International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

SIMULATION OF DC-DC SEPIC CONVERTER USING MODEL PRODICTIVE CONTROLLER

I Vidhyadhari[1],A Amir[2],G Sai Keerthi[3],Ch Priyanka[4],L Mohit[5],T Venkatesh[6]

[1,2,3,4,5,6] Undergraduate Student, Department of Electrical and Electronics Engineering, GMR Institute of Technology, Rajam-532127, Andhra Pradesh, India

ABSTRACT :

This paper investigates the integration of Model Predictive Control (MPC) with an auto-tuning factor to regulate a DC-DC SEPIC (Single-Ended Primary-Inductor Converter) converter, which is capable of stepping up or down the input voltage while providing a non-inverted output, making it ideal for renewable energy systems and battery management. The proposed control strategy employs MPC to optimize the converter's performance by predicting future states and adjusting control inputs accordingly. An innovative auto-tuning mechanism is introduced to dynamically adjust controller parameters based on real-time system behavior, enhancing responsiveness and adaptability to varying load conditions and input voltage changes. Simulation results demonstrate that the MPC with auto-tuning significantly improves transient response, reduces overshoot, and enhances steady-state accuracy compared to traditional control methods such as PID controllers. Additionally, the auto-tuning factor effectively manages system uncertainties and variations, ensuring safe and reliable operation under diverse conditions. This research highlights the potential of combining advanced control strategies with adaptive techniques to optimize the performance and efficiency of DC-DC converters in modern power electronics applications.

Keywords: SEPIC converter, Closed-loop control, Output voltage stability, Step-up mode, Step-down mode,Automotive power systems, Industrial applicatio

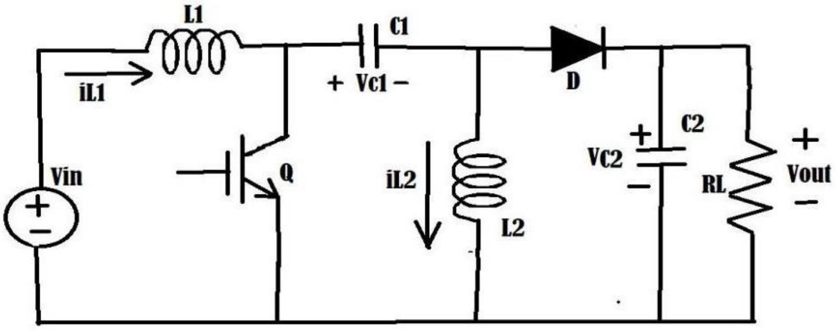
1.INTRODUCTION :

The demand for efficient and versatile power conversion systems has led to the widespread adoption of DC-DC converters in various applications, ranging from renewable energy sources , electric vehicles ,HVDC grids, photovoltaic applications and variable frequency operation[1]-[5]. Among these, the Single-Ended Primary-Inductor Converter (SEPIC) stands out due to its unique capability to provide a regulated output voltage that can be higher or lower than the input voltage, while also maintaining a non-inverted output. This feature makes SEPIC converters particularly useful in applications where input voltages can vary significantly[6]-[8].

Despite their advantages, SEPIC converters can exhibit challenges related to dynamic response and stability, especially under fluctuating load conditions and input voltages. Traditional control methods, such as Proportional-Integral-Derivative (PID) controllers, often struggle to maintain optimal performance in these scenarios, leading to issues such as overshoot, oscillations, and longer settling times[9].

Model Predictive Control (MPC) has emerged as a promising alternative, offering a predictive approach that anticipates future system behaviour to optimize control actions in real time. By solving a finite-horizon optimization problem at each control step, MPC can effectively handle constraints and improve the overall performance of the converter. However, the effectiveness of MPC heavily relies on the accurate tuning of its parameters, which can be a complex and time-consuming process. MPC is a reliable technique for finding the Maximum Power Point (MPP) of a photovoltaic (PV) system using Model Predictive Control (MPC) with only two sensors, replacing the voltage sensor with an observer from converter analysis. The algorithm can function with fixed or adaptive step sizes, enhancing flexibility and performance. Simulation results highlight its effectiveness in maximizing energy extraction while minimizing sensor requirements[10]. The proposed technique exhibits a fast dynamic response, excellent tracking capability (with near-zero steady-state error), and straightforward implementation, thanks to advanced digital signal processors. Model Predictive Control (MPC) relies on an accurate discrete-time model of the converter, incorporating prediction and optimization blocks. In the prediction block, future values are computed using real-time measurements from the converter and current control variable values during each switching state. This predictive approach allows the system to anticipate changes effectively. The predicted values are then sent to the optimization block, where an optimization problem is formulated based on these predictions and a predefined cost function. Solving this optimization problem yields the optimal switching actions needed for effective control. Overall, this structure enables the MPC to adaptively manage the converter, ensuring robust performance under varying conditions.[11].Fig-1 shows the circuit diagram of DC_DC SEPIC Converter

