A novel voltage lifting technique of switched-inductor cell based modified LUO converter topology for water pumping system

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ABSTRACT

The persistent exhaustion of traditional energy sources with their impacts on the environment has been initiating a significant interest in a selection of renewable-energy sources (RES) based water-pumping system. Among several renewable sources, solar-PV is the most promising and practical source for water-pumping applications that can be easily installed on a building's roof. The available solar-PV energy is integrated to AC electric motor through front-end DC-DC boost converter topology. Among the various DC-DC converter topologies, a novel switched-inductor type modified LUO converter has been proposed for solar-PV powered water pumping system. The proposed switched-inductor type modified LUO (SI-MLUO) converter have simple structure which delivers high voltage gain with low leakage currents, low current ripples, reduced voltage spikes, low dv/dt stress and high efficiency over the several conventional DC-DC converters. The operating modes and performance of proposed SI-MLUO converter topology is verified by using MATLAB/Simulink tool, simulation results are validated with conventional topologies.

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1. INTRODUCTION

Water has become more important than ever before as population growth has increased the demand for it. In rural areas, the significant energy source for lifting water from canals, rivers, ponds has become increasingly important in recent days [1]. The stand-alone solar-PV operated water-pumping system has been widely installed in rural areas for irrigation, household and drinking purposes. It excludes the usage of traditional diesel-operated pumping systems because of increased oil prices in global markets, environmental implications, high maintenance cost, low efficiency, short life-time and forced to adopt new alternative [2].

The renewable energy sources (RES) have extensive potentiality to limit the severe causes coming from diesel-operated pumping system. Also, many researchers or engineers are highly focused towards the renewable energy driven pumping system [3]. Globally, sincere efforts are being made to adopt renewable energy for social and economic growth. Among several renewable sources, solar-PV is the most promising and practical source for water-pumping applications that can be easily installed on a building's roof [4]–[6]. The solar-PV powered water pumping system is established to be eco-friendly, more economical, more reliable with low maintenance factor, high life span it can produce 20% to 38% of more energy compared to traditional pumping system [7]–[9]. The generalized block diagram of solar-PV powered water pumping system is shown in Figure 1.

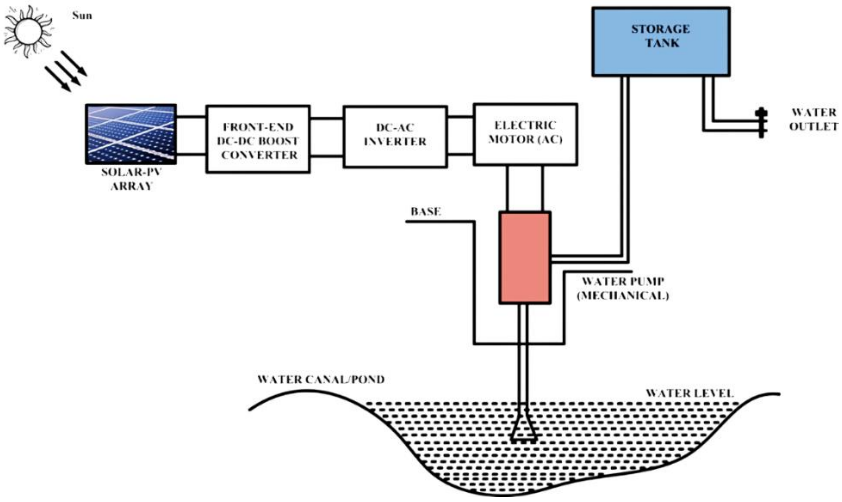


Figure 1. Generalized block diagram of solar-PV powered water pumping system

Generally, the solar-PV driven pumping system comprises of several components such as, solar-PV panel, front-end DC-DC converter, DC-AC inverter, AC electric motor, control unit, sensors, mechanical pump, storage unit and water outlet, so on. The available solar-PV energy is integrated to AC electric motor through power-electronic conversion interface, such interface comprises of DC-AC inverter followed by front-end DC-DC boost converter. The front-end DC-DC converter with high voltage boost capability is widely used in an energy conversion operation at voltage ranges from millivolts to kilovolts levels [10]–[13].

Generally, it converts low DC to high DC voltage by temporarily stored some energy in inductors or capacitors and delivers to load at higher levels. Some of prominent basic DC-DC converters are boost converter [14], CUK, SEPIC, LUO type converters [15] and so on. These basic DC-DC converters are inappropriate because, which are mostly functioned in high duty ratio's for producing higher voltage levels. In recent time, various DC-DC boost topologies have been explored to achieve higher voltage gain by modernization of basic DC-DC converter topology by including voltage multiplier or sub-module circuits. In this approach, features, technical analysis, merits and demerits of basic and modern DC-DC converter topologies for solar-PV powered water pumping system are presented in [16].

The main background of this work is from various literatures, Babaei and Mahmoodieh [17] proposed the design considerations of SEPIC converter for calculation of ripple factor in output-voltage under certain range of load resistance and input DC voltage. Varma and Ramkumar [18] proposes the novel modified non-isolated SEPIC converter for solar pumping system, it produces the high boost voltage without using any coupled inductors and coupled transformers. Tuvar and Ayalani [19] presents the technical analysis of interleaved non-isolated modified-CUK converter for high voltage gain application. Along with voltage gain, this converter reduces the ripple content and low settling time under load variations. Anbarasan *et al.* [20] proposes the solar-PV integrated grid connected system by using basic LUO converter topology. Most of researchers and practitioners are more interested on LUO converter due to simple operation, high voltage gain, compact structure, greater power density, high efficiency, reduced ripple content and inrush current. Pansare *et al*. [21] proposed the positive output modified LUO converter for solar-PV system. This modified LUO converter topology produces the high voltage gain, greater power capacity by utilizing the inductors and capacitors which are combined as sub-modules [21]–[23].

The above-studied converter topologies are not suited for this application due to several demerits such as requires more switching elements; it increases the dv/dt stress, complex design, high switching loss and reduced efficiency [24], [25]. The major problem in conventional topologies are, coupled inductors, multi-winding transformers can be adopted but [26], it has high leakage inductance, owing to high current ripples, more complicated design and requires large number of windings for attaining high-voltage gain. The proposed solution, an inventive idea of modified LUO converter topology has been developed to overcome above demerits by employing switched-inductors for lifting the voltage gain at load terminals. In this regard, a novel switched-inductor type modified LUO converter (SI-MLUO) has been proposed for solar-PV powered water pumping system. The proposed SI-MLUO converter delivers the high voltage gain, simple structure, low leakage currents, low current ripples, reduced voltage spikes, low dv/dt stress and high efficiency over the several conventional DC-DC converters. The operation and performance of proposed SI-MLUO converter topology is verified by using MATLAB/Simulink tool, simulation results are validated with conventional topologies.

2. PROPOSED METHOD

The proposed SI-MLUO converter is comes in non-isolated converter category; it transforms low voltage to high voltage and maintains constant DC voltage at load terminals. The proposed SI-MLUO converter is designed based on basic LUO converter, the main inductor in LUO converter is replaced with reduced rating of one switched-inductor cell. In fact, the switched-inductor cells reduce the leakage currents, low spikes at switches and have major advantages such as simple structure, high voltage gain in low duty ratio’s, continuous input current, low dv/dt switch stress and high efficiency. The high voltage boosting capability of proposed SI-MLUO converter is attained by using low switching elements and SI cell, it may operate either in continuous or discontinuous conduction modes (CCM/DCM) with aero current function in DCM mode. In reality, the operation of SI-MLUO converter is more significant in CCM because of load reliance on voltage boost capability, high current ripples, more voltage spikes and low efficiency are the key issues faced in DCM operation.

