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Augmented ASC Network for Photo Voltaic Applications

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ABSTRACT- This work uses a DC-DC converter that employs an Active Switched Capacitor (ASC) to provide high gain that makes it appropriate for the Photo Voltaic (PV) system. The transformer less converter with an ASC network consists of a capacitor and a diode that boosts voltage effectively. The well-liked converter operates effectually on both Continuous Conduction Mode (CCM) and Discontinuous Conduction Modes (DCM). The suggested topology of converter is easy to design, and it renders a less stress on auxiliary diode and capacitors. This preferred converter scheme is validated through MATLAB Simulink and the outcomes are confirmed using hardware prototype.

Keywords: Continuous Conduction Mode; high gain DC-DC converter; Active switched capacitor and Perturb and observe.

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1. INTRODUCTION

Step up gain converters are the class of converters that lifts the voltage to high value. Photovoltaic (PV) panels and battery sources generate low voltage outputs which should be increased to high voltages for grid-tied and standalone applications [1]. High gain converters are essential for renewable energy applications like photo voltaic systems, fuel cells etc. [2]. In [3], boost converter designed with switched inductor configuration is described. In order to boost voltage gain, Active Switched Inductor (ASL) converters are combined with Active Switched Capacitor (ASC) and Voltage Lift (VL) boosting techniques. Currently, renewable energy has wide application due to the energy crisis. By using the ASC based converter circuit, a higher gain can be achieved with high efficacy and less stress on the switches [4]. By utilizing split inductors, boost converters achieve a voltage increase. The converter that has low energy consumption, lesser-voltage stresses on switches and less control complexity is normally preferred in many applications. The high gain voltage conversion feature is more attractive, and it is employed for harnessing energy from renewable energy sources like fuel cells and photo voltaic. There is a new DC-DC high gain converter published in [5] that provides steady current and can be applied to DC microgrids. An improved DC-DC converter that is non-isolated and has low switching stress is described in [6]. A capacitor and inductor are utilized to maintain the converter voltage gain. This is achieved via a multi-cell arrangement as well. This paper introduces a switched capacitor DC-DC converter for boosting the voltage generated by solar panels to a higher level. Several works are reported in the literature for high gain DC-DC converters. With photovoltaic cell as the supply, this paper explains the multiplier topology SEPIC converter employed for renewable energy sources as the converter can provide high voltage gain [7]. The renewable energy sources provide intermittent output power. Flow of power can be controlled with the help of step-up DC-DC power converter that gives rise to efficient management of energy [8]. We present the active switched inductor [ASL] network with two capacitor cells for obtaining the desired voltage gain for PV and grid-tied applications.[9]. According to [10], DC converter output voltage can be adjusted by a fuzzy logic controller. The boosting power stage of converter is employed via current-fed voltage multiplier for distributed energy applications [11]. The high gain voltage conversion feature is more attractive, and it is employed for harnessing energy from renewable energy sources like fuel cells, photo voltaic. Based on experiments, the suggested converter can meet the converter performance requirements with an efficiency of around 95.5% [12]. Normal boost converters never provide the sufficient gain hence the transformer less high gain converter is preferred in this scope. Here the single stage conversion with ASL and a passive SC network is accomplished which makes this topology more attractive for renewable applications [13]. As a result of high output voltage, it is crucial to reduce the voltage stress across each conducting diode and switch. Thus, for boosting the gain, quasi ASL configuration is proposed. In [14], numerous SL and SC circuits are compared, and the voltage gain is boosted. The proposed DC-DC converter offering high gain uses fuzzy logic controller for uplifting the voltage obtained from solar panel [15]. In this scope, a novel H-SLC (Hybrid Switched inductor and capacitor) network is analyzed and implemented to enhance the voltage gain with high efficiency [16]. In [17], a new step-up converter of n stage is presented that find its application in integrating low voltage from solar PV. An active coupled inductor comprises of two coupled inductors for a renewable energy system is proposed in [18]. A transformer less three switched capacitor network that attains high gain with lesser duty ratio is elaborated in [19]. The literature review reveals there is a need to introduce high gain converters that prevail

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over the shortcomings like switching stress, high component count and high duty ratio. One such converter that overcomes the above said drawbacks is proposed in this paper.

