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DESIGN OF CLOSED LOOP MULTIPORT DC DC CONVERTER

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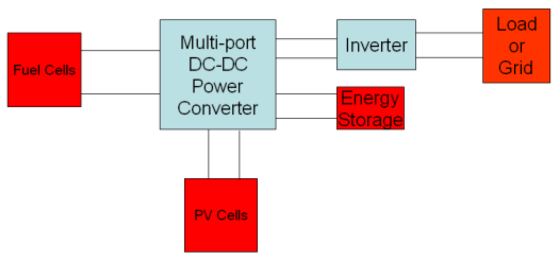
Abstract - In recent years, there has been lots of emphasis put on the development of renewable energy. While considerable improvement on renewable energy has been made, there are some inherent limitations for these renewable energies The Closed-Loop Multiport DC-DC Converter with Adaptive Sliding Mode Control (ASMC) is difficult in power electronics system designed to efficiently manage and control energy flow between multiple energy sources and loads in various applications, including renewable energy integration, electric vehicles, and microgrids. This paper provides an overview of the key features and benefits of this innovative converter system. Multiport DC-DC converters have gained significant attention due to their ability to interface multiple energy sources, such as solar panels and batteries with different voltage levels and power ratings, providing a versatile platform for energy management. The ASMC controller enhances the converter's performance by dynamically adjusting the control parameters based on system conditions and load requirements, thereby improving efficiency and reliability .The ASMC employs a sliding mode control strategy, a robust and adaptable control method, which ensures that the converter operates effectively under various operating conditions, including rapid changes in load and source characteristics. This control technique offers inherent advantages, such as fast transient response and reduced sensitivity to parameter variations, contributing to superior system performance. The ASMC controller optimizes power conversion by minimizing switching losses and ensuring that the converter operates close to its peak efficiency. The controller continuously adapts to changes in input voltage, output voltage, and load conditions, ensuring stable and reliable operation even in dynamic environments. The sliding mode control strategy enables rapid response to sudden load changes, making it suitable for applications with varying power demands.

Key Words: DC-DC converter, Sliding-mode control, Battery, Solar PV.

1. INTRODUCTION

Renewable energy sources have gained significant attention and adoption in recent years due to the growing concerns about climate change and the depletion of traditional fossil fuels. These sustainable energy sources, such as solar, wind, hydro, and geothermal power, offer a promising solution to reduce greenhouse gas emissions and secure a more sustainable energy future. However, integrating renewable energy into the existing electrical grid poses unique challenges, including variable energy generation, fluctuating demand, and the need for efficient energy conversion and storage systems.

To harness the full potential of renewable energy sources, advanced power electronics converters are essential. Among these, multiport closed-loop DC-DC converters have emerged as a crucial technology for efficiently managing and transferring energy between various renewable energy sources, energy storage systems, and the grid. These converters play a pivotal role in optimizing the use of renewable energy by efficiently matching the energy generation with the load demand while ensuring the stability and reliability of the power system.



In this design proposal, we will explore the concept of a multiport closed-loop DC-DC converter and its applications in renewable energy systems. We will delve into the key components, operation principles, and advantages of such converters, as well as their potential to enhance the performance and reliability of renewable energy systems. The development of innovative technologies, like multiport closed-loop DC-DC converters, is critical to achieving a sustainable energy future and ensuring a reliable and resilient power supply shown in fig 1. This proposal serves as a starting point for further research and development in the field of renewable energy and advanced power electronics, with the goal of creating cleaner, more efficient, and more reliable energy systems for a sustainable world.

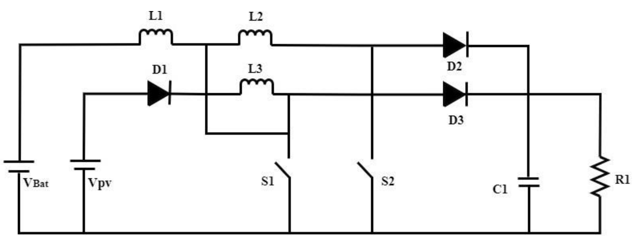


Fig 1. Multiport dc-dc converter

A non-isolated closed-loop multiport DC-DC converter is a specialized electronic circuit used for transferring electrical energy between multiple DC (direct current) sources and loads while maintaining electrical isolation between the sources. This type of converter is designed for various applications, including renewable energy systems, electric vehicles, and power distribution, where multiple sources and loads need to be efficiently managed and interconnected.