The schematic diagram of proposed SI-MLUO converter is shown in Figure 2. It consists of one MOSFET switch S_{a1}, one switched inductor cell named as SI cell-1, one boosting capacitor C_{a1}, one clamping diode D_{a3}, one output capacitor C_o and one output diode D_o, respectively which energizes the resistive load R_o. The SI cell-1 comprises of two inductors named as L_{a1}, L_{a2}, three diodes named as D_{a1}, D_{a2}, and D_{a12}, respectively. The proposed converter topology is generally powered by input DC voltage of V_{in1} and produces high voltage gain and constant output voltage V_o at load terminals. The high voltage at load terminal is produced by energizing the respective inductors in SI cell and boost capacitor symmetrically through sequential switching of switch S_{a1} by means of output diode D_o and output capacitor C_o in a certain manner.

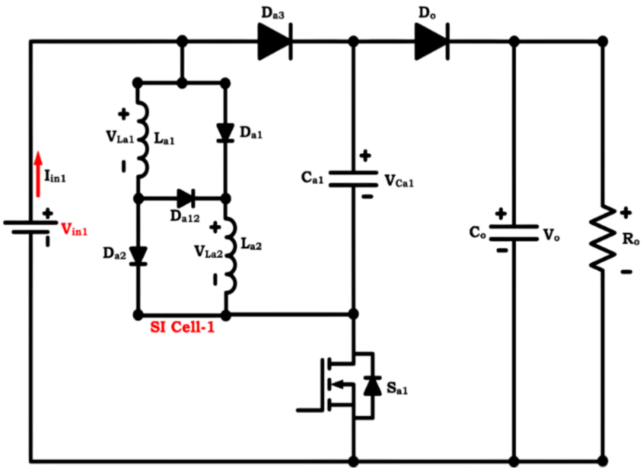
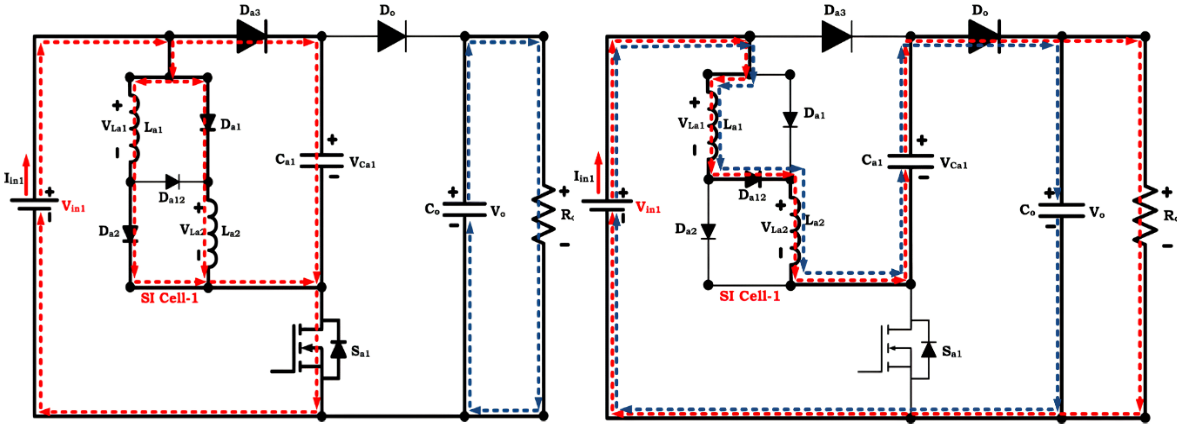


Figure 2. Schematic diagram of proposed SI-MLUO converter topology

The operating modes and steady-state analysis of proposed SI-MLUO converter topology is depicted in Figure 3 and explained clearly as below:

- Mode-I (t_0-t_1): during this operating mode-I, the switch S_{a1} is switched-on by giving the gate-pulses produced by gate-drive circuitry. The input DC voltage V_{in1}, energizes the boost capacitor C_{a1} and also charging the inductors in SI cell L_{a1}, L_{a2} through SI cell diode of D_{a1}, D_{a2}, respectively. It has been stored some energy through switch S_{a1} as parallel charging technique. Then, voltage across two inductors in SI cell of L_{a1}, L_{a2} is V_{La1}, V_{La2} which is equal to the input DC voltage of V_{in1}. Although, the input DC current I_{in1} is continuously flow towards boost capacitor and inductors of SI cell of C_{a1}, L_{a1} and L_{a2}, the current flow in capacitor and SI cell inductors are i_{Ca1}, i_{La1} and i_{La2} which is linearly increased. So, the input DC current doesn’t flow to resistive load because of, the output diode D_o is in reverse-biased due to switch S_{a1} is in conduction region. Thus, the output capacitor C_o provides the continuous energy to load R_o and the maintains output voltage V_o is constant until switch S_{a1} comes to non-conduction state. The operating mode-I of proposed SI-MLUO converter is shown in Figure 3(a).
- Mode-II (t_1-t_2): during this operating mode-II, the switch S_{a1} is switched-OFF by terminating the gate-pulses produced by gate-drive circuitry. Then the, energy stored in inductors of SI cell-1 L_{a1}, L_{a2} and boost capacitor C_{a1} are de-energized through diode of D_{a12} and output diode D_o. It has been delivered energy to resistive load with input voltage V_{in1} as series dis-charging technique. Hence, the voltage across two inductors in SI cell of L_{a1}, L_{a2} is $-V_{La1}$, $-V_{La2}$ which is equal to the boost capacitor voltage of V_{C1}.

Although, the load current I_O is continuously flow towards boost capacitor and inductors of SI cell of C_{a1}, L_{a1} and L_{a2} and decreased linearly and delivers energy to load and output DC capacitor C_o. So, the current continuously flow to resistive load due to output diode D_o is in forward-biased and switch S_{a1} is in non-conduction region which produces high voltage gain at load terminals.