2. MATERIALS AND METHODS

There is a constant rise in energy demand worldwide, and scientists are still searching for ways to address these needs by exploiting alternative sources of energy. In terms of alternate sources of energy, solar energy offers the most advantages since it is abundant and clean. The schematic representation of PV system is portrayed in *Figure 1*. The converter serves as an integrating platform for harvesting energy from renewable sources. Here the interface between solar and load is ASC based DC-DC converter. It is possible to utilize the energy acquired from the PV for a variety of applications. Because it offers high gain in voltage, the proposed system is ideal for grid-connected applications.

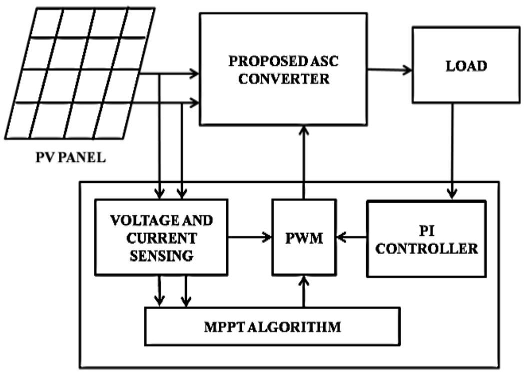

Figure 1: Schematic diagram of proffered system

2.1 Active Switched Capacitor Based Exalted Convolution

The proposed converter topology has a conventional ASL converter. Along with the existing ASL network, a diode and a capacitor are included to ensure that the power switch is under low stress and therefore provides enhanced gain. The proposed converter circuit is presented in *Figure 2*.

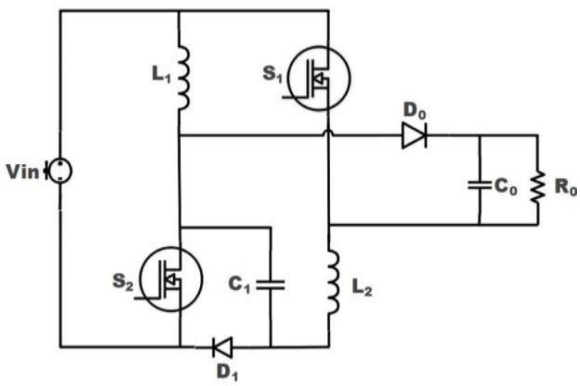

Figure 2: High gain converter with ASC

This active switched capacitor-based converter is made to increase the output of a solar PV system. The traditional ASL network contains inductors L_1 and L_2 and switches S_1 and S_2. Diode D_1 and capacitor C_1 share a common switch S_1 in the existing circuit. *Table 1* enlists the design specifications of the propounded converter.

Table 1: Design specifications

Criterions	Value
Input voltage	48 V
Output voltage	120 V
Inductor L_1	200 µH
Inductor L_2	720 µH
Capacitor C_1	10 µF
Capacitor C_2	100 µf
Resistor	144 Ω
Duty cycle	0.3
Switching frequency	50 kHz

2.2 Proposed Power Converter Operation

There exist two operating modes. The converter is made to operate under CCM. It is taken that all the devices used in the converter are in ideal state. The current flow path under CCM of converter is picturized in *Figures 3(a) and 3(b).*

2.2.1 Mode 1

In this mode, switches S_1 and S_2 are turned ON so that inductors L_1 and L_2 are charged parallelly and capacitors C_1 and C_0 are being discharged. In this condition diodes D_1 and D_0 remains off due to reverse bias. Capacitor C_0 is feeding the load and L_2 is getting charged via load. Equation (1) and (2) reveals inductor voltages.

