

# Study on Time Sharing Control for Boost Converter in Solar PV Applications

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**ABSTRACT:**This paper presents the literature review regarding to dynamic power flow management system for a solar PV system employing a single stage inductor based dual input/output DC-DC Boost converter feeding standalone DC loads backed up by a rechargeable battery. A time-sharing voltage mode control scheme has been designed for power flow management between solar PV, standalone DC load and battery. Converter maintains a constant DC load voltage and performs MPPT operation of solar PV. The steady state performance of the single stage converter has been studied with the relevant analytical expressions derived along with the characteristics. In this paper the influence of control Scheme and pulse generation were studied.

**KEYWORDS:**DC-DC power converter, Batteries, Solar power generation, Boost converter Power converter, Photovoltaic power systems.

## I. INTRODUCTION

Renewable energy sources such as wind energy, solar energy, tidal, etc. is critical for overcoming problems due to global warming and environmental degradation caused by the use of fossil fuels. Among all renewable energy sources, solar PV is abundant, has high power density, is modular and scalable. Solar PV is used both in grid connected applications and standalone applications. It can be used in a wide range of applications from a microwatt internet of things (IoT) system to a megawatt scale solar PV plant. Solar PV operates in a wide range of DC voltages, while electrical and electronic systems also have different levels of DC voltage requirements. Hence, it is necessary to use power electronic interfaces for solar PV applications.

The energy from solar PV is intermittent in nature, it is necessary to combine energy storage systems and other renewable energy sources to maintain reliable operation for standalone PV

systems. This can be achieved by many single input/output (dual port) DC-DC converters in parallel or multiport DC-DC converters. The centralized architecture of multiport converters uses fewer switches, has compact structure, lower cost, higher efficiency and avoids the need to use communication systems as compared to multiple single input/output DC-DC converters.

The various functional blocks of the power flow management system are as follows:

Fig.1. consists of a solar PV module as power source, battery as energy storage element to supply during absence of solar PV, a single stage inductor based dual input/output DC-DC Boost converter feeding a standalone DC load and a controller which modulates power flow between a solar PV module, a battery and a standalone DC load and performs voltage regulation at the standalone DC load terminals.

**A. SOLAR PV MODULE:** The solar PV module is the primary source of power for the standalone DC load. The power generated by the solar PV module for a given temperature and level of irradiation depends on PV voltage and current drawn by the load. Hence, in order to do load matching, a maximum power point tracking (MPPT) control is used to set the converter at maximum power point (MPP) by varying the duty ratio of the appropriate switch and hence the current drawn by the converter from the solar PV module. There are many algorithms used to track the MPP like constant voltage, perturb and observe, incremental conductance, particle swarm optimization and beta method.

The output current of the solar PV module used in modelling is,

$$I_{PV} = I_L - I_0 \left( e^{\frac{q(V+IR_s)}{nKT}} - 1 \right) \quad \text{-----} \quad 1$$

$I_{PV}$  = Solar PV current,

$I_L$  = inductor current,  
 $I_o$  = load current or output current  
 $q$  = charge of an electron,

