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A Novel Design for Enhancing the Lifetime of Satellite Batteries Using a 3-Port DC-DC Converter

M. Krishna Kumar[1], M. Santhana Muthu[2] and M. Kanagaraj[3]
[1]Assistant Professor, [2 & 3] UG Scholar, Department of Electronics & Communication Engineering,
Chandy College of Engineering, Thoothukudi - 628 005, Tamil Nadu, India

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Abstract - **In previous days, the lifetime of the battery in satellite is less. The challenge is to increase lifetime of the satellite by using the electronic circuit. This paper proposes a new design that can be used as a tool for increasing the lifetime of the batteries used in the satellite. Normally the satellite gets the energy from sun as well as battery for its day to day activities. During the night time the satellite could not get the energy from the sun and so it gets the energy from battery only. During the time (6-10 AM & 2-6 PM), the satellite gets the energy from both sun and battery. And during the time (10 AM to 2 PM) the satellite fully gets the energy from sun but at the same time the battery will be charged from solar power. In this project the life time of the power consumption is decreased by means of a booster circuit. The project presents the control strategy and power management for an integrated 3 port converter which interface one solar input port, one bidirectional battery and an isolated output port.**

Keywords: **Component, Formatting, Style, Styling, Insert**

I. INTRODUCTION

The integrated multiport converter, instead of several independent converters, has advantages such as less component count and conversion stage because resources like switching devices and storage elements are shared in each switching period. As a result the integrated system will have a lower overall mass and more compact packaging. In addition some other advantages of integrated power converters are lower cost improved reliability and enhanced dynamic performance due to power stage integration and centralized control.

It requires no communication capabilities that would be necessary for multiple converters. Therefore, the communication delay and error can be avoided with the centralized control structure. The multiport converter has integrated power stage and thus multi-input, multi-output (MIMO) feature it necessitates proper decoupling for various control-loops design.

Due to the advantages of multiport converter recently there have been extensive researches that result in a wide variety of topologies. One simple approach is to interface several converter stages to a common dc bus with independent control for each converter stage. A multi input boost-type converter was designed for hybrid electric vehicles using such loose structure.

A buck-based topology was used to interface spacecraft front-end power systems. But the battery port is unidirectional and cannot be charged from solar port. Modeling of this converter was further discussed in but plenty of interacting control loops was neither analyzed nor decoupled. A multi input buck–boost-topology-based converter was proposed to accommodate various renewable sources.

But there is neither bidirectional port nor isolated power port to interface battery and comply with safety requirement for certain applications. The most reports focus on converter's open loop operation and lack of investigation on control strategy such as system-level power management for different operational modes and various interacting control-loop design.

Therefore, it is interesting to solve problems like how to deal with different operational modes and let them transit between each other smoothly and seamlessly, and how to decouple control loops and design optimized compensators to minimize interactions of the MIMO converter system

II. Related Works

Many researches has been going on for obtaining W. Jiang *et.al* [1] in their research proposed a multiple input dc-dc power converter (MI-PEC) dedicated to combine the power flowing from combined on-board energy sources; the proposed arrangement for the propulsion system includes electric generator (EG), ultra capacitor tank (UC) and battery systems. F.D Rodriguez *et.al* [2] in their article presented a two-input tri-state DC/DC converter. In this paper, the small-signal stability of the tri- state converter is analyzed and a large-signal averaged model is derived capable of predicting the dynamic behavior during and allowing transitions to and from this fourth state. B.G.Dobbs et.al proposed a new topology for multiple energy source conversion. The topology is capable of interfacing sources of different voltage-current characteristics to a common load, while achieving a low part count. A fixed frequency switching strategy is investigated and the resulting operating modes are analyzed [3]. N.D. Benavides et.al discussed the use of a multiple-input buck-boost converter for budgeting power between different energy sources is discussed in their research. This idealized converter can accommodate arbitrary power commands for each input source while maintaining a prescribed output voltage [4].