$$V_{L1} = V_{in} \quad (1)$$

$$V_{L2} = V_{in} + V_{c1} \quad (2)$$

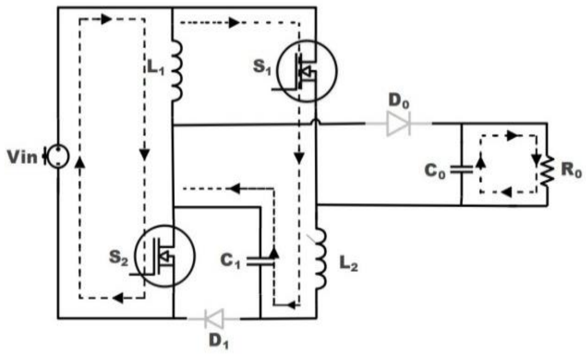

Figure 3(a): Mode I switches ON

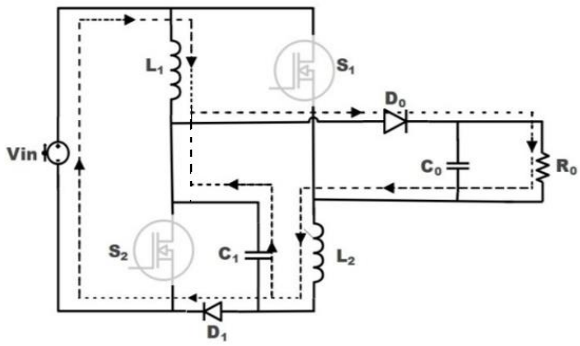

Figure 3(b): Mode II switches OFF

2.2.2 Mode 2

The diodes (D_1 and D_0) are ON, when switches S_1 and S_2 are OFF. The inductors L_1 and L_2 now deliver stored energy to charge the capacitor C_0. Meanwhile, capacitor C_1 is charged through inductor L_1. The inductor voltages are derived as in equations (3) and (4).

$$V_{L1} = V_{c1} - V_{in} \quad (3)$$
$$V_{L2} = V_o - V_{c1} \quad (4)$$

2.3 Converter Design Equation

Assume the converter is operated in CCM and the design equations are given in equations (5) to (10).

$$\frac{V_0}{V_{in}} = \frac{1+D+D^2}{(1-D)^2} \quad (5)$$
$$L_1 = \frac{DV_{in}}{I_{L1} f_S} \quad (6)$$
$$L_2 = \frac{D(2-D)V_{in}}{(1-D)I_{L2} f_S} \quad (7)$$
$$C_1 = \frac{DI_0}{(1-D)V_{C1} f_S} \quad (8)$$
$$C_0 = \frac{DI_0}{V_{C0} f_S} \quad (9)$$
$$R = \frac{V_0^2}{P} \quad (10)$$

2.4 Converter Switching Waveforms

The customary switching waveform in CCM mode is depicted in *figure 4.*

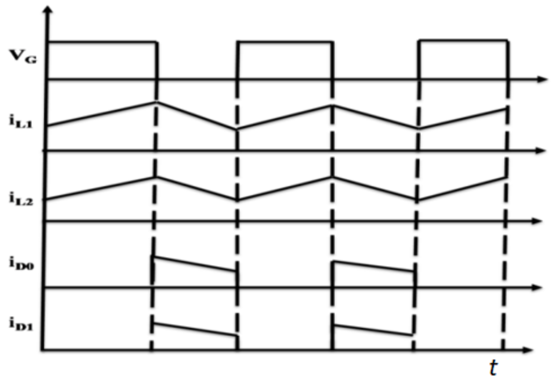

Figure 4: Switching waveforms obtained under CCM mode for the proposed converter

3. RESULTS AND VERIFICATION

Simulation outcomes of proposed DC-DC converter with Active Switched Capacitor obtained using MATLAB/ SIMULINK and are presented below.