(a) (b)

Figure 3. Operating modes of proposed MLUO converter (a) mode-I and (b) mode-II

Thus, the switched inductors and boost capacitor provides the continuous energy to load R_o and maintains output voltage V_o is constant until switch S_{a1} comes to conduction state. The operating mode-II of proposed SI-MLUO converter is shown in Figure 3(b). The typical waveforms of proposed SI-MLUO converter are shown in Figure 4. The steady-state analysis of proposed SI-MLUO converter is illustrated by using voltage-second balance principle, The average value of voltage induced in the switched-inductors are represented as:

$$V_{La1} = V_{La2} = 0 \tag{1}$$

during mode-1 (S_{a1} ON, t_{on}=DT), the voltage induced and current flow in the switched inductors are formulated as:

$$V_{La1} = V_{La2} = V_{in1} \tag{2}$$

$$V_{Ca1} = V_{in1} \tag{3}$$

$$I_{La1}(t) = I_{La2}(t) = \frac{V_{in1}}{L} \tag{4}$$

during mode-II, (S_{a1} OFF, t_{on}=(1-D)T), the voltage induced and current flow at load terminals are formulated as (5).

$$V_{in1} - V_{La1} - V_{La2} + V_{Ca1} - V_O = 0 \tag{5}$$

Based on switch-OFF period, the induced voltages are expressed as (6).

$$V_{La1} = V_{La2} = \frac{3V_{in1} - V_O}{2} \tag{6}$$

According to principle of volt-sec balance principle across the switched inductors L_{a1} and L_{a2} as expressed as (7).

$$V_{in1}DT + \frac{3V_{in1} - V_O}{2}\,(1 - D)T = 0 \tag{7}$$

Therefore, the relation for voltage gain ratio can be expressed as in (8).

$$\frac{V_O}{V_{in1}} = \frac{4-D}{1-D} \tag{8}$$

The (8) can be simplified and the final voltage gain (VG_{CCM}) is expressed in (9).

$$VG_{CCM}\ (boost) = \frac{V_o}{V_{in}} = \frac{4-D}{1-D} \quad (9)$$

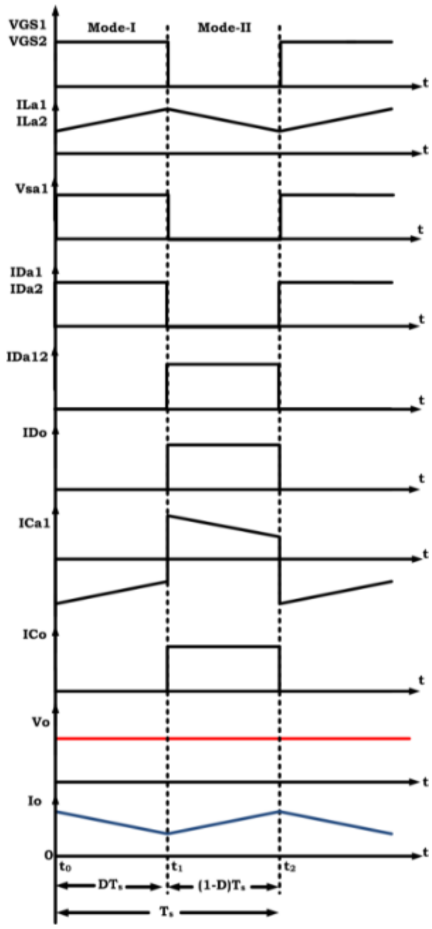


Figure 4. Typical waveforms of proposed SI-MLUO converter topology

3. RESULTS AND DISCUSSION

The performance of proposed SI-MLUO converter topology is verified by using MATLAB/Simulink tool, simulation results are validated with conventional topologies. The MATLAB/Simulink design specifications of proposed SI-MLUO converter topology are illustrated in Table 1.

Table1. Design specifications

S.No	Design specifications	Values	S.No	Design specifications	Values
1	Input DC voltage	V_{in1}=65 V	6	Output capacitor	C_o=470 µF
2	Output DC voltage	V_o=500 V	7	Switching frequency	F_s=50 KHz
3	Output DC power	P_o-1 KW	8	Resistive load	R_L=250 Ω
4	Switched inductors	L_{a1}=L_{a2} =10 mH	9	Duty ratio	D-55%
5	Boost capacitor	C_o=15µF			

3.1. Performance of proposed SI-MLUO converter topology

The simulation results of proposed SI-MLUO converter topology have been presented as shown in Figure 5 (see Appendix). The proposed SI-MLUO converter topology is energized with input DC voltage V_{in1}-65 V for charging the switched inductors to attain required voltage at load terminals as depicted in Figure 5(a). It delivers the required load voltage of 500 V with a load current of 2 A to drive the resistive load as shown in Figures 5(b) and 5(c). The switching pulses of switch S_{a1} is given by switching frequency of 50 KHz as shown in Figure 5(d). The switched-inductors L_{a1}, L_{a2} of SI cell are charged by switching the switch S_{a1} through gate-pulses, then the inductors are charged linearly in a positive-slope region with an average current i_{La1}, i_{La2} of 0.59 A and voltage across inductor V_{La1}, V_{La2} of 60 A as shown in Figures 5(e) and 5(f).

The voltage across diodes and diode currents of proposed SI-MLUO converter topology is shown in Figure 6 (see Appendix). In mode-I, the switch S_{a1} is to be conducted, the voltage appeared across the switch is zero and maximum current flow during switch-ON of S_{a1} of 21 A. Likewise, in mode-II, the switch S_{a1} is to be non-conducted and then the zero current flow and some voltages are appeared across switch S_{a1} during OFF-state i.e., 220 V as shown in Figures 6(a) and 6(b). In mode-I, the diodes D_{a1}, D_{a2} are in forward bias and D_{a12} are in reverse-bias, thus the average current flow of diodes during these modes is 0.55 A, 0.55 A, 0.6 A, and some voltage is appeared across the diodes is -75 A, -75 A, and -60 A, respectively as shown in Figures 6(c) and 6(d). The diodes D_{a3} is in forward bias in mode-I and D_{a3} is in reverse-bias in mode-II, thus the average current flow through diode during these modes is 14 A, and voltage appeared across the diode is -220 A, respectively as shown in Figures 6(e) and 6(f).

The current and voltage across load-side capacitor/diodes of proposed SI-MLUO converter topology is shown in Figure 7 (see Appendix). The boost capacitor C_{a1} is in forward bias during mode-I and reverse bias in mode-II, thus the average current flow through capacitor these modes are 14 A and voltage appeared across the diode is 64 A as shown in Figures 7(a) and 7(b). The diode D_O is in reverse-bias during mode-I and D_O is in forward-bias during mode-II, thus the average current flow through output diode during these modes is 2.7 A and the voltage appeared across diode during these modes is -220 V as shown in Figures 7(c) and 7(d). And also, the maximum current flow through output capacitor during these operating modes is 1.8 A is shown in Figure 7(e).

The comparison of voltage gain (M_{CCM}) vs duty ratio (D) in conventional and proposed SI-MLUO DC-DC boost converter topology is illustrated in Table 2. The proposed SI-MLUO converter topology produces high voltage gain over the various conventional basic and modified DC-DC converters. The comparison of semi-conductor devices and energy storage devices in conventional and proposed SI-MLUO converter topologies is illustrated in Table 3. The proposed SI-MLUO converter topology requires low semi-conductor and energy storage devices over the various conventional basic and modified DC-DC converters.