Unlike isolated converters that provide electrical isolation between input and output, non-isolated converters do not provide galvanic isolation. In other words, the voltage at one port can be directly connected to the voltage at another port. This feature makes non-isolated converters suitable for applications where isolation isn't required, and it can result in higher efficiency and a more compact design.

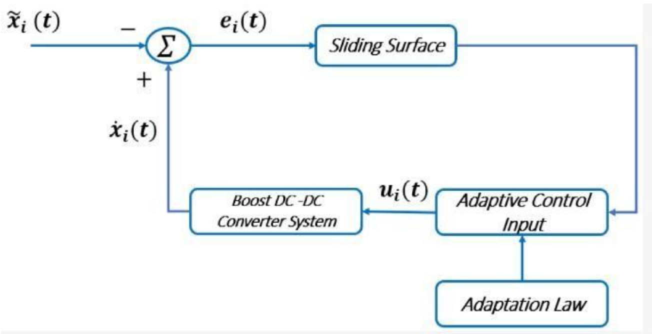
Closed-loop control means that the converter continuously monitors the input and output voltages and currents and adjusts its operation to maintain desired output characteristics. This control mechanism allows the converter to respond to changing conditions, such as variations in input voltage or load, to ensure stable and regulated output .In summary, non-isolated closed-loop multiport DC-DC converters are advanced electronic circuits that efficiently manage and transfer electrical energy between multiple sources and loads in applications where isolation is not required.

Designing a closed-loop multiport DC-DC converter with a PID (Proportional-Integral-Derivative) controller involves creating a control system that can efficiently manage and regulate the power flow between multiple input and output ports. The PID controller is a widely used control algorithm that helps maintain desired output characteristics and respond to changing conditions.

Proper design and tuning of the PID controllers are critical for the converter's overall functionality and efficiency in managing multiple input and output ports.

Designing a closed-loop multiport DC-DC converter using adaptive sliding-mode control involves creating a control system that can efficiently manage and regulate the power flow between multiple input and output ports. Sliding-mode control is known for its robustness and ability to handle nonlinear systems, making it suitable for various applications

The use of an Adaptive Sliding-Mode Controller (ASMC) in a DC-DC converter can be particularly beneficial in applications that require robust control, precise regulation, and the ability to handle parameter variations or uncertainties. ASMC combines the principles of sliding-mode control with adaptation mechanisms to achieve improved performance.



Block diagram of ASMC controller

2. LITERATURE REVIEW

M. Forouzesh (2018) "High-efficiency high step-up DC-DC converter with dual coupled inductors for grid-connected photovoltaic systems" This shows that the essential focal point of the paper is on accomplishing high energy change effectiveness. With regards to photovoltaic frameworks, further developing productivity is significant to expand how much sun oriented energy that can be taken care of into the lattice. The paper manages a DC converter, which is a power gadgets gadget used to change over one DC voltage level to another. "High move forward" recommends that the converter can fundamentally expand the voltage level of the information, which is frequently expected in PV frameworks to match network voltage levels. The presence of double coupled inductors recommends that the converter uses various inductors that are electrically associated. Coupled inductors can assist with working on the exhibition of a DC converter by giving extra energy stockpiling and decreasing voltage weight on exchanging parts.

S. Kumaravel (2019) "Dual input–dual output DC-DC converter for solar PV/battery/ultra-capacitor powered electric vehicle application," This demonstrates that the converter has two information sources (for this situation, sun based PV and either

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batteries or ultra-capacitors) and two result ports. The converter is possible answerable for effectively overseeing power stream between these information sources and circulating it to the vehicle's electrical frameworks or drive framework. The paper centers around applications in which electric vehicles are controlled by a mix of sun powered chargers, batteries, and ultra-capacitors. This infers a reasonable and flexible energy hotspot for EVs.