3.1 Open Loop Simulation Results of the Proposed Converter

The simulations are performed in open loop and the waveforms obtained from simulation are displayed in *figure 5* and *figure 6.*

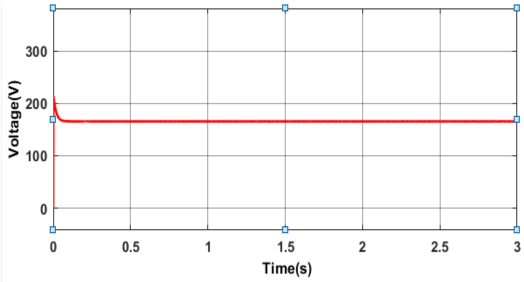

Figure 5: Output voltage waveform for preferred the converte

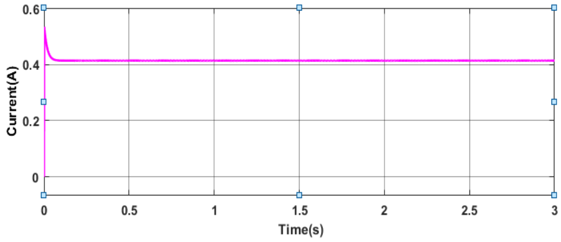

Figure 6: Output current waveform for the preferred converter

3.2 Closed Loop Simulation Outcomes of the Proposed Converter with Solar MPPT technique

The closed loop simulation of the proposed converter is then performed with solar MPPT and the results are analyzed. The specifications of the solar PV panel are mentioned in *table 2.*

Table 2: Specifications of the Solar PV Panel

Parameters	Solar panel values
Sc	7.244 A
Voc	44.816 V
Im	6.925 A
Vm	36.83 V

3.3 Closed Loop Analysis of the Converter with Solar MPPT Technique

3.3.1 Type 1: For 1000W/m^2 Irradiation and Temperature of 25°C

Table 3 summarizes the results of the converter for quick changes in load under 1000 W/m^2 of irradiation and 25°C of temperature. The voltage waveform attained is depicted in *Figure 7 (a).*

Table 3. Constant irradiation level and temperature (1000W/m^2 & 25°C)

Power (W)	Load Voltage (V_0)	Load Current (I_0)	Efficiency (%)	Resistive Load (Ω)
100	120	0.8334	90	144
75	120	0.625	88	192
50	120.1	0.4167	83	288

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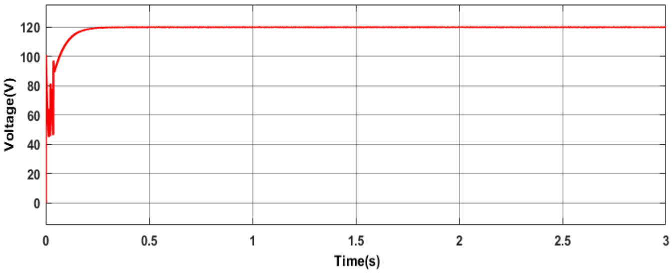

Figure 7(a): Load voltage waveform at 1000W/m2 and 25˚C

The *Figure 7(b)* interprets the output voltage waveform at standard temperature and irradiation level and *Figure 7(c)* portrays voltage waveform under load adjustments.