Table 2. Comparison of voltage gain (M_{CCM}) vs duty ratio (D) in conventional and proposed SI-MLUO DC-DC boost converters

Type of Converter	Voltage Gain (M_{CCM})	Duty Ratio (D) 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Basic SEPIC converter [17]	$V_0 = \frac{D}{(1-D)}V_{in}$	0.11	0.25	0.42	0.66	1	1.5	2.33	4	9
Modified SEPIC converter [18]	$V_0 = \frac{1+D}{(1-D)^2}V_{in}$	1.35	1.87	2.65	3.88	6	10	18.89	45	190
Basic CUK converter [19]	$V_0 = \frac{D}{(1-D)}V_{in}$	0.11	0.25	0.42	0.66	1	1.5	2.33	4	9
Modified CUK converter [19]	$V_0 = \frac{1}{(1-D)^2}V_{in}$	1.24	1.56	2.04	2.77	4	6.25	11.12	25	100
Basic LUO converter [20]	$V_0 = \frac{D}{(1-D)}V_{in}$	0.11	0.25	0.42	0.66	1	1.5	2.33	4	9
Modified re-lift positive-output LUO converter [21]	$V_0 = \frac{2}{(1-D)}V_{in}$	2.22	2.5	2.85	3.33	4	5	6.66	10	20
Proposed SI-MLUO converter	$V_0 = \frac{4-D}{(1-D)}V_{in}$	4.33	4.75	5.28	6	7	8.5	11	16	31

Table 3. Comparison of semi-conductor devices and energy storage devices in conventional and proposed SI-MLUO DC-DC boost converters

Converter topology	Output gain	No. of semi-conductor device: Diodes	Switches	No. of energy storage devices: Capacitors	Inductors
Basic SEPIC converter [17]	$V_0 = \frac{D}{(1-D)}V_{in}$	1	1	2	2
Modified SEPIC converter [18]	$V_0 = \frac{1+D}{(1-D)^2}V_{in}$	4	1	4	3
Basic CUK converter [19]	$V_0 = \frac{D}{(1-D)}V_{in}$	1	1	2	2
Modified CUK converter [19]	$V_0 = \frac{1}{(1-D)^2}V_{in}$	3	2	3	3
Basic LUO converter [20]	$V_0 = \frac{D}{(1-D)}V_{in}$	1	1	2	2
Modified re-lift positive-output LUO converter [21]	$V_0 = \frac{2}{(1-D)}V_{in}$	5	1	4	3
Proposed SI-MLUO converter	$V_0 = \frac{4-D}{(1-D)}V_{in}$	4	1	2	2

4. CONCLUSION

In this work, a novel switched-inductor cell based modified LUO converter has been proposed and it is best suited converter for solar-PV powered pumping system. The SI-MLUO is the most significant converter topology for transforming high voltage gain at load terminals by utilizing reduced switching devices and energy storage elements. The proposed SI-MLUO converter requires only 1 switch, 4 diodes, 1 SI cell, and 2 capacitors over the conventional basic and modified DC-DC converters as presented in literature. The proposed SI-MLUO converter topology produces nearly 8 times gain voltage of input DC voltage operated with a duty ratio of D-0.55, with a calculated efficiency of 92.5%. Moreover, the proposed SI-MLUO converter have recognized advantages such as, low leakage currents, low spikes, and continuous input current. The proposed SI-MLUO converter has gained more interest to develop a cascaded connection of multiple SI-MLUO converters for attaining high voltage gain with low duty-ratio has been proposed in future.

APPENDIX

(a)
(b)

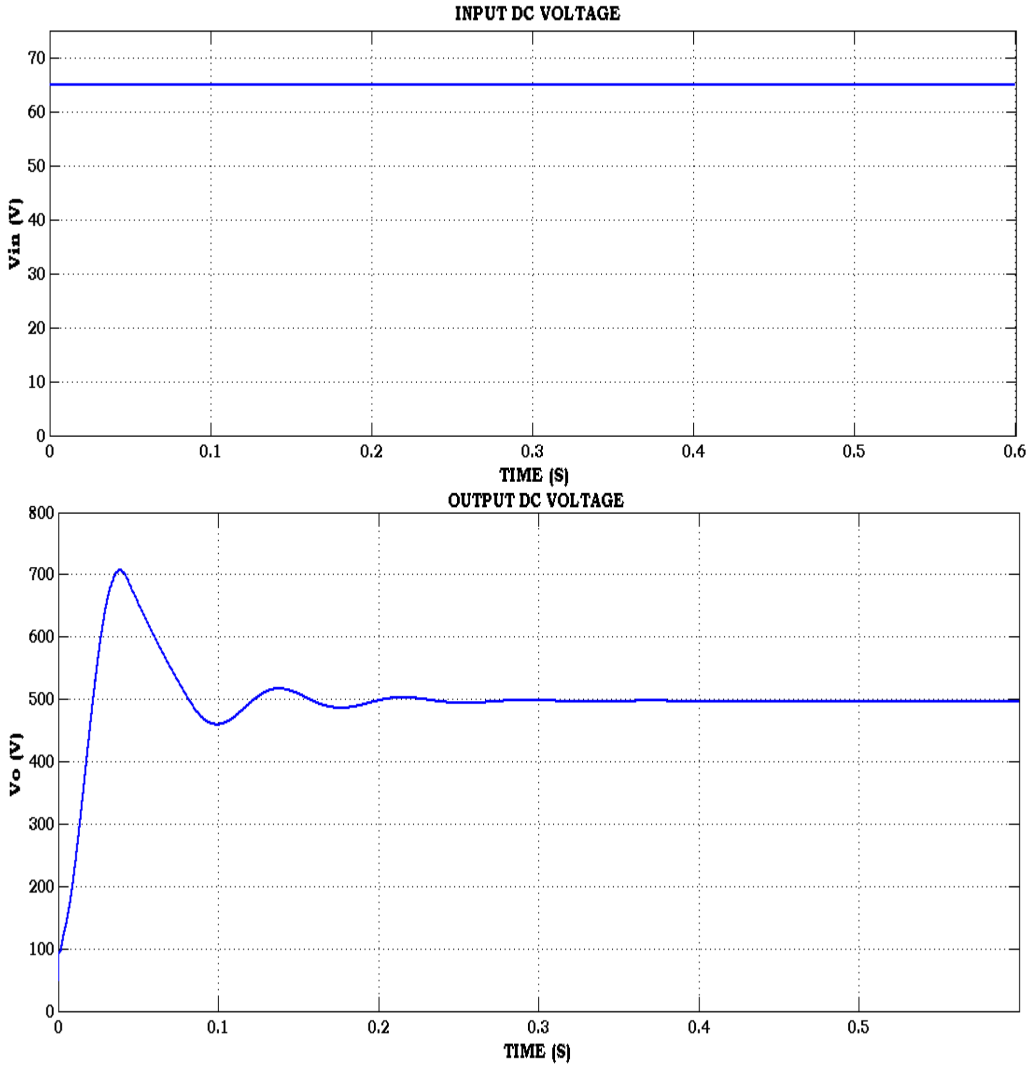


Figure 5. Simulink results of proposed SI-MLUO converter topology: (a) input DC voltage and (b) output DC voltage

