Journal of Information Systems Engineering and Management
2025, 10(45s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Simulation Analysis and Performance Analysis of the Modern Converters for Solar Photovoltaic power system

Ponshankar S[1*], C Kathirvel Chinnasamy[1] , S Venkatesh Kumar[1]
[1]*Electrical And Electronics Engineering, Dr.N.G. P Institute Of Technology, Coimbatore 641048*
** Corresponding Author*
Email : Ponshankar444@Gmail.Com

ARTICLE INFO

Received: 26 Dec 2024

Revised: 14 Feb 2025

Accepted: 22 Feb 2025

ABSTRACT

Introduction**:** Photovoltaic cell is one of the most energizing green energy sources to generate the electricity by implementing it as solar polar plant. Photovoltaic cells is considered as alternate and sustainable energy source as demand to electricity is increasing periodically and clean resource to generation of electricity is very limited. Especially photovoltaic cell changes the energy market dynamically as their output determined on environmental situations. Hence it becomes necessary to conserve the electricity for reliable and safe operation of the existing power system using power electronics converters with maximum power point tracking functions. Photovoltaic sources are considered as clean energy, it is highly significant to evaluate the suitable grid system to various types of the photovoltaic technologies. Due to changing environmental operating conditions such as temperature, irradiance, effects of partial shading and humidity, stability and generation of Photovoltaic cells will be affected largely. Meanwhile, it adversely affects the stability of the grid systems. In this article, detailed performance and simulation analysis of the various types of grid connected system to multiple types of converter to photovoltaic cell towards power generation has been analyzed. Typically Photovoltaic cell generates the DC voltage which is fed into the DC micro grid system as it is modern trend due to loads using DC voltage. Further analysis helps to identify the suitable converter design to photovoltaic cell on basis of significance and challenges of power generation mechanism. Multiple types of converter design are monitored and necessary environmental data was recorded and electricity distributed to various types of grid connected system is also measured. Based on the analysis, the converter topologies to photovoltaic cell such as sepic converter, scott ternary solar multilevel converter, Flyback converter, zeta converter and multiport converter are used to transmit the generated power to various types of micro grid connected system such as off grid system, on grid system, DC connected grid system and hybrid connected grid system under static and dynamic characteristics has analyzed in detail. Power Converter belongs to two main categories such as high step converters as parallel optimizer to PV module level applications and buck boost converter as series optimizer to PV string applications. Among those sepic converter proves to be outperforming on compared with other types of converter system on the simulation using matlab Simulink software.

Keywords: Photovoltaic cell, Converter, Grid Connected system, Energy Generation, Green Energy Technologies

1.INTRODUCTION

Energy is a material base for the survival of human society. Thus energy evolution and revolution has been carried out in parallel with renewable sources as the core. Photovoltaic source is largely adopted green technologies due to energy saving and fast penetration of renewable sources [1]. Photovoltaic source is high reliable and sustainable green energy sources to generate the electricity by implementing it as solar polar plant due to advantages of low cost, high efficiency, low maintenance and high consistency [2]. Due to changing climatic conditions and environmental operating conditions such as temperature, irradiance, effects of partial shading and humidity, stability and generation of Photovoltaic cells will be affected largely. Meanwhile, it adversely affects the stability of the grid connected systems [3].

Journal of Information Systems Engineering and Management
2025, 10(45s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Thus it becomes important to incorporate the power electronics components such as inverter and converter to improve the reliability and stability. Photovoltaic energy generated by power system is fed into microgrid which connects the variety of the different loads. Nowadays, microgrid systems are developing rapidly to mitigate the various challenges of the distributed grid connections on effective utilization of power. Further it provides reduced emission and better power quality with improved power efficiency. Microgrid system utilizes multiple types of power convertors to the power system generators. In Particular, microgrid is classified into categories such as AC distributions, DC distributions and Hybrid distributions. In AC distribution, frequency stability and reactive power issues is eliminated on reducing the cost of the grid system. A DC distribution is high efficient in battery energy storage using reduced power conversation stages [4]. Especially modern home appliances and HVAC system are easily adaptable to DC microgrids

In this paper, detailed performance and simulation analysis of the various types of power converter employed to photovoltaic cell towards power generation. Further analysis helps to identify the suitable converter to photovoltaic cell on basis of significance and challenges of power generation mechanism. Multiple types of Photovoltaic cell using power converter are monitored and necessary environmental data was recorded and electricity distributed to various types of grid connected system[5] is also measured to predict the reliable converter to PV cell for various types of grid connected systems.Based on the analysis, the converter to photovoltaic cell such sepic converter, scott ternary solar multilevel converter and multiport converter are used to transmit the generated power to various types of grid connected system such as off-grid system, on-grid system, DC connected grid system and hybrid connected grid system. Especially sepic converter found to be better performing on the PV cells with respect to the adverse effects of the module on operating and non-operating condition along environment factors [6]. Finally, performance of the scheme is represented on basis of metric such as resultant energy output, system energy outcomes, convertor performance ratio, convertor capacity factor, and converter efficiency

The remaining part of the article is summarized into following parts, section 2 describe the related works of the converter based PV system on energy distribution to Grid connected system modules. Section 3 presents the performance analysis of converter design to various types of photovoltaic cells. Section 4 discusses simulation results of the various converter based PV cell to grid connected system on basis of various performance measures. Finally Section 5 summarizes the article with major findings.