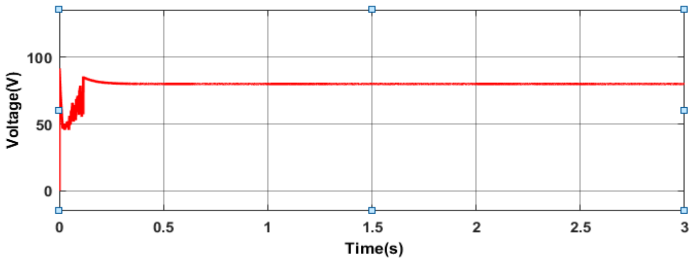

Figure 7(b): Load voltage waveform at 1000W/m2 and 25˚C

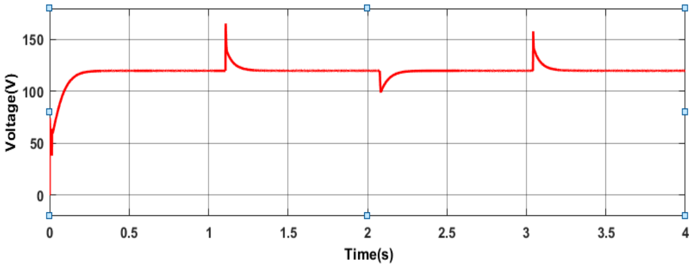

Figure 7(c): Sudden change in output voltage at 1000W/m2 and 25˚C

3.3.2 Type 2: For 850W/m^2 Irradiation and Temperature of 20°C

Table 4 displays the simulation outcomes achieved with 850 W/m^2 irradiation and 20 ˚C temperature for different loads. *Figures 8(a)* exhibits output voltage waveform obtained. The regulated output voltage for change in reference and change in load conditions are represented in *figures 8(b) and 8(c).*

Table 4. Constant irradiation level and temperature (850W/m^2& 20˚C)

Power (W)	Resistive Load (Ω)	Load Current (I_{out})	Load Voltage (V_{out})	Efficiency (%)
100	144	0.8334	120	91
75	192	0.625	120	89
50	288	0.4168	120.1	83

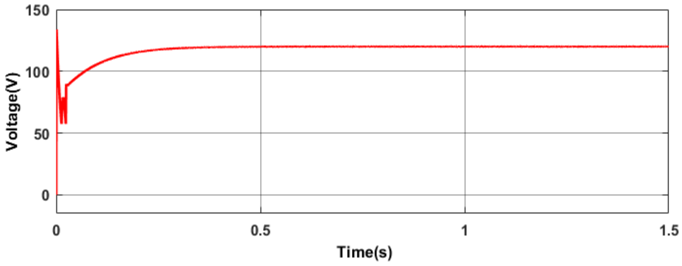

Figure 8(a): Simulation waveform of load voltage at 850W/m^2 and 20˚C

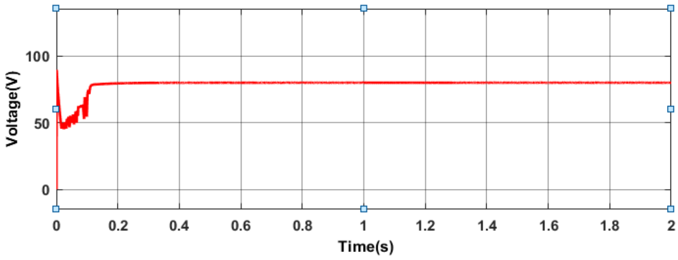

Figure 8(b): Output voltage waveform at 850W/m^2 and 20˚C.

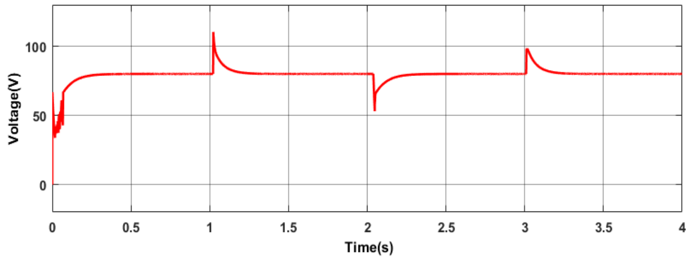

Figure 8(c): Simulation waveform of sudden change in output voltage obtained at 850W/m2 and 20˚C

3.4 Comparative Results of Proposed Converter

The analogies of various converter topologies are displayed in *Table 9* to justify that the suggested converter exhibits the high gain.

