, the solar array should be sized at the MPP corresponding to the distance from the sun at which it will be exploring and implementing.

RADIATION DEGRADATION
The findings revealed that, the major types of radiation damage in solar cells occur through ionization and atomic displacement. The effect of this degradation is to reduce the short circuit current and open circuit voltage of the cells, thus reducing the maximum power point of the cells. The research shows that for over a five year span those losses can be approximately a six to twelve percent short circuit current loss and about a two to five percent open circuit voltage loss. The general degradation effect by comparing the beginning-of-life (BOL) and end-of-life (EOL) of the vehicle is shown in figure 1.2 below. Therefore, the spacecraft’s power system should be designed based on the EOL rather than on the BOL – an extract from IEE; (1991).

![Radiation Effect](image)

THE BATTERY
Batteries have been in use for spacecraft application since the flight of sputnik as secondary power storage system. Right from that time, batteries have metamorphosed from non-rechargeable one-use power systems to rechargeable multi-use back up power systems. In the early years of spaceflight, relatively short flight times encouraged the use of batteries as a primary source of power. As the mission duration grew longer, solar energy took over as the primary source which is fundamental or basis that forms the substance of this paper. Batteries provided power as secondary power source when the primary source could not. Especially when a satellite with solar panels enters a period of eclipse, batteries provide power until the satellite emerges from the occultation.

POWER STORAGE AND MANAGEMENT SOFTWARE
Power and energy management software (PEMS) is part of the software system dedicated to the performance of EPS, health monitoring, central and protection. In case of emergencies or during planned mission operations, PEMS Shield loads in a preset sequence, when the battery state of charge cannot support all loads. The battery telemetry consists of the battery voltages and the internal pressures of the selected cells. Most of these telemetry readings goes to PEMS in accordance’s with Patel, (2005).
LOADS
The terms load includes all loads as, the payloads (receiver, transmitters, measuring, instruments, etc) and the bus system loads. Most loads in satellites are constant power loads. The orbit average power requirement is taken into account in sizing PV array and the battery for all loads.

GROUND POWER CORD
In order that the battery power is preserved during pre-launch testing and final clicks before lift-off the on-board system uses external ground power via a univocal cord. To further preserve the battery, power transfer is scheduled as late as possible in the countdown.

BUS VOLTAGE CONTROL
As earlier mentioned shunt mode regulates the bus voltage by using a shunt dissipator which is the tools employed in this paper.

CONTROL CIRCUIT
The control circuit employed in this paper is digital control circuit. Digital control circuit is an alternative to the traditional analog control. A digital shunt regulator uses relatively small shunt dissipater to provide small signal control of the bus. Analog shunt is unstable in response but offers much better dynamic response to the power bus transients. But digital control is preferred in this research as it offers flexibility in tailoring the system to multiple missions. By simply changing the gain constant in the software table, one can adjust the system’s transient response. One can also incorporate a number of different battery charge regimes, and then adjust the charge rate in orbit with single command from the ground. This arrangement is adaptable to a variable number of solar array segments and to a number of array configurations. The result is more flexibility in using standard modules of the solar array and the battery which translates into cost reduction (Patel; 2005).

RESULTS AND DISCUSSION
It has been shown that consideration for power storage and distribution for satellite system will guarantee a stable power distribution for spacecraft. The right and appropriate choice of solar cells in its right of installation with enviable power storage consideration will enhance in-interruptible power supply and effective management control for spacecraft. The Table 1.0 below is a prototype spacecraft test-run test obtained for three different flight by aeronautic training institute, Kaduna shows the reliability of Un-interrupted Power Supply (UPS) without intelligent based device, ups with intelligent based device and ups with intelligent based device and management control device for winter and summer season under a specific mission periods in hour per day.

<table>
<thead>
<tr>
<th>Mission Periods (Hour/Day)</th>
<th>Power Equipment Reliability Test for Spacecraft</th>
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<tbody>
<tr>
<td></td>
<td>Winter</td>
</tr>
<tr>
<td></td>
<td>1st Test Flight</td>
</tr>
<tr>
<td>Ups without intelligent based device</td>
<td>16</td>
</tr>
<tr>
<td>Ups with intelligent based device</td>
<td>24</td>
</tr>
<tr>
<td>Ups with intelligent based Device And Management Control System</td>
<td>24</td>
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</tbody>
</table>

It can be seen from the table that, the ups with intelligent based device and management control system sustained an aircraft stably for the mission period of one day under test for both summer and winter periods.

LIMITATION
In order to avoid the application packages from being corrupted, the software should be saved on a non-volatile part of memory such as Eeprom.

CONCLUSION AND RECOMMENDATIONS
This paper was able to achieve a stable choice of Un-interruptible power supply for a spacecraft mission. The consideration for solar power generation and consideration for power storage helps to determine the accurate power needed to be generated and stored for the use of the satellite on an Un-interrupted note. A control circuit developed to interface and monitored battery charge and discharge process as battery State of Charge (SOC) and depth of discharge (DOD) and actuated suitable battery charge rate regime for stable and Un-interruptible power supply. Moreover, it can be recommended that, the control circuit should be incorporated with the ability to determine heating or thermal condition of the satellite mass as well as checking radiation degradation to forestall maximum power losses.

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