$K$  = Boltzmann's constant,  
 $n$  = diode ideality factor

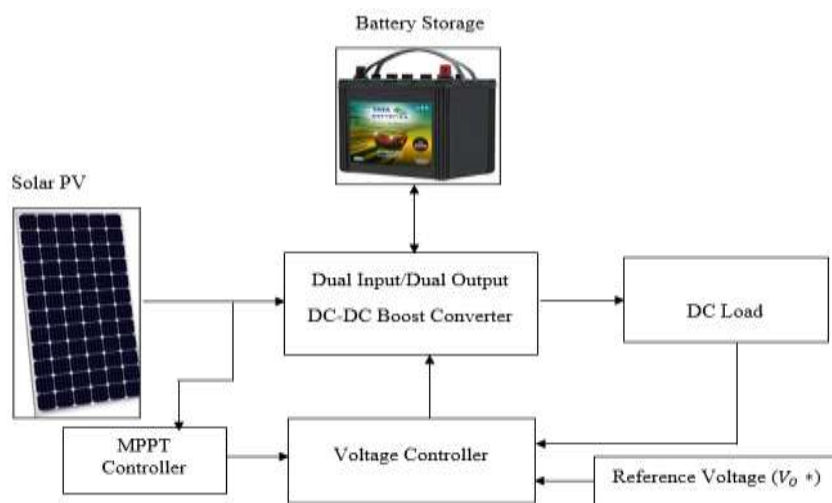


Fig.1. Block Diagram of power flow management system

**B. Battery Storage:** Since the power from the solar PV module is intermittent, a rechargeable battery has to be used as an energy buffer to maintain continuous operation of the arrangement. During times of surplus PV power, it stores excess energy and during times of deficit or absence of PV power, it complements or replaces the solar PV module as the power source. There are primarily two types of rechargeable batteries used for stationary power applications - the lead acid battery and the lithium-ion battery. Lead acid batteries are inexpensive and have less safety issues.

## II. LITERATURE SURVEY

**Venkatramanan D et al (2019)** analysed the MPPT Performance of Solar PV Charge Controller based on Buck Converter. In this paper, a small-signal model is used for a single-stage PV fed buck converter that acts as battery charge-controller. The effects of parasitic storage elements present in the PV source and the interlocking cable from rooftop are discussed in detail, along with the impact of series-parallel connection of the PV modules for power scaling. A full-order as well as a reduced-order model of the system and various relevant transfer functions are analytically derived. The design facilitates the selection of perturbation period of a typical MPPT control algorithm for improved tracking performance. The steps involved in system model development and control design are generalized and can be extended to other converter topologies as well. A voltage-based P&O MPPT scheme is implemented and it is shown

through experiments that the perturbation period of such a MPPT algorithm should be greater than the settling time of the control-loop for MPPT convergence and accurate tracking performance.

**Bader N. Alajmi et al (2020)** experimented an isolated high-frequency (HF) multi-port dc/dc converter for PV interfacing systems. In the multi-port converter, an HF transformer with multiple input windings and single output winding is utilized. Each input port is based on a two-quadrant inverter topology which connects a PV module to the HF transformer. The output port is connected to a dc-bus using a rectifier. The two-quadrant inverter topology prevents current flow from the ac-side to the dc-side. This action avoids circulating currents between different ports. Each two-quadrant inverter is controlled to yield maximum power from its related PV module. The analysis and operation set-up of the multi-port converter are discussed. In this article, the two-quadrant inverter topology brought two main contributions. First, it prohibits circulating currents from flow between input ports operating at different PV voltages. Second, the power flow between an input port and the output port is achieved by regulating the duty cycle of the input port without the need for phase-shift control.

**Dongsheng Ma et al (2020)** observed an integrated single-inductor dual-output boost converter. This converter adopts time-multiplexing control in providing two independent supply voltages (3.0

Vand 3.6 V) using only one 1-  $\mu\text{H}$  off-chip inductor and a single control loop. This converter is analyzed and related with existing counterparts in the aspects of architecture, system stability, integration, and control scheme. Implementation of the power stage, the peripheral, and the controller functional blocks is discussed. The design was fabricated with a standard 0.5- $\mu\text{m}$  CMOS n-well process. The power conversion efficiency reaches 88.4% at a total output power of 350 mW at an oscillator frequency of 1 MHz. This topology can be extended to have multiple outputs and can be applied to flyback, buck, and other kinds of converters. Compared to existing designs, the converter requires fewer inductors, power devices, and control loops, which is suitable for portable applications and system-on-chips. System implementation problems were discussed. Experimental results demonstrate the functionality and show good performance of the design on voltage regulation, power efficiency, and cross-regulation suppression. The SIDO converter provides a cost-effective solution in designing on-chip power management systems and realizing voltage scheduling techniques.