N. Zhang, D. Sutanto (2019) “A review of topologies of three-port DC-DC converters for the integration of renewable energy and energy storage system” The paper centers around DC converters with three information or result ports. These converters are intended to proficiently oversee power stream among various energy sources or loads. The paper would close by summing up the discoveries from the audit, featuring the meaning of three-port DC converters in sustainable power reconciliation, and offering experiences into the eventual fate of this innovation.

4. METHODOLOGY

In this methodology we use dual input power supply by the help of battery and solar panel, single output is connected with a load. During the day time the continuous power supply is provided by solar panel ,but in night time and partially cloud time we use the battery power supply. In this circuit we use three inductors to store the energy, two switches (mosfet) for switching operation, capacitor to store energy, PID controller (asmc) shown in fig 2.

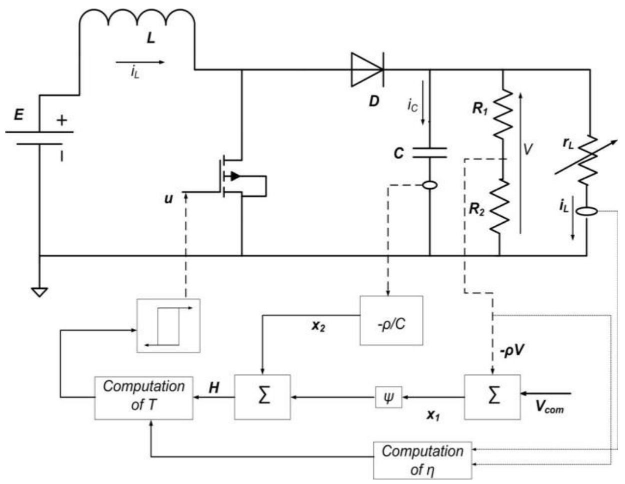

Fig2.DC-DC Boost Converter with adaptive SMC

Designing a DC-DC boost converter with an Adaptive Sliding-Mode Controller (ASMC) involves several critical steps to ensure efficient power conversion, precise regulation, and robust performance .Determine the input voltage range (Vin) and desired output voltage (Vout). Specify the maximum load current and the load variation range. Define transient response requirements, efficiency targets, and desired control objectives. Choose appropriate power electronic components, including MOSFETs or IGBTs, diodes, inductors, and capacitors, based on the voltage and current requirements. Select the switching frequency based on efficiency and size considerations. Develop the ASMC control algorithm by the sliding surface to represent the desired output voltage. Design adaptive laws to estimate and compensate for parameter variations (e.g., input voltage changes, load variations). Implement voltage and current sensors at the input and output of the boost converter.Condition and filter the sensor signals to minimize noise.Use a microcontroller or dedicated PWM controller to generate the control signals for the power switches (e.g., MOSFETs).

The ASMC control algorithm adjusts the duty cycle to regulate the output voltage.Implement safety features such as overvoltage protection, overcurrent protection, and thermal protection to safeguard the converter and connected components.Simulate the boost converter system, including the ASMC control algorithm, using software tools like MATLAB/Simulink or SPICE to verify its performance under various operating conditions.Fine-tune the ASMC controller parameters, including the gains and adaptive laws, to achieve the desired control objectives and transient responses.Optimize the converter's performance, taking into account efficiency and response time.