Figure 9 portrays the representation of propounded converter's performance with other topologies of the converters. The voltage gain obtained from suggested converter is high compared to other traditional converters.

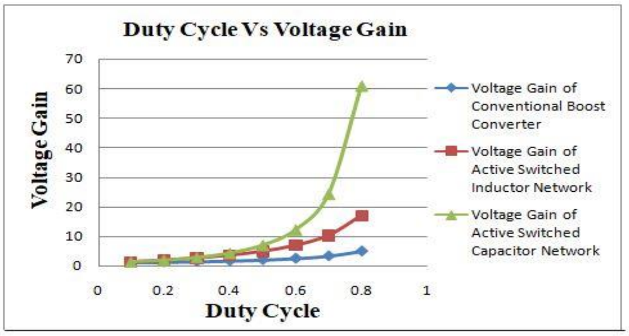

Figure 9: Graphical representation of voltage ratio versus duty ratio of various topologies

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3.5 Hardware Results

The real time implementation of proposed converter of 100 W power rating with 120V rated supply voltage is designed with the derived parameter values as shown in *table 5*. *Figure 10* shows the hardware arrangement of the proposed converter offering high gain. *Figures 11 and 12* portrays the gating signal and output voltage observed with the prototype.

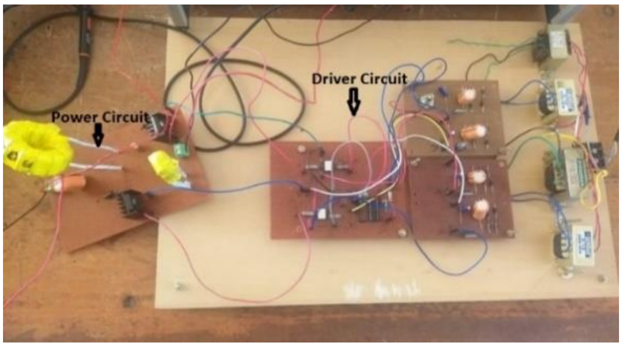

Figure 10: Hardware setup of the proposed converter

Table 5: Hardware specifications for the preferred converter

Parameters	Specifications
Duty cycle	0.65
Input Voltage	20V
Resistance (R)	144Ω
Power	100W
Output Voltage	200V
MOSFETs (S_1, S_2)	IRFP150
Diodes	FF306/3.0A, 800V
Switching Frequency	50kHz

The gate signal generation is done using TL294 IC to drive the MOSFET switches.