**Hui-Hsuan Lee et al (2020)** analysed a single-inductor dual-input dual-output power converter with two-dimensional adaptive-on-time (2-D AOT) control for Internet of things (IoT) applications. This system combines energy from a 0.55–0.7 V photovoltaic (PV) segment with a non-rechargeable 1.4-V zinc–air battery to encompass the battery life. The converter employs the buck-boost mode for the battery and the buck mode for the PV module to produce two output voltages for different loading currents. The 2-D AOT technique not only reduces the output voltage ripple but also improves the dual-source conversion efficiency over a wide input voltage range. Moreover, the response time of the self-tracking zero-current detector can also be enhanced by the 2-D AOT. The energy flow of two outputs and eliminates cross regulation between the outputs without using any compensation components. The operation mode was configured automatically by using the mode detection circuit, which monitors both the PV input and the output to minimize battery usage.

**Hui Shao et al (2014)** analysed single-inductor dual-input dual-output dc–dc converter with pulse width modulation control is used for a solar energy harvesting system. The first input of the converter is from photovoltaic (PV) cells and the second input is a rechargeable battery. Apart from the conventional role of providing a regulated output

voltage to energize the loading circuits, the converter also clamps the PV cells voltage to the extreme power point value to exploit efficiency. When the PV cells yields more power than the load, the excess energy is used to charge the rechargeable battery. When the PV cells cannot yield sufficient power, the converter schedules the battery and the PV cells to power the load together. SI-DIDO dc–dc converter with PWM control is designed for solar power management systems. It regulates one of the input voltages that is connected to the PV cells to track with the MPP voltage. At the same time, it generates a regulated output voltage to power the loading circuits. When the PV cells output power is insufficient for the load, the converter schedules the PV cells and the battery to power the load together. When the PV cells output power is larger than the load requirement, the converter diverts the surplus PV cells energy to charge the rechargeable battery. A test chip was designed and fabricated to verify the function of the SI-DIDO dc–dc converter and demonstrate its power transfer efficiency.

**Gayatri Nayak et al (2020)** designed Coupled inductor single-input dual-output (CISIDO) dc-dc converter is an alternative to various parallel dc-dc converters for applications requiring multiple regulated supplies. CI-SIDO shows the merits of reduced ripple, high efficiency, and small volume. However, the coupling of inductor currents results in coupled outputs leading to cross-coupling and crossregulation problems. The compensator design becomes complex due to cross-coupling of the output voltages. This paper involved in a decoupled voltage-mode control to address the issue of crosscoupling of output voltages. converter also demonstrates the stability boundary for controller design. The controller is designed using simple analog Type-II compensator. A systematic compensator design procedure is also established. The controller decouples the output voltages, ensures good stability margin as well as good load regulations and audio susceptibility. The decoupled control significantly suppresses the cross-regulation with fast transient response speed for the load, input and reference variation. A transient performance comparison of decoupled voltage control mode for CISIDO buck converter with state-of-art control techniques for single inductor SIDO (SI-SIDO) buck converter is also presented. Cross-coupling and cross-regulation are the problems found in CI-SIDO converters due to the presence of the coupled inductor. The detailed analysis performed shows that the two outputs can be

decoupled by designing the compensator with high gain or high crossover frequency.

**I-Chou Chen et al (2019)** analysed A single-inductor dual-input dual-output (SI-DIDO) dc-dc converter for photovoltaic and piezoelectric energy harvesting systems. The buck-boost topology is used by SI-DIDO dc-dc converter. A MPPT algorithm is examined to share the single inductor between all the inputs and outputs in one switch cycle. Light-load or heavy-load mode is determined by current mode pulse width modulation (PWM) control. Moreover, a delay lock loop (DLL) based zero-current detector (ZCD) is used to lock the pre-opening time of the comparator. The peak efficiency of the SI-DIDO buck-boost dc-dc converter is 88.1%.