4.MODE OF OPERATION

MODE 1:

When the two switches S1,S2 are opened the current flow is across the inductor L1,L2,L3 and diode D1,D2,D3,D4,so the output voltage is partially same as the input voltage because the output voltage is added with the inductor voltage. The working model is shown in the figure 3,

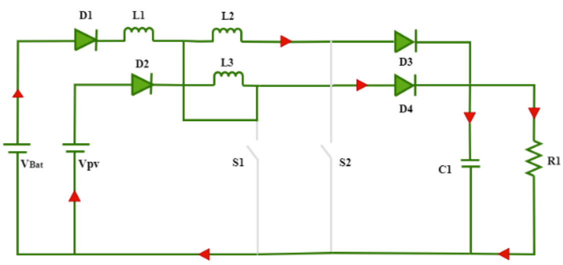

Figure 3

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MODE 2:

When the switch (mosfet) S1 is closed the current flow is across the diode D1,D2 and inductor L1 and L3 finally connected to the load. During the time of switch closed the gets charged and in the time of next switching the battery voltage is added to the inductor voltage to boost up the output voltage. The capacitor in the circuit is used for continuous power supply to the load instead of getting the value 0.Finaaly the output voltage is increased. The working model is shown in the figure 4,

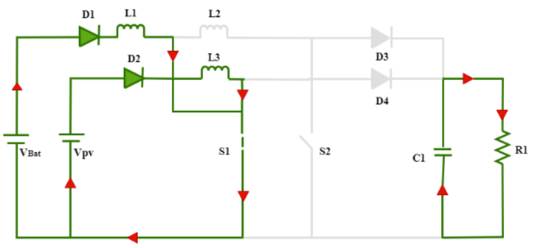

Figure 4

MODE 3:

When the switch S2 is closed the current flow is across the diode D1 inductor (L1 and L2)During the time of switch S2 is closed the inductors gets charged. When the solar power is minimum the circuit will operate in the battery supply and the inductor gets charged shown in the figure 5. When the solar power is maximum the circuit operates in solar power shown in the fig 6.

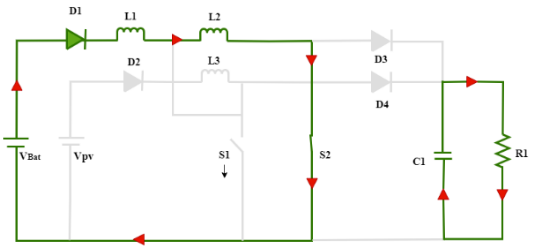

Figure 5

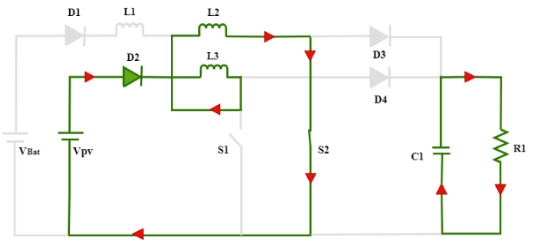

Figure 6

MODE 4:

When the both switches S1,S2 is gets closed the current flow is across the both the diode (D1,D2,D3)and the inductor (L1,L2,L3),and the capacitor to maintain the continuous output voltage. Similar to the second mode working this mode also performs like as same .shown in the figure 7.

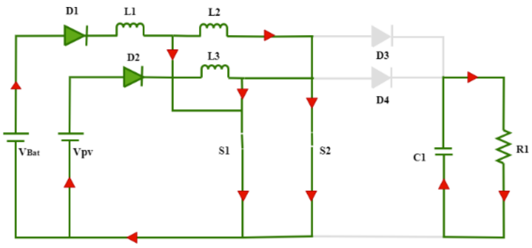

Figure 7

5. ALGORITHM OF ADAPTIVE SLIDING MODE CONTROLLER:

The proposed adaptive sliding-mode controller is given by:

$$s = \left(i_{L_1} - \frac{V_d^2}{E}\hat{\theta} \right) + \frac{K_p e_o}{1+\alpha^2 e_o^2}, e_o = v_o - V_d$$

$$\frac{d\hat{\theta}}{dt} = -\frac{\gamma e_o}{1+\alpha^2 e_o^2}, \alpha, \gamma > 0$$

$$u = \begin{cases} 0\, if\ s > 0 \\ 1\, if\ s < 0 \end{cases}$$

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The sliding surface s is given by the actual inductor current error and a proportional term which provides system damping. The reference inductor current is $I_{L1}=V_d 2E\theta$, Where the estimate of the load resistance is θˆ and θ=1R . Normalized error is used so that when the error is large due to changes in the load and reference input, larger controller gains can be used to achieve better transient performance .