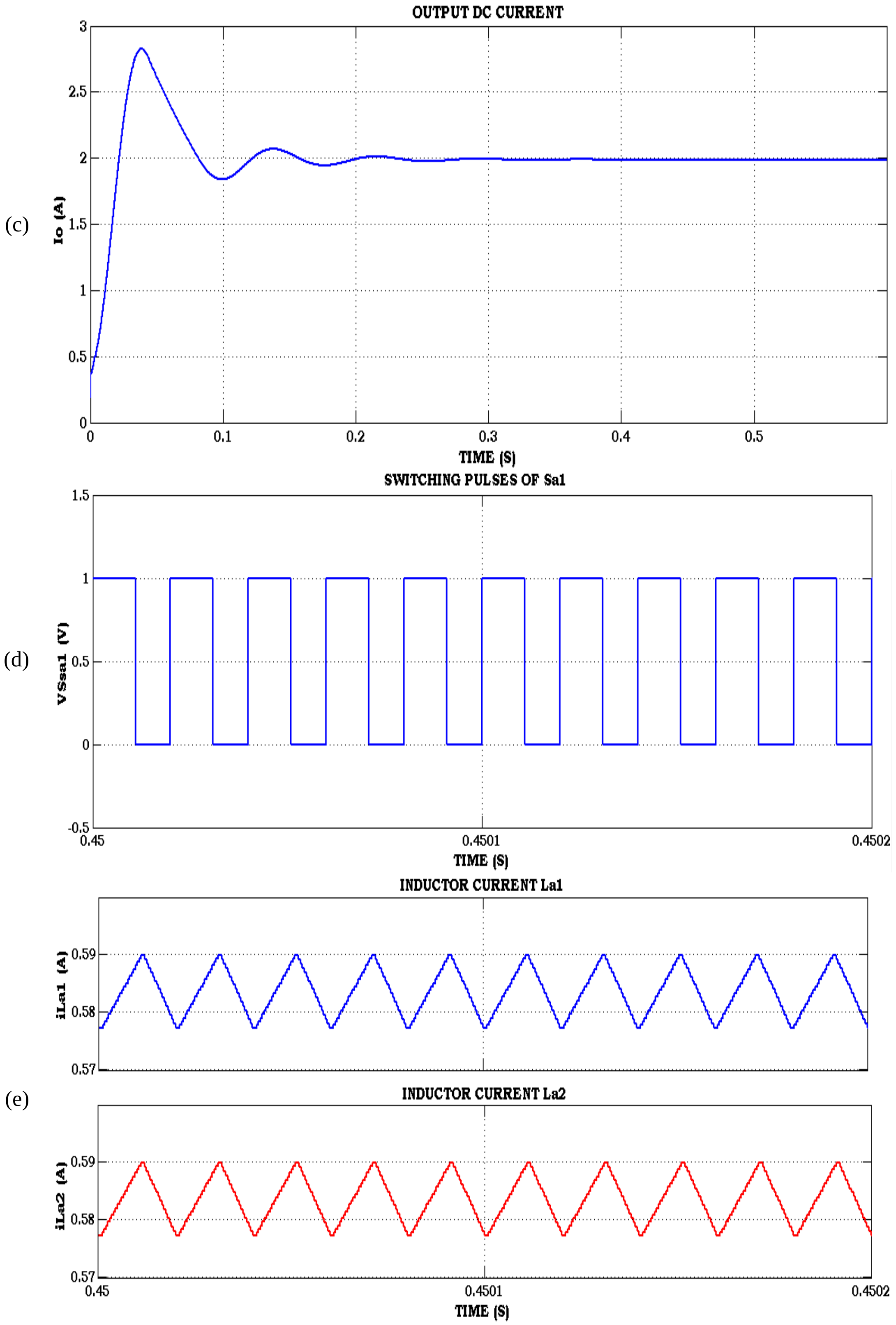


Figure 5. Simulink results of proposed SI-MLUO converter topology: (c) output DC current, (d) switching/gate pulses of switch S_{a1}, and (e) inductor currents of L_{a1}, L_{a2} (continue)

(f)

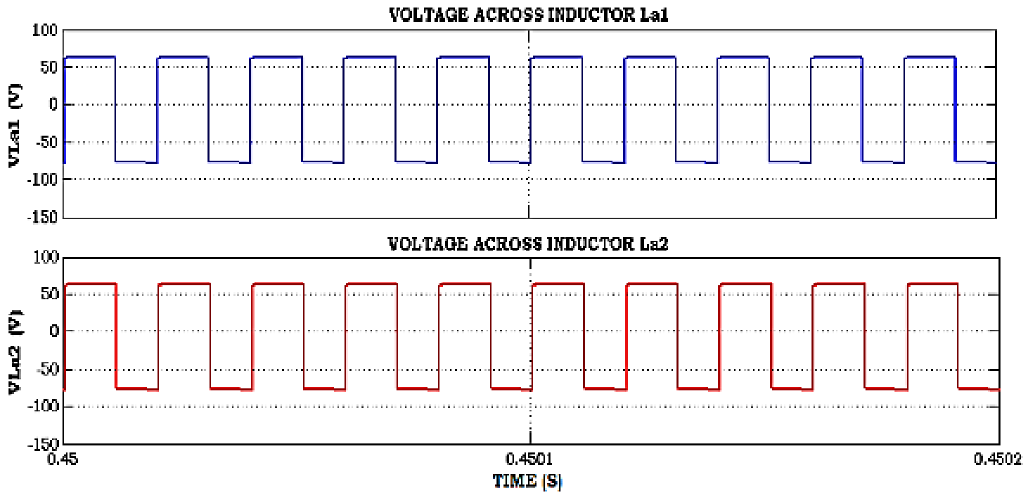


Figure 5. Simulink results of proposed SI-MLUO converter topology: (f) voltage across inductors L_{a1}, L_{a2} (continue)

(a)

(b)

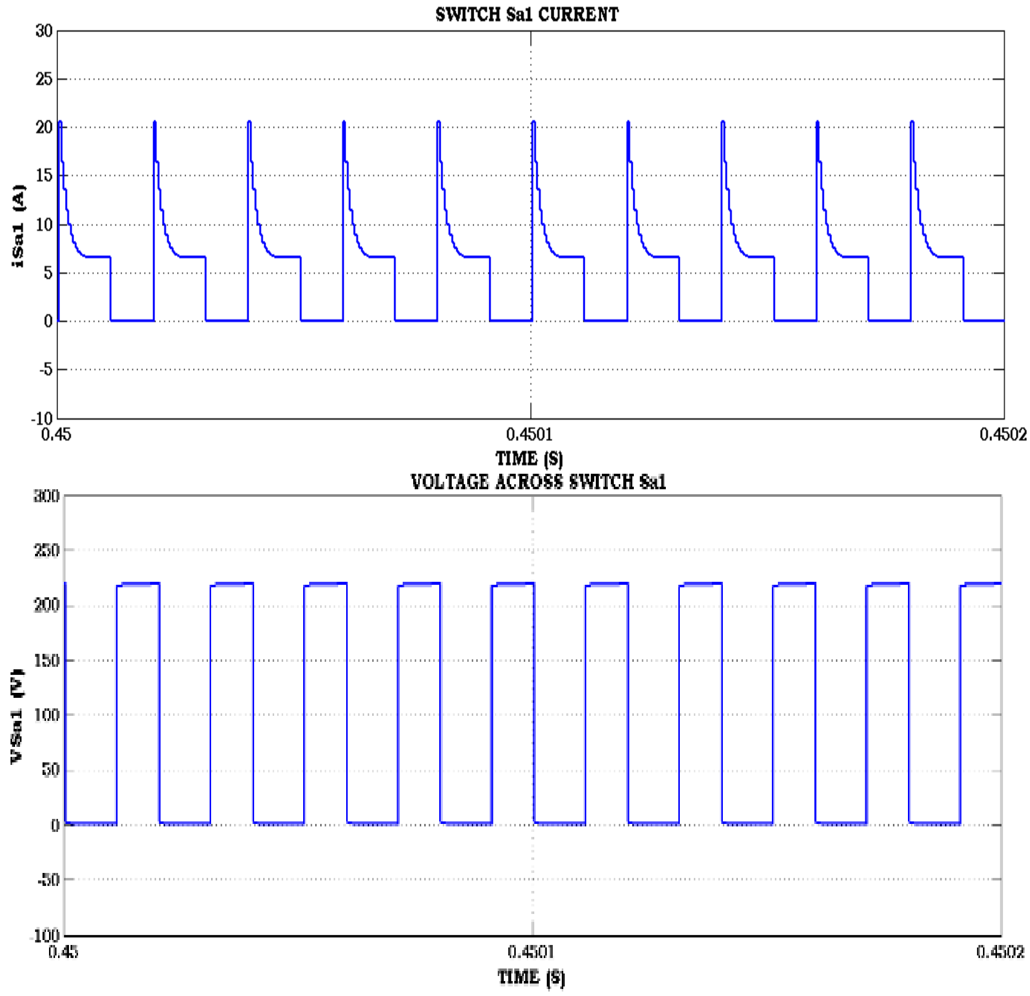


Figure 6. Voltage across diodes and diode currents of proposed SI-MLUO converter topology: (a) switch S_{a1} current and (b) voltage across switch S_{a1}