Fig-1:Circuit diagram of DC-DC SEPIC Converter



1. Equations :

The differential equation for inductor current can be written as following

$$_1/t = (1/1)[_n - _{11} - (_1 + _{ut})\ (1\text{-V})] \quad (1)$$

where V denotes the switching state, which is 1 for ON state and 0 for OFF state. The continuous-time derivative of iL1 can be approximated in discrete-time by using Euler's forward method as follows:

$$1/t \approx _1 \ +1 \ (-_1 \ /) \quad (\ ) \quad (2)$$

where is the sampling period. By making use of (1) and (2), the future value of iL1 at (k + 1)th sampling instant can be obtained as Equation (3) predicts the value of iL1 in the next sampling interval.

$$(\ +1) = _1 \ (+)(/1)[_n \ - _{11}()(-)(_1 \ + _{ut}())\ (1-(\ )\ ())] \quad (3)$$

Equation (3) predicts the value of iL1 in the next sampling interval.

The objective of the MPC method is to minimize the error between the predicted and reference values. The current error in the next sampling interval can be obtained by the following cost function:

$$(1 \ =)^* \ |_1 -(_1)+1 \ (\ )| \quad (4)$$

As mentioned before, the main objective of MPC method is to determine the optimum control action in each sampling time for all possible switching states such that the cost function in (4) is minimum. In [8] and [11], it is pointed out that the cost function requires a second term to penalize the difference between two consecutive switching states as follows:

$(\ =)|\ -\ -(1)|$ (5) Hence, the

total cost function can be written by combining (4) and (5) as follows:

$$(\ \ +)1 \ = (\ +1\ ) + ()\quad (6)$$

$$/(1-) = \text{Vout/Vin=Iout/Iin} \quad (7)$$

where Iin is the average of iL1. Assuming that vout is equal to its reference (v∗ out) in the steady-state, a is the duty ratiocan be written as

$$= {}^*ut/({}^*ut + n) \quad (8)$$

Assuming that the duty ratio is known from (8), iin can be written as follows:

$$_n = ut/(1\text{-a}) \quad (9)$$

Substituting iout = vout/RL into (9) yields the expression of iin in terms of vout and RL as follows:

$$_n = ut/\ 1 - (\ \ ) \quad (10)$$

SIMULATION RESULTS :

Fig 2 represents the simulation output for the DC-DC SEPIC Converter using MPC controller when input voltage is 30,referance voltage is 48V and the output voltage attained is 48 V with some error.It is concluded that the output voltage is greater than input voltage,so this converter is used as boost converter.