**Xiaolu Lucia Liet al (2020)** analysed multi-input multi-output (MIMO) DC-DC converters can integrate multiple input sources and output loads simultaneously. This paper has a new single-inductor MIMO DC-DC converter with a wide conversion ratio. The converter allows input sources to be added or removed seamlessly with no cross-regulation problem. Meanwhile, the outputs are controlled independently, i.e., the load change at one output cell will not affect the other interrelated output cells. Constant current control is the key of control requirement. When constant current control is given to all input cells, the power provided by each input source is proportional to the voltage magnitude of the source. When the constant current control is given to some of the input cells, the input sources with direct duty-cycle controlled input cells can give specific power through controlling the duty cycles of the switches of the corresponding input cells. Moreover, the switching time of switches is unrelated. Therefore, it is simple to realize the huge extension capability for arbitrary inputs/outputs. A dual-input dual-output prototype is created to illustrate the performance of the converter. The corresponding component design is presented.

**Guipeng Chen et al (2020)** experimented that the demand of single-input dual-output (SIDO) or dual-input single-output (DISO) dc-dc converters, employing two distinct single-input single-output (SISO) converters is a solution. However, the number of components is doubled results high overall cost. In order to decrease costs, this paper has a novel topology synthesis methodology, with variety of SIDO and DISO dc-dc converters with reduced components can be derived. The principle of topology synthesis states that integrated SIDO

and DISO dc-dc converters can be simply established from conventional SISO converters by replacement of a diode with a basic cell inclusive of additional input/output port. The principle is effective for many SISO dc-dc converters, and as an example, topology synthesis based on buck, boost, buck-boost, Cuk, sepic, and zeta SISO converters is performed in this paper. In order to achieve better understanding of the converters, the integrated SIDO Cuk converter is specifically analyzed and experimentally verified. In comparison with the conventional scheme of two separate SISO Cuk converters has good cross regulation is retained while the number of capacitors, diodes and inductors is condensed in the SIDO Cuk converter. In addition, zero-voltage-switching operation of one switch is attained, contributing to lower switching losses. Finally, a prototype circuit with 48-V input and 156 V/1 A, 24 V/4 A outputs is constructed to validate the theoretical analysis.

**Amir Ganjavi et al (2018)** examined a novel non-isolated single-input dual-output three-level dc-dc converter (SIDO-TLC) appropriate for medium voltage and high voltage applications. The SIDO-TLC is an integration of the three-level boost and buck converters, whose output voltages are regulated simultaneously. Improving efficiency, reducing voltage stress across semiconductor devices and reducing inductors size are among the main merits of the innovative topology. Moreover, due to the considerably condensed volume of a small film capacitor, the step-down filter capacitor can be used instead, whose advantages are lesser ESR and a higher lifespan. A closed-loop control system has been considered based on a small-signal model derivation along with the capacitors voltage balancing is used in order to regulate the output voltages. A 300 W prototype was built and experimented, in order to verify the theoretical and simulation results. The results prove the aforementioned advantages of the SIDO-TLC, and the high effectiveness of the balancing control strategy. Additionally, the converter shows very large stability, even under simultaneous step changes of the loads and input voltage.

**Sen Song et al (2019)** examined with the increasing demand of applications that have two different output voltages, the single-input dual-output (SIDO) converter with smaller number of components is becoming the cost-effective option instead of employing two single-input single-output converters. However, the cross regulation of different outputs is still a difficult in SIDO

converters design. To save cost and obtain improved cross regulation performance, a novel SIDO converter consisting of three active switches is used in this paper. Due to the use of a voltage multiplier circuit, a high step-up voltage conversion ratio is attained with relatively low voltage stress of switches. Owing to the independent power flow and two control variables, the cross-regulation performance is enhanced, and simultaneous buck as well as boost output voltages are grasped. Additionally, all switches can attain zero-voltage switching operation, which contributes to a significant switching loss drop. The operation characteristics, design considerations, and control strategy of the converter are analyzed.

### III.CONCLUSION

From the literature survey, the results are concluded as, A power flow management system for battery backed standalone solar PV systems employing by using Buck, Boost, Buck-Boost, Cuk, Sepic converters. A time-sharing voltage mode control scheme and PWM Control schemes are used for control the solar PV, battery and DC loads to maintain constant DC load voltage and also extract maximum power from solar PV. The converter is capable of operating both in surplus and deficit PV power. the controller is maintaining the desired DC load voltage, under the varying operating conditions of solar PV insolation and consumer load.

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