2.RELATED WORKS

In this part, various literatures on the analysis of converter to PV cell which is grid connected system has been analyzed on basis of load demand and energy generation as alternate energy source to meet the power demand is been represented in detail as follows.

2.1. Problem statement

Primary concerns in the photovoltaic system are as follows

- Reduced Power generation due to variation in operating situations such as temperature and irradiance
- The analytics cost on incorporating the maximum power point tracking approaches
- Computation cost towards increasing the PV array output during sudden variation in weather conditions

2.2. Objective of the modern Converters

- It is to obtain the maximum power from the modern convectors connected PV power system and to control the reactive power exchange through converter model
- It is to improve the current injected to the grid through dynamic converter model

2.3. Performance evaluation of converter to solar photovoltaic systems under changes of temperature and climatic conditions

In this literature, Performance evaluation of converter interfaced with solar photovoltaic systems under changes of the temperature and climatic conditions is carried out through performance metric such resultant energy output, system energy outcomes, convertor performance ratio, convertor capacity factor, and converter efficiency [6].

Journal of Information Systems Engineering and Management
2025, 10(45s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Converters extract maximum power from the PV power systems on regulating its output voltage. Converter topologies for PV integration to the Microgrid is based on its regularization range, cost, functions such as buck converters, boost converters and buck–boost converters and amount of conversion of the power converter as full power and partial power convertors. The outcomes represent that grid-connected PV power system produces better performance based on its location, topology and PV module types with respect to climate conditions such as temperature and solar radiation [7].

3.PROPOSED MODEL

In this section, design of different converter design to photovoltaic cells and different grid distribution system is analyzed on various factors is as follows

3.1. Design Analysis of various converter technologies

Design of converter photovoltaic technologies is analyzed on its voltage and current characteristics to various operating condition is as follows

3.1.1. Scott Ternary Solar multilevel converter

Scott Ternary Solar Multilevel Converter is applied to medium voltage applications. This voltage source converter are combined to form a two-phase model and it is considered as multi winding transformers which is interfaced in a Scott structure to design a multi -level three-phase power managing PV system. It produces higher power generation to the transformer turn ratios as it produces ternary progression. The designing of the power system is mentioned, and a closed-loop power control strategy is included to produce reduced voltage losses [8].

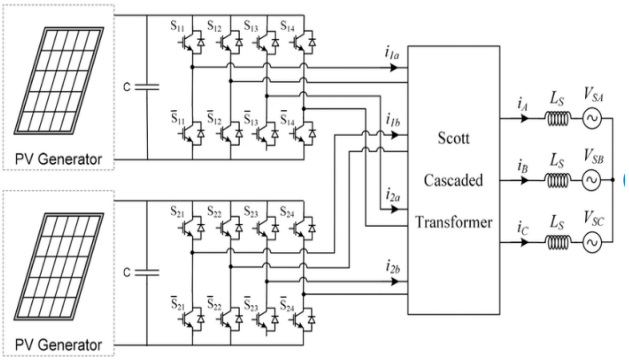

Figure 1: Circuit Diagram of the Multilevel Scott Ternary Solar Power Converter for Solar photovoltaic system

Figure 1 represents the Circuit Diagram of the Multilevel Scott Ternary Solar DC-DC Converter for solar photovoltaic system.

3.1.2. Multiport Convertors for Solar Photovoltaic system

Multiport converter is employed to photovoltaic system as optimal measure to enhance the power density. Particular power systems produces high efficient, more reliable, and high-quality energy conversion operations as evaluated against single-sourced systems. Multiport DC-DC Converters are required for to equalize the load and grid demand, for obtaining MPPT control along improving the steady-state and dynamic characteristics of the generated power [8].

Further it includes a reduced number of conversion stage and system components as storage components and switching components are pooled for each transition epoch.