In [11], [12] the siding surface is given by:

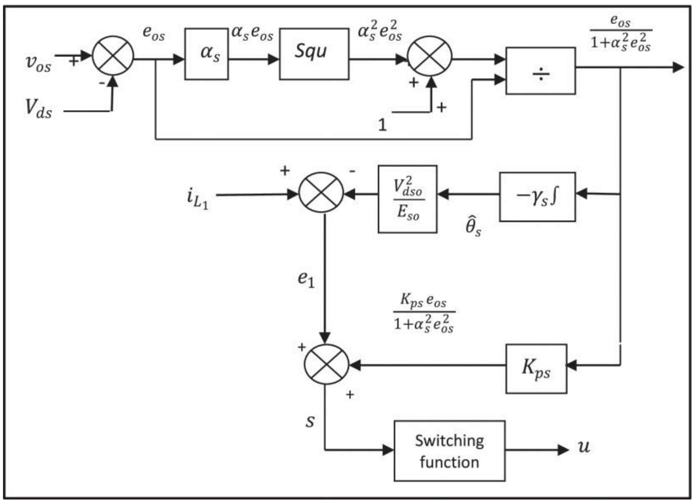
$$s = i_L - (-K_{p1}e_o - K_{I1}\int e_o dt)$$

$$s = i_L - \left(-\frac{K_{p2}e_o}{1+\alpha^2 e_o^2} - K_{I2}\int \frac{e_o}{1+\alpha^2 e_o^2}dt\right)$$

$$s = i_{L_1} - \frac{V_d^2}{E}\{\hat{\theta}(0) - \int \frac{\gamma e_o}{1+\alpha^2 e_o^2}dt\} + \frac{K_p e_o}{1+\alpha^2 e_o^2}$$

In a DC-DC converter, SMC involves defining a sliding surface that represents the desired state of the system. This sliding surface guides the system's dynamics towards the desired equilibrium point. For example, in a voltage regulation scenario, the sliding surface might represent the desired output voltage, and the controller aims to keep the system states (output voltage, current, etc.) on this surface.

ASMC adds an adaptive mechanism to the traditional SMC framework. This adaptive mechanism continuously estimates and compensates for system uncertainties or parameter variations. The estimated parameters are used in adaptive laws that adjust the controller gains or control laws in real-time. These adaptive laws ensure that the control action remains effective even when the system parameters change.



6. Simulation and results:

By using the reference paper we simulate the circuit for closed loop multiport dc dc converter for EV application etc,. The ASMC controller enhances the converter's performance by dynamically adjusting the control parameters based on system conditions and load requirements, thereby improving efficiency and reliability .The ASMC employs a sliding mode control strategy, a robust and adaptable control method, which ensures that the converter operates effectively under various operating conditions, including rapid changes in load and source characteristics. Finally fined tuned the controller to get the desired output voltage level. Here the circuit for closed loop multiport dc dc converter by using the ASMC controller is shown in the figure 8.

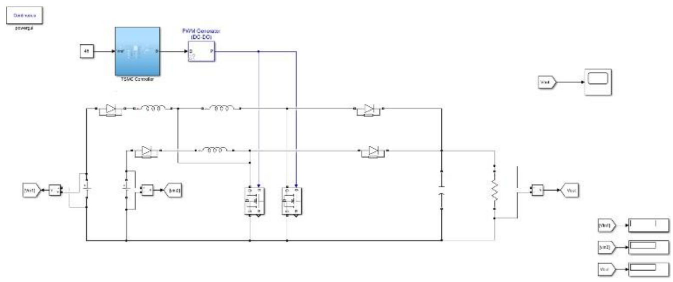


Figure 8

The desired output is verified in the mathlab simulink, The load voltage is to attain 80 V in the short time by turning the controller and the load current is about 8 amps. The output load voltage is shown in the figure 9 and output load current is shown in the figure 10.