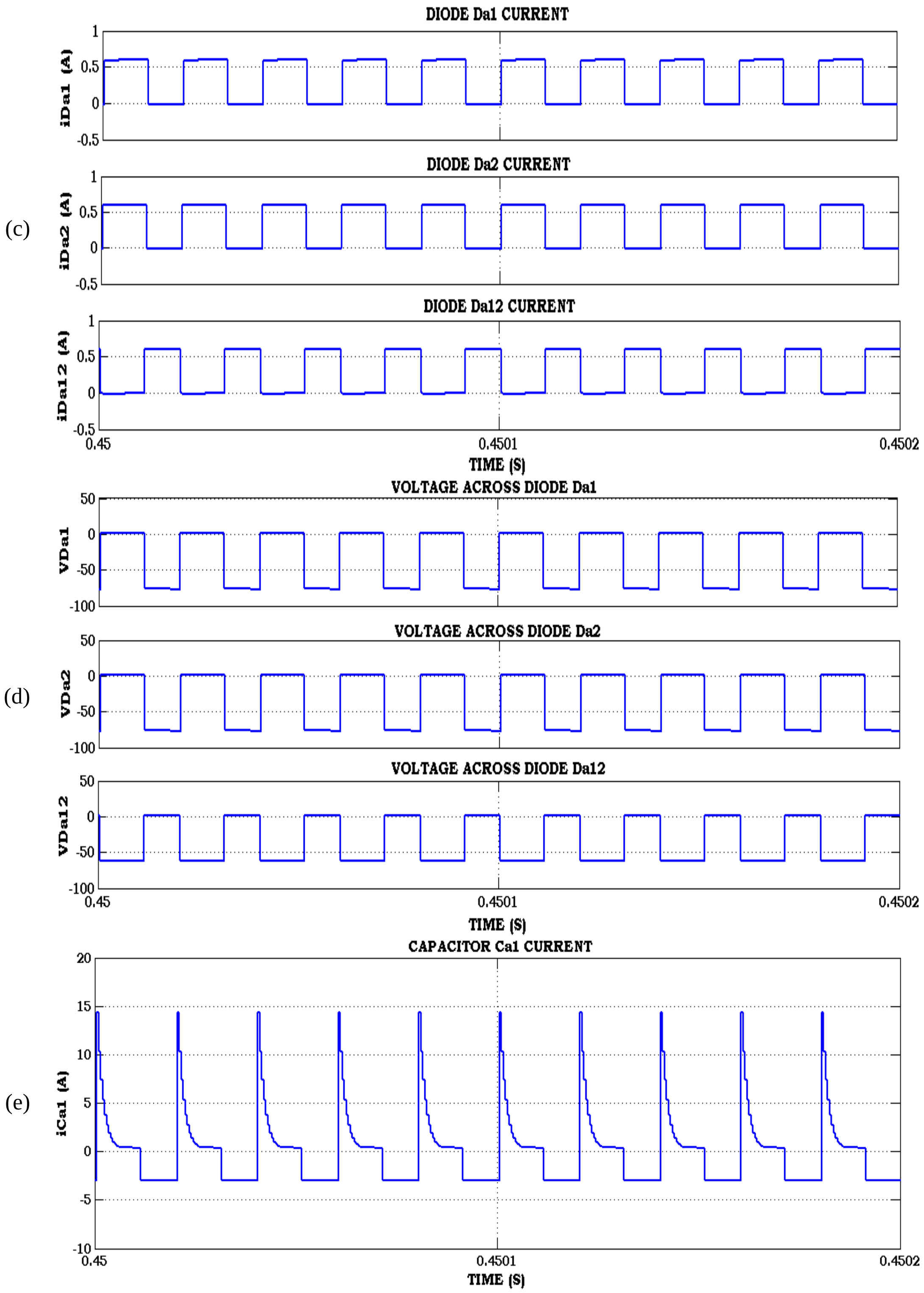


Figure 6. Voltage across diodes and diode currents of proposed SI-MLUO converter topology: (c) diode D_{a1}, D_{a2}, and D_{a12} currents, (d) voltage across diodes D_{a1}, D_{a2}, and D_{a12}, and (e) diode D_{a3} current (continue)

(f)

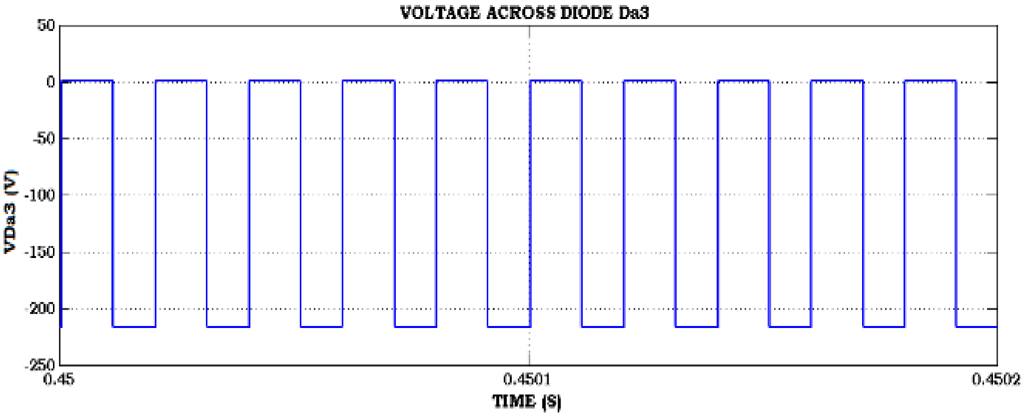


Figure 6. Voltage across diodes and diode currents of proposed SI-MLUO converter topology:
(f) voltage across diode D_{a3} (continue)

(a)

(b)

(c)