Journal of Information Systems Engineering and Management
2025, 10(45s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

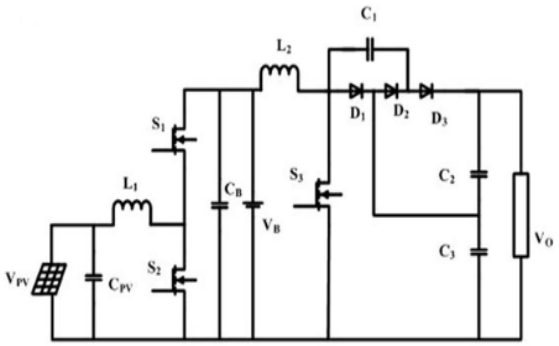

Figure 2: Circuit diagram of the Multiport Converters to the solar photovoltaic systems

Figure 2 represents the multiport converter design for the solar photovoltaic power system which is fed into DC microgrid

3.1.3. Modified Sepic Converter

A modified SEPIC converter is employed for PV power generation system in the continuous conduction mode due to its advantages like enhanced step-up ratio and enhanced power efficiency. Further low voltage control strategy is applied to the output voltage and output current levels in the PV system[9]. Figure 3 represents the modified sepic converter.

The Power converter has two modes of operation:

Mode 1: When S = 0, the convertor switch turns off and the circuit is configured as a boost converter. Further input voltage is fed to the output voltage through the circuits of inductors and capacitors.

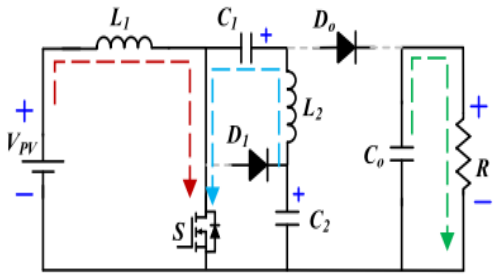

Figure 3: Modified Sepic Converter

Mode 2: When S = 1, the convertor switch is turned on and its circuit is reconfigured as a buck converter. The output voltage is fed to the input voltage through the circuits of inductors and capacitors. The converter circuit can be operated in hybrid mode to attain the specified output voltage. The selection of mode varies according to the load.

3.1.4. Active Clamp Fly back converter

Active clamp flyback converter is used to eliminate non linearity and temperature drift of the controller in the feedback circuit of the photovoltaic circuit. Controller employs the soft switching technique for discontinuous modulation. Further it realizes zero voltage switching in different load conditions to different operation modes[10]. Figure 4 represents the active clamp flyback converter for PV power system .

Journal of Information Systems Engineering and Management
2025, 10(45s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

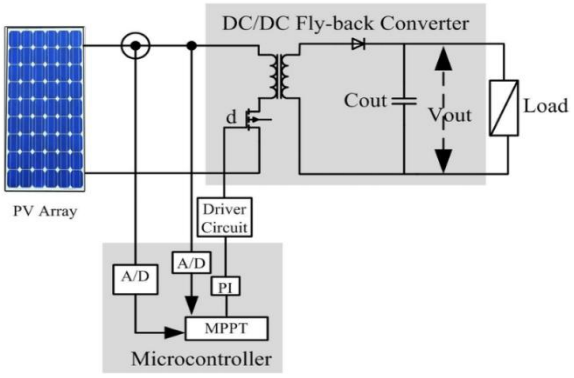

Figure 4: Circuit diagram of the flyback Converters to the solar photovoltaic systems

Converter operates in the continuous current mode of the inductor. Transfer function is obtained through average model to handle the changes in voltage conditions.

3.1.5. Zeta Converter

Zeta Converter is used for high voltage conversion with small duty cycle to ensure most efficient conversion under static and dynamic characteristics[12]. Zeta converter produces low input and output current ripples. Frequency characteristics of the converter is represented in equation is as follows

$W_d(s) = \frac{V_{in}}{L}$

Where L is smoothing filter

Further it results in reduced core losses while tracking the maximum power point on the various modes.

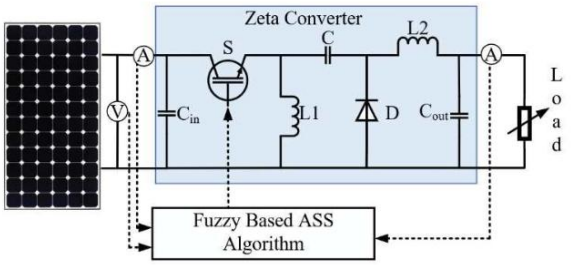

Figure 5: Circuit diagram of the Zeta Converters to the solar photovoltaic systems

Table 1 presents the comparison of different modern converters to the photovoltaic system on basis of the variables such as input current, power level, peak efficiency, input voltage range, output voltage, losses and cost.