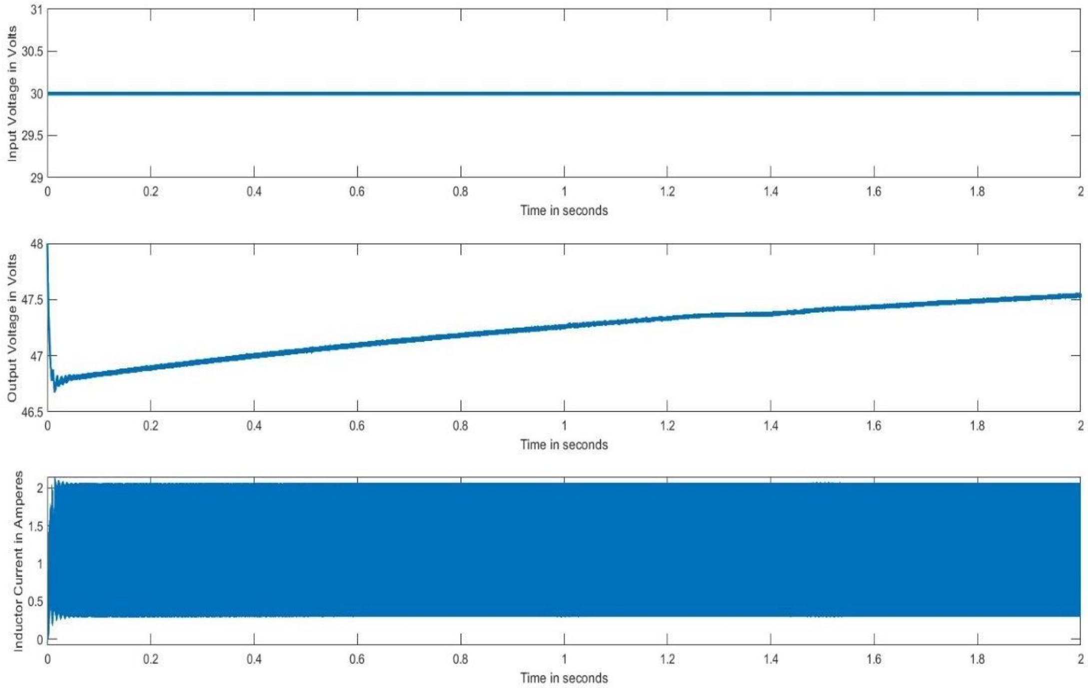


Fig-2:Simulation results for input voltage,output voltage and inductor current

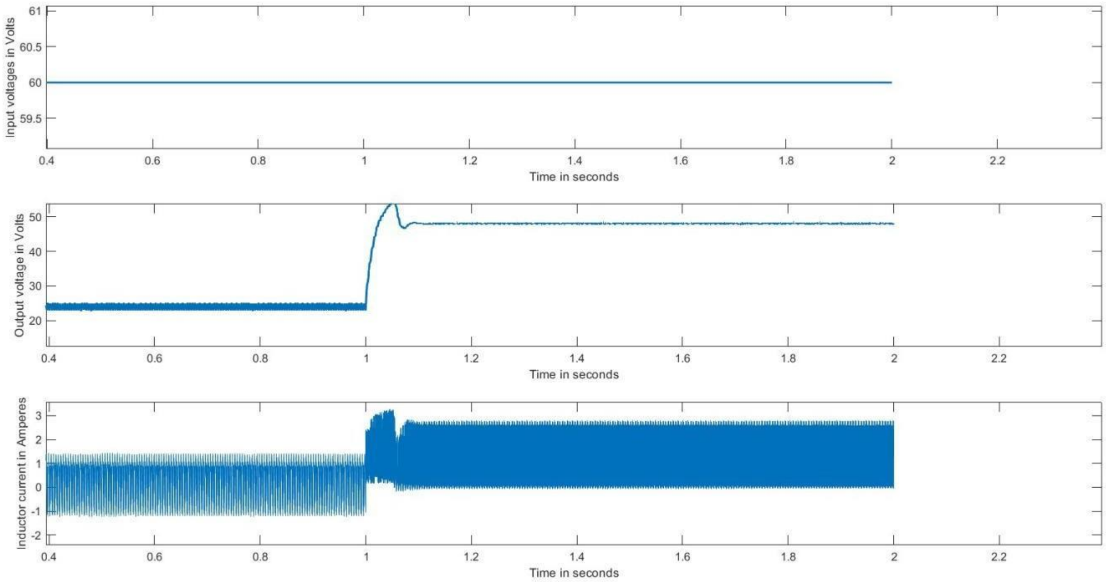


Fig 3: Simulation results for input voltage,output voltage and inductor current

Fig 3 represents the simulation output for the DC-DC SEPIC Converter using MPC controller when input voltage is 60,initial referance voltage is 24V,final referance voltage is 48V and the output voltage attained is 24 V and after 1 second

output voltage is 48V.From Fig 3,it is concluded that output voltage can be attained even there is a sudden change inreferance voltage