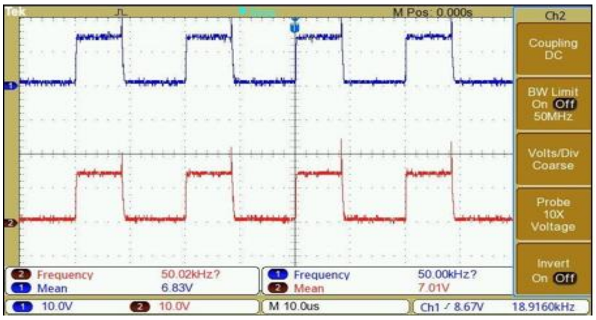

Figure 11: Gate Pulse Generation of the Preferred Converter

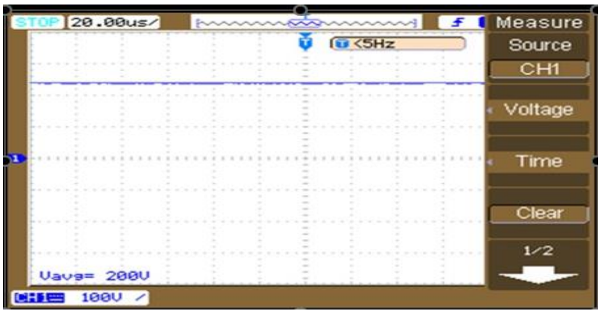

Figure 12: Output Voltage Waveform of the Preferred Converter

4. DISCUSSION

The suggested ASC converter is built and tested in MATLAB and the results are presented in the *Section 4.1 to 4.5*. The open loop simulation results for various duty ratio are presented. The results show that when duty ratio varies there is a corresponding variation in output voltage. The closed loop simulation of the converter with solar MPPT technique is presented. The results verify that the converter maintains a constant voltage at the output under different solar irradiations and temperature. A 100 W, 120 V prototype is developed in the laboratory and its open loop results are presented in *Section 4.6*.

5. CONCLUSION

ASC-based converters with a higher gain are proposed here in order to harness energy from a PV panel. By operating the converter with optimal duty cycle, desired gain value of output voltage is obtained. This converter is compact as it has lesser number of elements. An illustration of the preferred converter's response to constant insolation level and temperature was presented. A Proportional Integral controller keeps a steady output voltage under load modifications. Perturb and Observation MPPT method is employed for acquiring maximum power from the solar PV panel. The efficacy achieved is 80-90% in simulation. With the MATLAB/Simulink platform the findings are substantiated. At rated condition the converter efficiency achieved with the experimental prototype is 85%. The proposed converter is suitable for use with renewable energy and all drive applications. The work can be further extended by implementing the proposed work with intelligent controllers.

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REFERENCES

[1] Muhammad Hafeez, Mohamed Hariri, Mohd Khairunaz Mat Desa , Syafrudin Masri, and Muhammad Ammirrul Atiqi Mohd Zainuri, "Grid-Connected PV Generation System -Components and Challenges: A Review," Energies., vol. 13(17), 4279, pp. 1-28, 2020, doi: org/10.3390/en13174279.

[2] Xiaogang Wu, Mingliang Yang, Meilan Zhou, Yu Zhang, and Jun Fu, "A Novel High-Gain DC-DC Converter Applied in Fuel Cell Vehicles," IEEE Trans. Veh. Technol., vol. 69, no. 11, pp. 12763-12774, 2020, doi: 10.1109/TVT.2020.3023545.

[3] Shima Sadaf, Mahajan Sagar Bhaskar, Mohammad Meraj, Atif Iqbal, and Nasser Al-Emadi, "A Novel Modified Switched Inductor Boost Converter with Reduced Switch Voltage Stress". IEEE Trans. Ind. Electron., vol. 68, no. 2, pp. 1275-1289, 2021, doi: 10.1109/TIE.2020.2970648.

[4] Avneet Kumar, Yi Wang, Xuewei Pan, Raghuram M, Santosh Kumar Singh ,Xiaoguang Xiong, Abhishek K. Tripathi, "Switched-LC Based High Gain Converter with Lower Component Count," IEEE Trans. Ind. Appl., vol. 56, no. 3, pp. 2816-2827, 2020, doi: 10.1109/TIA.2020.2980215.

[5] Javed Ahmad, Mohammad Zaid , Adil Sarwar, Chang-Hua Lin , Mohammed Asim, Raj Kumar Yadav, et al., "A new high-gain DC-DC converter with continuous input current for DC microgrid applications," Energies, vol. 14(2629), pp. 1-14, 2021, doi: 10.3390/en14092629.

[6] Premkumar M, Kumar C, Anbarasan A, Sowmya R, "A novel non-isolated high step-up DC–DC boost converter using single switch for renewable energy systems," Electr. Eng., vol. 102, pp. 811 829, 2020, doi: 10.1007/s00202-019-00904-8.

[7] RathinaPrabha N, Gnanavadivel J, KrishnaVeni KS., "Performance Investigation of Single Switch Dual Output DC-DC SEPIC Converter for PV Applications," Int. J. Adv. Sci. Technol., vol. 29, no. 5, pp. 4676-4683, 2020.