A.Kwasinski *et.al* [5] in their work devised a single input dc–dc converter that can be expanded into their multiple input converter version. The analysis is based on several assumptions, restrictions, and conditions, including the goal of minimizing the total number of components and the use of at least one forward-conducting bidirectional blocking switch in each input leg. These conditions may affect the outcome of the multiple-input converter synthesis and lead to different configurations from those suggested before in the literature [5]. L.Solero *et.al* [6] in their research developed a double-input single-output power converter, developed for combined wind-photovoltaic generating systems, aims to mitigate the output power fluctuations due to the intermittent nature of both solar and wind energy. Digital control of the whole apparatus also contributes to optimise the converter modes of operation, running both the energy input circuits at their maximum power level. H.Al-Atrash *et.al* [7] proposed a novel converter topology that interfaces three power ports: a source, a bidirectional storage port, and an isolated load port. The proposed converter is based on a modified version of the isolated half-bridge converter topology that utilizes three basic modes of operation within a constant-frequency switching cycle to provide two independent control variables. This allows tight control over two of the converter ports, while the third port provides the power balance in the system. The switching sequence ensures a clamping path for the energy of the leakage inductance of the transformer at all times. This topology promises significant savings in component count and losses for power-harvesting systems. The proposed topology and control is particularly relevant to battery-backed power systems sourced by solar or fuel cells. Z. Qian *et.al* in their research presented the control structure for a novel three-port converter topology. This topology has the advantage of low switch count, high power density, high efficiency, so it is a valuable choice for space applications. The three port converter for space application interfaces one solar panel input port, one bi-directional battery port and an isolate output port. Maximum Power Point Tracking (MPPT) is adopted to maximize the solar energy input. Two of the three ports can be simultaneously regulated. However, the two control loops have interactions with each other due to the integrated power trains of the three ports. Therefore, implementing the closed loop requires careful analysis of their dynamic behaviors. In this paper, the dynamic behavior of the converter during different operational modes is fully characterized and studied [8].

III. Modes of Power Usage By Satellite

The power consumption of the components in a satellite can be categorized into four depending upon the reception of the solar power from the sun. In fig (a) the satellite is behind earth, sunrays will not fall on the solar panel in the satellite and so the supply is taken from the battery. In fig (b) the satellite is to the left of earth, small amount of sun-rays would fall on the panel and hence the supply is taken from both the panel and battery.

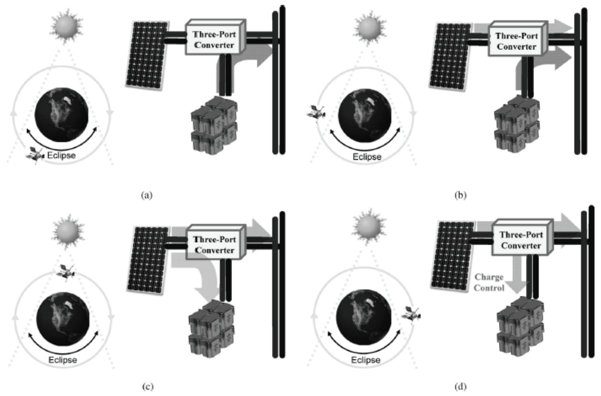

Fig. 1 Different Modes of Operation of Satellite
(a) Early Morning (b) Between 9 am to 12 pm (c) At 12 pm (d) Evening

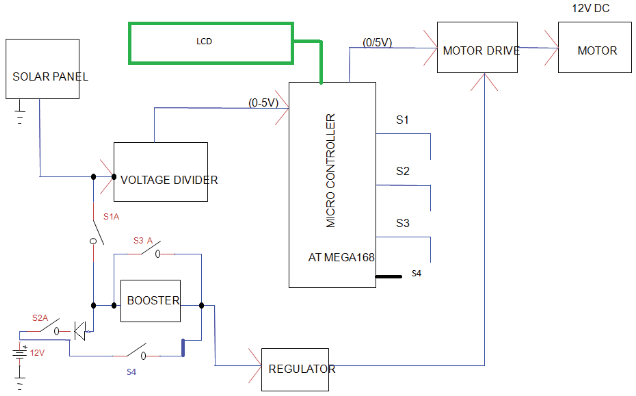

Fig. 2 Proposed System Architecture

In fig (c) the satellite is at the top of earth; maximum amount of sunrays would fall on the panel and hence the supply is taken only from that abundant solar power falling on the panel and at the same time battery will be charged. Fig (d) shows a similar case like fig (b) but with the satellite is at the right of the earth and now components of the satellite will be using the power from the battery.

The fig. 2 shows the block diagram of the proposed system. The circuit diagram is shown in the fig.3.