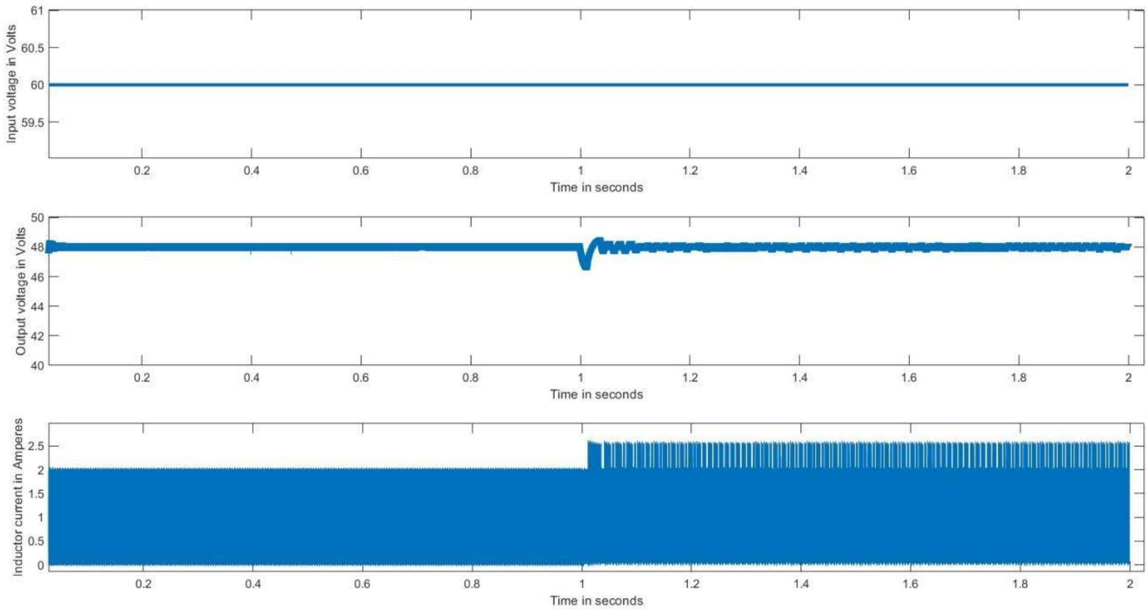


Fig 4:Simulation results for input voltage,output voltage and inductor current

Fig 4 represents the simulation output for the DC-DC SEPIC Converter using MPC controller when input voltage is 60V,referance voltage is 48V,load resistances,R1=80 ohm and R2=80 ohm and the output voltage attained is 48 V even there is a sudden change in load resistance from 80 ohm to 40 ohm.From this it is concluded that output voltage is not sensitive to load variation.

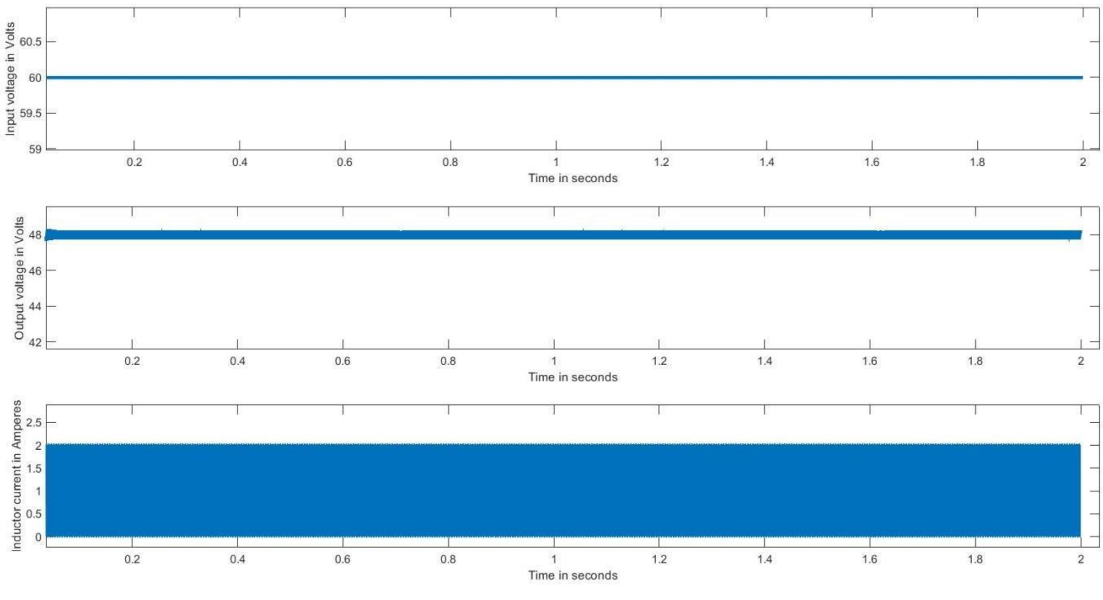


Fig-5: Simulation results for input voltage,output voltage and inductor current

Fig 5 represents the simulation output for the DC-DC SEPIC Converter using MPC controller when input voltage is 60,referance voltage is 48V and the output voltage attained is 48 V.From this, it can be cocluded that the output voltage is less than the input voltage, so this circuit can be used as buck converter.

CONCLUSION :

This paper concluded that DC-DC SEPIC Converter using Model Predictive Controller maintains stability under load fluctuations,input variation,etc. From the results of the simulation, it can be concluded that DC-DC sepic converter using MPC can be used in applications where the constant output voltage have to be maintained even there is a sudden change ininput voltage and load.