[8] JayanthiK, Senthil Kumar N, Gnanavadivel J, "Energy management of distributed renewable energy sources for residential DC microgrid applications," Int. Trans. Electr. Energy Syst., vol. 30, no. 3, pp. 1-15, 2020, doi: 10.1002/2050-7038.12258.

[9] Gnanavadivel J, Shunmathi M, Muthu Thiruvengadam P, Narthana S., "Analysis of DC-DC Converter with High Step -up Gain for Alternative Energy Sources, " International Journal of Engineering Trends and Technology, vol. 69, no. 4, pp. 62-168, 2021.

[10] Kalarathi M, Jayanthi K. "A Solar PV Fed Switched Capacitor Boost Circuit for DC Microgrid," International Journal of Engineering Trends and Technology, vol. 69, no. 3, pp. 127-132, 2021.

[11] Amirhossein Rajaei, Reza Khazan, Mehrdad Mahmoudian, Mohammad Mardaneh, Mohsen Gitizadeh, "A Dual Inductor High Step-Up DC/DC Converter Based on the Cockcroft-Walton Multiplier, " IEEE Trans. Power Electron., vol. 33, no. 11, pp. 9699-9709, 2018, doi: 10.1109/TPEL.2018.2792004.

[12] Van-Thuan Tran, Minh-Khai Nguyen , Youn-Ok Choi, Geum-Bae Cho, "Switched-Capacitor-Based High Boost DC-DC Converter," Energies, vol. 11(987) pp. 1-15, 2018, doi: 0.3390/en11040987.

[13] Marcos Antonio Salvador, Telles BrunelliLazzarin, Roberto Francisco Coelho. "High Step-Up DC-DC Converter with Active Switched-Inductor and Passive Switched-Capacitor Networks," IEEE Trans. Ind. Electron., vol. 65, no. 7, pp. 5644-5654, 2018, doi: 10.1109/TIE.2017.2782239.

[14] Hongchen Liu and Fei Li. "A Novel High Step-up Converter with a Quasi-active Switched-Inductor Structure for Renewable Energy systems," IEEE Trans. Power Electron., vol. 31, no. 7, pp. 5030-5039, 2016, doi: 10.1109/TPEL.2015.2480115.

[15] Kalarathi M, Jayanthi K. "Dual State DC-DC Converter with PI and Fuzzy PI Controller for LED Drivers," International Journal of Engineering Trends and Technology, vol. 69, no. 3, pp. 180=184, 2021.

[16] Behdad Faridpak, Mohammad Bayat, Mojtaba Nasiri, Rahim Samanbakhsh, Meisam Farrokhifar. "Improved Hybrid Switched Inductor/Switched Capacitor DC–DC Converters," IEEE Trans. Power Electron., vol. 36, no. 3, pp. 3053-3062, 2021, doi: 10.1109/TPEL.2020.3014278.

[17] Shanthi T, Prabha S U, Sundaramoorthy K. "Non-isolated n-stage High Step-up DC-DC Converter for Low voltage DC Source Integration,". IEEE Trans. Energy Convers., vol. 36, no. 3, pp. 1625-1634, 2021, doi: 10.1109/TEC.2021.3050421.

[18] Ramin Rahimi, Saeed Habibi, Pourya Shamsi, Mehdi Ferdowsi. "A Dual-Switch Coupled Inductor-Based High Step- Up DC-DC Converter for Photovoltaic-Based Renewable Energy Applications," In proceedings of IEEE Texas Power and Energy Conference (TPEC), 2021, pp. 1-6, doi: 10.1109/TPEC51183.2021.9384916.

[19] Truong-Duy Duong, Minh-Khai Nguyen, Tan-Tai Tran, Young-Cheol Lim, Joon-Ho Choi. "Transformer less High Step-Up DC-DC Converters with Switched-Capacitor Network," Electronics, vol. 8(1420), pp. 1-19, 2019, doi: 10.3390/electronics8121420.