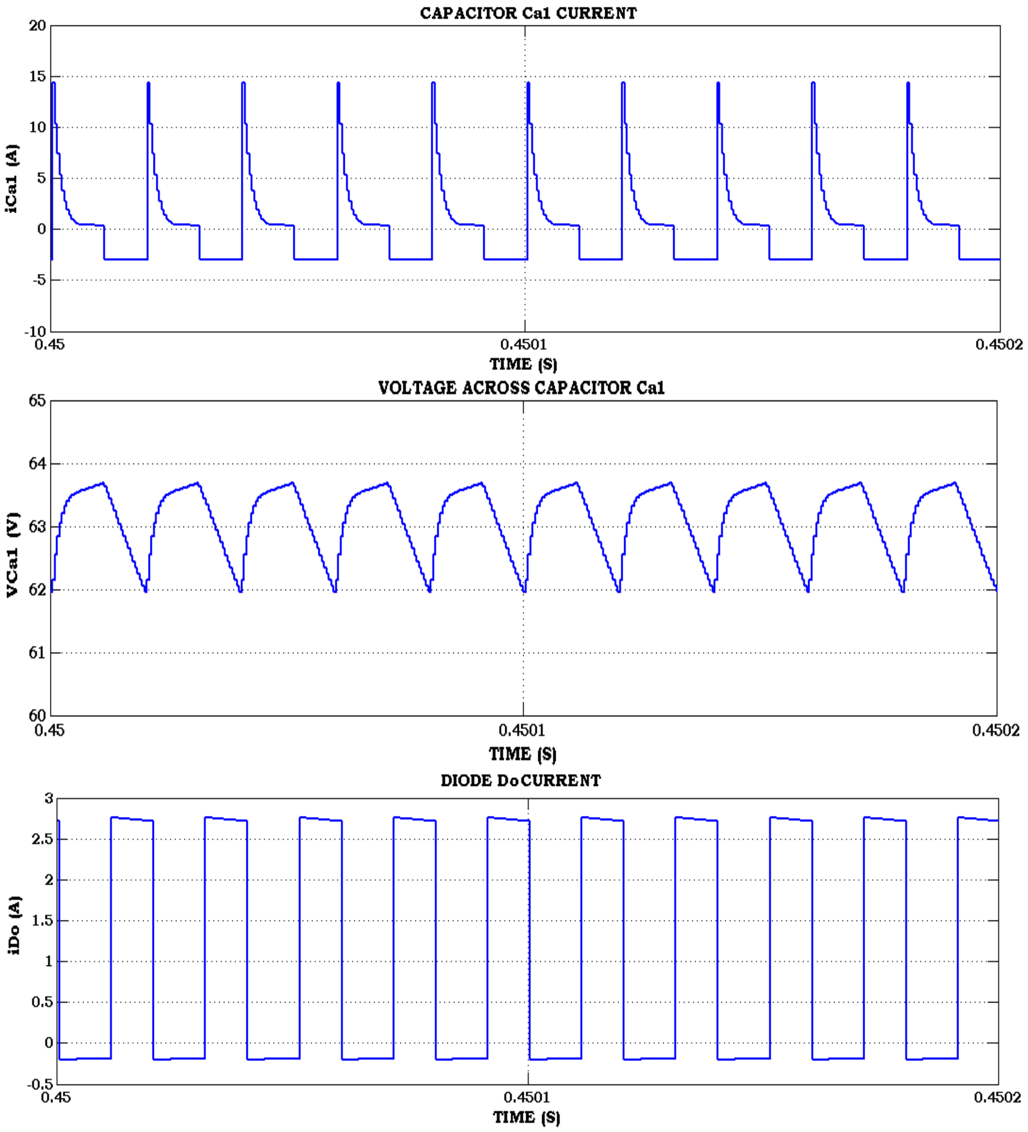


Figure 7. Current and voltage across load-side capacitor/diodes of proposed SI-MLUO converter topology:
(a) capacitor C_{a1} current, (b) voltage across capacitor C_{a1}, and (c) diode D_O current

(d)

(e)

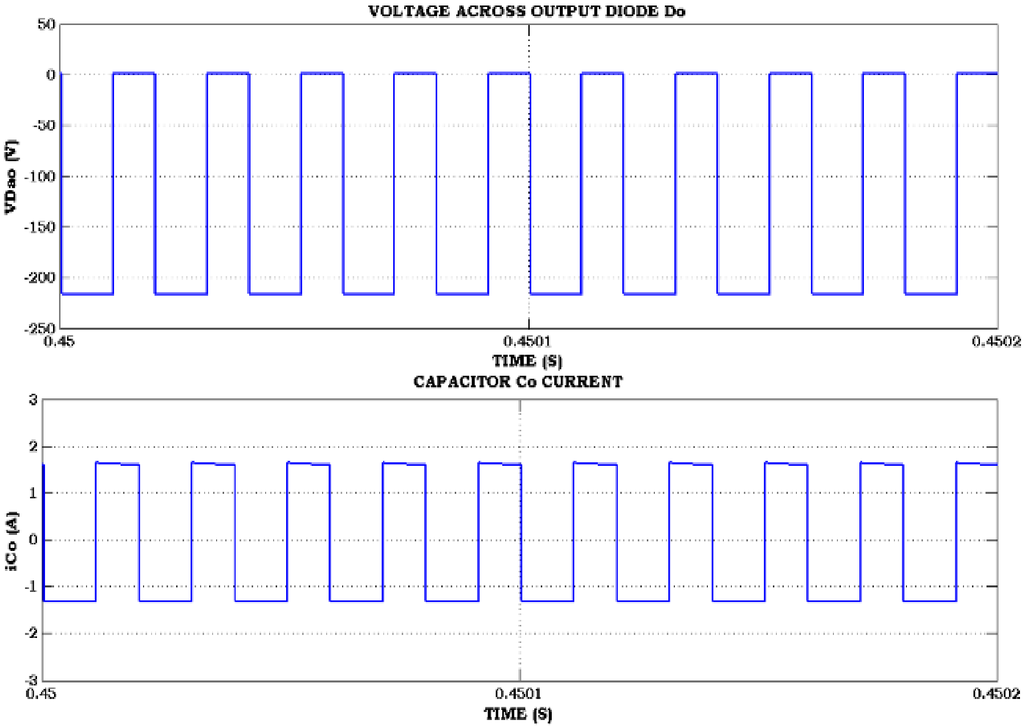


Figure 7. Current and voltage across load-side capacitor/diodes of proposed SI-MLUO converter topology: (d) voltage across diode D_O, and (e) capacitor C_O current (continue)

REFERENCES

[1] S. R. Moole, "Water Purification for Human Consumption," in *2021 IEEE Integrated STEM Education Conference (ISEC)*, Mar. 2021, pp. 209–209, doi: 10.1109/ISEC52395.2021.9764038.

[2] E. C. Carmo, V. C. Onofri, and V. F. Mendes, "Analysis of water pumps start powered by diesel generator," in *2018 Simposio Brasileiro de Sistemas Eletricos (SBSE)*, May 2018, pp. 1–6, doi: 10.1109/SBSE.2018.8395779.

[3] N. I. Sarkar, A. I. Sifat, N. Rahim, and S. M. S. Reza, "Replacing diesel irrigation pumps with solar photovoltaic pumps for sustainable irrigation in Bangladesh: A feasibility study with HOMER," in *2015 2nd International Conference on Electrical Information and Communication Technologies (EICT)*, Dec. 2015, pp. 498–503, doi: 10.1109/EICT.2015.7392004.

[4] M. Bragard, N. Soltau, S. Thomas, and R. W. De Doncker, "The Balance of Renewable Sources and User Demands in Grids: Power Electronics for Modular Battery Energy Storage Systems," *IEEE Transactions on Power Electronics*, vol. 25, no. 12, pp. 3049–3056, Dec. 2010, doi: 10.1109/TPEL.2010.2085455.