The Solar panel receives the solar energy from the Sun rays and it produces a Voltage of about (0-14) V. The maximum voltage i.e., 14V is produced at the time when the Solar panel is perpendicular to the direction of the Sun rays. The voltage produced by the Solar panel depends upon the angle of impact of Sun rays on the panel.

The purpose using the Voltage divider is to split the Voltage from the Solar panel into a lower Voltage level that is compatible for the operation of the Micro Controller. In case, if the Voltage from the Solar panel is 14V, then the voltage divider converts into 3.5V, as the operating range for a microcontroller is (0-5)V.

The Booster circuit is employed before the Regulator block so as to provide the right level of voltage the Regulator need. For instance, if the Voltage from the Solar panel is <12V, then the regulator can’t be operated at that Voltage. So the booster boosts up the Voltage<12V into 12V. It also provides boosted output voltage to the regulator.

The Regulator regulates the voltage from the Solar Panel into the voltage required for the operation of the motor. If the voltage from the solar panel is >12V (8-11V), then the input to the Regulator will be provided from the booster. If the voltage from the Solar panel goes below 8V, then the input to the Regulator will be provided by the battery.

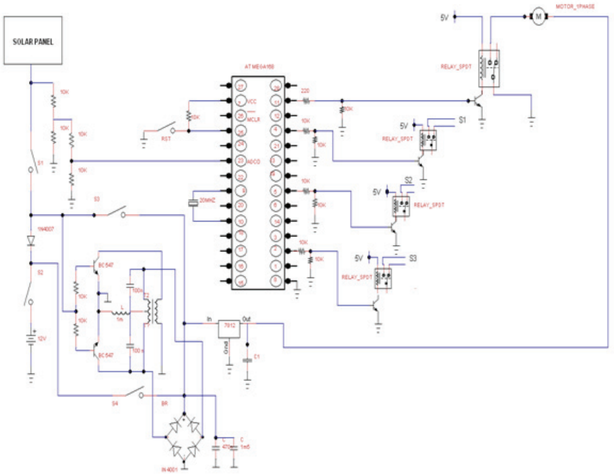

Fig. 3 Circuit Diagram of the Proposed System

The battery gets charged when the output from the solar panel is >12V. When the output from the Solar panel is (8-11) V, the booster provides a boosted output voltage to the regulator, so that it gets operates. But when the panel output goes less than 8V, the battery provides the charge it gathers during the charging period.

The Micro Controller that is used here is ATMEGA8. The microcontroller operates at a voltage range of about (0-5) V. So the input is given to the microcontroller from the voltage divider. The microcontroller controls the operation of the switches in the circuit. Then it delivers 0/5V to the motor drive. It decides whether a switched should be opened or closed based on the voltage produced.

The Switches S1, S2, S3, S4 are employed to change the mode of operation based on the available voltage level. The switches are connected between the Booster, Regulator and Battery so as to get sufficient level of voltage round the clock. The microcontroller decides the on and off function of the switches.

The output voltage from the Micro Controller cannot be directly sent to the load (DC motor).So a motor drive is employed to provide the voltage that is needed to run the motor. The load for the circuit is a 12V DC motor. Thus the DC motor runs with the voltage that is produced by the solar panel.

V. Hardware KIT and Working

The microcontroller will decide which of the switches opened will be opened and which of them will be closed. This is shown in table 1. Whenever the voltage level exceeds 12 volt, switches S1, S2, S3 is closed; S4 is opened.

Whenever the voltage level is between 8-11volts then S1, S2 is closed and S3, S4 is opened. Whenever the voltage level is below 8 volt the microcontroller then will open S1, S2, S3 and closes S4.

Table I Operation of The System Under Various Voltage Levels

Condition {based on VOLTAGE} volts	S1	S2	S3	S4
>12	Close	Close	Close	Open
8-11	Close	Close	Open	Open
<8	Open	Open	Open	Close

Fig. 4 Fabricated Hardware Kit of the Proposed System

VI. Conclusion

The control strategy and modeling of the three-port dc/dc converter for satellite application that interfaces a solar input panel, a rechargeable battery port, and an isolated output port were presented in this paper. The converter has three circuit stages to allow two control inputs that are used to regulate two of the three ports. The output voltage is regulated at any given time, but either input port or battery port can be regulated depending on which is most urgently needed according to available solar power and battery state of charge. The design proposed seems to be very effective and it can be seen from the experimental study. A competitive method was utilized to realize autonomous mode transitions. Control-loop design examples in all operational modes were presented in detail.

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