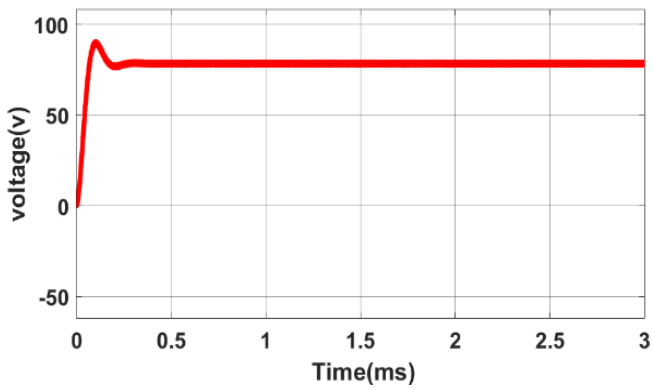


Figure 9

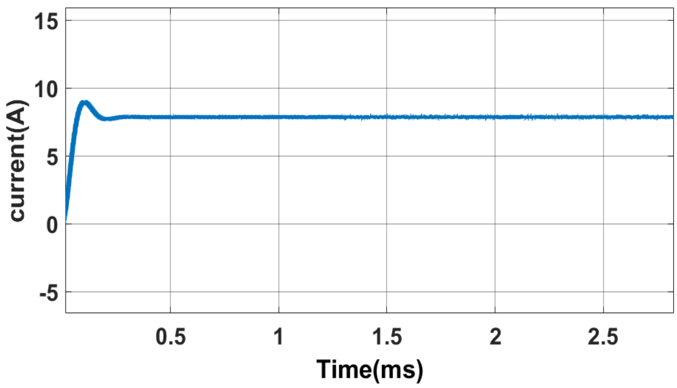


Figure 10

The inductor (L1) voltage and current are shown in the figure.

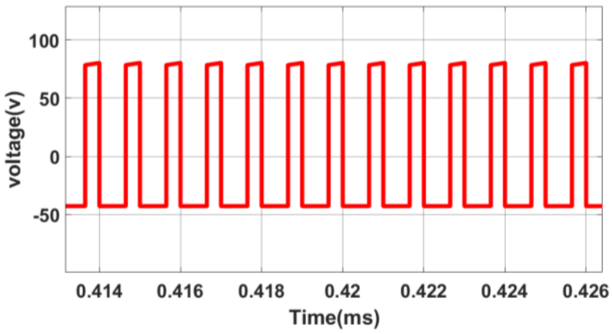


Figure 11

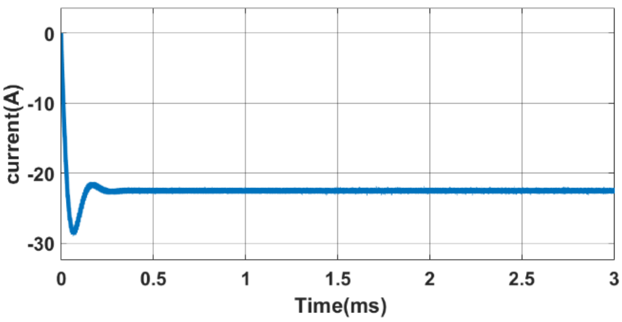


Figure 12

8. CONCLUSIONS

In conclusion, the closed-loop multiport DC-DC converter, when equipped with the Advanced Sliding Mode Control (ASMC) controller, represents a significant advancement in power electronics and energy management systems. The ASMC controller optimizes the converter's operation by dynamically adjusting the switching signals, leading to improved efficiency in energy conversion.Closed-loop control ensures stable and reliable performance even in the presence of disturbances or changes in load conditions, making it suitable for various applications. Multiport converters allow for multiple input and output ports, enabling integration into complex energy systems such as renewable energy sources, hybrid vehicles, and microgrids.ASMC controllers are known for their fast response to transient conditions, which is crucial in applications where rapid load changes occur.The controller can mitigate harmonic distortions in the output voltage, ensuring a cleaner power supply to connected loads.it's important to note that the successful implementation of a closed-loop multiport DC-DC converter with ASMC control requires careful design, modeling, and tuning to achieve the desired performance.

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