[5] M. A. Mossa, O. Gam, N. Bianchi, and N. V. Quynh, "Enhanced Control and Power Management for a Renewable Energy-Based Water Pumping System," *IEEE Access*, vol. 10, pp. 36028–36056, 2022, doi: 10.1109/ACCESS.2022.3163530.

[6] R. Kumar and B. Singh, "A Simple BLDC Motor Drive for Solar PV Array Fed Water Pumping System," *IET Power Electronics*, Jun. 2016.

[7] U. K. Kalla, N. Bhati, K. Chariya, and I. Qureshi, "Design and Analysis of Solar PV Fed IMD Water - Pumping System," in *2021 International Conference on Sustainable Energy and Future Electric Transportation (SEFET)*, Jan. 2021, pp. 1–6, doi: 10.1109/SeFet48154.2021.9375744.

[8] B. Singh, U. Sharma, and S. Kumar, "Standalone photovoltaic water pumping system using induction motor drive with reduced sensors," *IEEE Transactions on Industry Applications*, vol. 54, no. 4, pp. 3645–3655, Jul. 2018, doi: 10.1109/TIA.2018.2825285.

[9] Y. Mahmoud and W. Xiao, "Evaluation of Shunt Model for Simulating Photovoltaic Modules," *IEEE Journal of Photovoltaics*, vol. 8, no. 6, pp. 1818–1823, Nov. 2018, doi: 10.1109/JPHOTOV.2018.2869493.

[10] R. F. Rajakumari and M. Deshpande, "Comparative Analysis of DC-DC Converters," in *2019 2nd International Conference on Power and Embedded Drive Control (ICPEDC)*, Aug. 2019, pp. 504–509, doi: 10.1109/ICPEDC47771.2019.9036624.

[11] E. Mattos, A. M. S. S. Andrade, G. V. Hollweg, J. Renes Pinheiro, and M. Lucio da Silva Martins, "A Review Of Boost Converter Analysis And Design In Aerospace Applications," *IEEE Latin America Transactions*, vol. 16, no. 2, pp. 305–313, Feb. 2018, doi: 10.1109/TLA.2018.8327380.

[12] M. Forouzesh, Y. P. Siwakoti, S. A. Gorji, F. Blaabjerg, and B. Lehman, "Step-Up DC–DC Converters: A Comprehensive Review of Voltage-Boosting Techniques, Topologies, and Applications," *IEEE Transactions on Power Electronics*, vol. 32, no. 12, pp. 9143–9178, Dec. 2017, doi: 10.1109/TPEL.2017.2652318.

[13] M. A. Chewale, R. A.Wanjari, V. B.Savakhande, and P. R.Sonawane, "A Review on Isolated and Non-isolated DC-DC Converter for PV Application," in *2018 International Conference on Control, Power, Communication and Computing Technologies (ICCPCCT)*, Mar. 2018, pp. 399–404, doi: 10.1109/ICCPCCT.2018.8574312.

[14] N. Swaminathan and Y. Cao, "An Overview of High-Conversion High-Voltage DC–DC Converters for Electrified Aviation Power Distribution System," *IEEE Transactions on Transportation Electrification*, vol. 6, no. 4, pp. 1740–1754, Dec. 2020, doi: 10.1109/TTE.2020.3009152.

[15] Deepak, R. K. Pachauri, and Y. K. Chauhan, "Modeling and simulation analysis of PV fed Cuk, Sepic, Zeta and Luo DC-DC converter," in *2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES)*, Jul. 2016, pp. 1–6, doi: 10.1109/ICPEICES.2016.7853596.

[16] A. Sweatha, B. Baskaran, and P. Duraipandy, "An Extensive Review of DC-DC Converter Topologies for Water-Pumping Application," in *2022 International Conference on Innovations in Science and Technology for Sustainable Development (ICISTSD)*, Aug. 2022, pp. 151–156, doi: 10.1109/ICISTSD55159.2022.10010591.
[17] E. Babaei and M. E. Seyed Mahmoodieh, "Calculation of Output Voltage Ripple and Design Considerations of SEPIC Converter," *IEEE Transactions on Industrial Electronics*, vol. 61, no. 3, pp. 1213–1222, Mar. 2014, doi: 10.1109/TIE.2013.2262748.
[18] K. V. K. Varma and A. Ramkumar, "Implementation of SPV-powered water pumping system using non-isolated SC converter topology," *Electrical Engineering*, vol. 103, no. 3, pp. 1433–1444, Jun. 2021, doi: 10.1007/s00202-020-01170-9.
[19] B. B. Tuvar and M. H. Ayalani, "Analysis of a Modified Interleaved Non-Isolated Cuk Converter with wide range of load Variation and reduced Ripple content," in *2019 3rd International Conference on Trends in Electronics and Informatics (ICOEI)*, Apr. 2019, pp. 406–411, doi: 10.1109/ICOEI.2019.8862665.
[20] P. Anbarasan, M. Venmathi, M. Vijayaragavan, and V. Krishnakumar, "Performance Enhancement of Grid Integrated Photovoltaic System Using Luo Converter," *IEEE Canadian Journal of Electrical and Computer Engineering*, vol. 45, no. 3, pp. 293–302, 2022, doi: 10.1109/icjece.2022.3178696.
[21] C. Pansare, S. K. Sharma, C. Jain, and R. Saxena, "Analysis of a modified positive output Luo converter and its application to solar PV system," in *2017 IEEE Industry Applications Society Annual Meeting*, Oct. 2017, pp. 1–6, doi: 10.1109/IAS.2017.8101849.
[22] S. Sreenu, J. Upendar, and B. Sirisha, "Analysis of switched impedance source/quasi-impedance source DC-DC converters for photovoltaic system," *International Journal of Applied Power Engineering (IJAPE)*, vol. 11, no. 1, pp. 14–24, Mar. 2022, doi: 10.11591/ijape.v11.i1.pp14-24.
[23] E. Sreelatha, A. Pandian, and M. S. Kuppusamy, "A novel topology for single-inductor single input triple output DC-DC power converter," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 14, no. 1, pp. 304–310, Mar. 2023, doi: 10.11591/ijpeds.v14.i1.pp304-310.
[24] J. Upendar, S. R. Kumar, S. Sreenu, and B. Sirisha, "Implementation and study of fuzzy based KY boost converter for electric vehicle charging," *International Journal of Applied Power Engineering (IJAPE)*, vol. 11, no. 1, pp. 98–108, Mar. 2022, doi: 10.11591/ijape.v11.i1.pp98-108.
[25] A. Siva and V. Rajendran, "A novel auxiliary unit based high gain DC-DC converter for solar PV system with MPPT control," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 13, no. 4, pp. 2386–2395, Dec. 2022, doi: 10.11591/ijpeds.v13.i4.pp2386-2395.
[26] A. Sanam, L. S. Rao, R. Kommineni, S. Shaik, V. Regulagadda, and G. saiakhil Doddi, "A Solar-PV/BESS Powered Multi-Input DC-DC Boost Converter Fed BLDC Motor Drive," in *2022 International Conference on Intelligent Controller and Computing for Smart Power (ICICCSP)*, Jul. 2022, pp. 1–6, doi: 10.1109/ICICCSP53532.2022.9862420.

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