REFERENCES :

1. Inovations in Power and Advanced Computing TechnologSivakumar S, Sathik MJ, Manoj PS, Sundararajan G. An assessment on performance of DC–DC converters for renewable energy applications. Renewable and Sustainable Energy Reviews. 2016 May 1;58:1475-85.
2. Paez JD, Frey D, Maneiro J, Bacha S, Dworakowski P. Overview of DC–DC converters dedicated to HVdc grids. IEEE Transactions on Power Delivery. 2018 Jun 11;34(1):119-28.
3. Taghvaee MH, Radzi MA, Moosavain SM, Hizam H, Marhaban MH. A current and future study on non-isolated DC–DC converters for photovoltaic applications. Renewable and sustainable energy reviews. 2013 Jan 1;17:216-27.
4. Priewasser R, Agostinelli M, Unterrieder C, Marsili S, Huemer M. Modeling, control, and implementation of DC–DC converters for variable frequency operation. IEEE transactions on power electronics. 2013 Mar 7;29(1):287-301.
5. Bellur DM, Kazimierczuk MK. DC-DC converters for electric vehicle applications. In2007 Electrical Insulation Conference and Electrical Manufacturing Expo 2007 Oct 22 (pp. 286-293). IEEE.
6. Rajakumari RF, Deshpande M. Comparative analysis of DC-DC converters. In2019 2nd International Conference on Power and Embedded Drive Control (ICPEDC) 2019 Aug 21 (pp. 504-509). IEEE.
7. Kircioğlu O, Ünlü M, Camur S. Modeling and analysis of DC-DC SEPIC converter with coupled inductors. In2016 International Symposium on Industrial Electronics (INDEL) 2016 Nov 3 (pp. 1-5). IEEE.
8. Khodabandeh M, Afshari E, Amirabadi M. A family of Ćuk, Zeta, and SEPIC based soft-switching DC–DC converters. IEEE transactions on Power Electronics. 2019 Jan 9;34(10):9503-19.
9. Khather SI, Ibrahim MA. Modeling and simulation of SEPIC controlled converter using PID controller. International Journal of Power Electronics and Drive Systems. 2020 Jun 1;11(2):833.
10. Abdel-Rahim O, Alghaythi ML, Alshammari MS, Osheba DS. Enhancing photovoltaic conversion efficiency with model predictive control-based sensor-reduced maximum power point tracking in modified SEPIC converters. IEEE Access. 2023 Sep 13.
11. Guler N, Biricik S, Bayhan S, Komurcugil H. Model predictive control of DC–DC SEPIC converters with autotuning weighting factor. IEEE Transactions on Industrial Electronics. 2020 Sep 29;68(10):9433-43.
12. Ayyarao, Tummala SLV, et al. "War strategy optimization algorithm: a new effective metaheuristic algorithm for global optimization." IEEE Access 10 (2022): 25073-25105.
13. Ayyarao, Tummala SLV. "Modified vector controlled DFIG wind energy system based on barrier function adaptive sliding mode control." Protection and Control of Modern Power Systems 4.1 (2019): 1-8.
14. Tummala, Ayyarao SLV. "A robust composite wide area control of a DFIG wind energy system for damping inter- area oscillations." Protection and Control of Modern Power Systems 5.1 (2020): 25.
15. Ayyarao, Tummala SLV, Nishanth Polumahanthi, and Baseem Khan. "An accurate parameter estimation of PEM fuel cell using war strategy optimization." Energy 290 (2024): 130235.
16. Ayyarao, Tummala SLV, and Polamarasetty P. Kumar. "Parameter estimation of solar PV models with a new proposed war strategy optimization algorithm." International Journal of Energy Research 46.6 (2022): 7215-7238.
17. Kishore, G. Indira, et al. "A novel single switch high gain DC-DC converter topology for renewable energy systems." Energy Eng. 118.2 (2021): 199-209.
18. Kishore, G. Indira, and Ramesh Kumar Tripathi. "A novel high voltage gain single-phase AC-DC PFC converter using switched-capacitor." 2017 4th International Conference on Power, Control & Embedded Systems (ICPCES). IEEE, 2017.
19. Tummala, Ayyarao SLV, et al. "Multi-input Converters for Electric Vehicles: A Comprehensive Review of Topologies, Control Strategies, and Future Research Trends." Journal of The Institution of Engineers (India): Series B 105.2 (2024): 397-416.
20. Kishore, G. Indira, Tummala SLV Ayyarao, and Mudadla Venkatesh. "Performance of Integrated High Voltage Gain DC-DC Converter and Diode Clamped Multi Level Inverter with Renewable Energy Source in Standalone Applications." Journal of The Institution of Engineers (India): Series B (2024): 1-9.
21. Gupta, Pavan Prakash, G. Indira Kishore, and Ramesh Kumar Tripathi. "Implementing High Gain DC-DC Converter with Switched Capacitor for PV System." 2019 Inies (i-PACT). Vol. 1. IEEE, 2019.