Table 1: Performance Analysis of different modern converter to the photovoltaic systems

Topology	Power Level	Peak Efficiency	Input Voltage range	Output Voltage	Losses	Cost
Scott Ternary	2.5kW	91%	220-430 V	320 V	Medium	Medium
Multiport	2kW	92.4%	229-440 V	360 V	Medium	Medium
Modified Sepic	3kW	93%	200-500 V	365 V	Medium	Medium
Fly back	3.5kW	97.5%	100-500 V	375 V	Low	Medium
Zeta	3.6kW	98.5%	100-500 V	380 V	low	Medium

Journal of Information Systems Engineering and Management
2025, 10(45s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

4.SIMULATION ANALYSIS

In this section, performance analysis of the converter design to photovoltaic generation system to grid connected system is simulated using MATLAB Simulink [13]. It is to identify the suitable scheme which consumes less energy and produces maximum output is predicted on basis of the energy usage data and various specification and characteristics of the technology. Matlab is data analysis software of the grid connected PV system [14]

4.1. Analysis of the Multilevel Scott-ternary solar DC-DC converter

Efficiency of the photovoltaic base power generation system under steady-state and dynamic irradiance on employment of Scott-ternary solar multilevel converter is analyzed on converter voltage and grid current is represented in the figure 6.

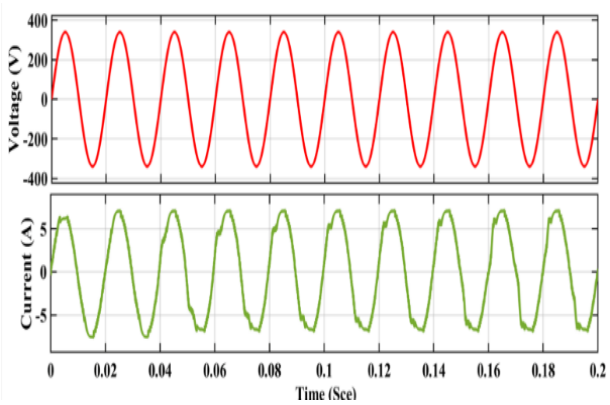

Figure 4: Voltage and Current Characteristics of the Multilevel Scott Ternary Solar based power converter to solar photovoltaic system

4.3. Analysis of the Multiport Converter

Efficiency of the Photo Voltaic system under multiple conditions under steady-state and dynamic characteristics through employment of Scott-ternary solar multilevel converter is analyzed with respect to output voltage and output current is represented in the figure 7.

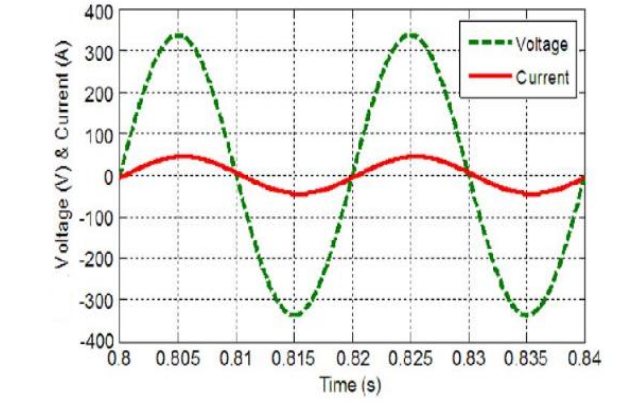

Figure 7: Voltage and Current Characteristics of Multi Port converter to solar photovoltaic system

4.3. Analysis of Sepic Converter

Efficiency of the photovoltaic based power generation system under various condition such as steady-state and dynamic irradiance on employment of Sepic - converter is analyzed on output voltage and output current is represented in the figure 8

Journal of Information Systems Engineering and Management
2025, 10(45s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

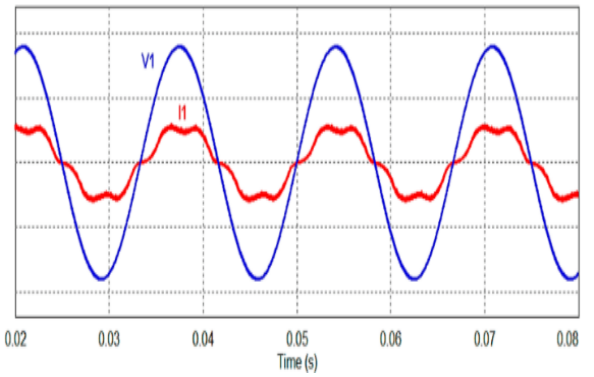

Figure 8: Voltage and Current Characteristics of the Modified Sepic converter to solar photovoltaic system

4.4. Analysis of the Flyback Converter

Efficiency of the solar PV system under steady-state and dynamic irradiance on employment of flyback converter is analyzed on converter voltage and grid current is represented in the figure 9. It generates the high efficiency on minimizing the ripple voltages [15].

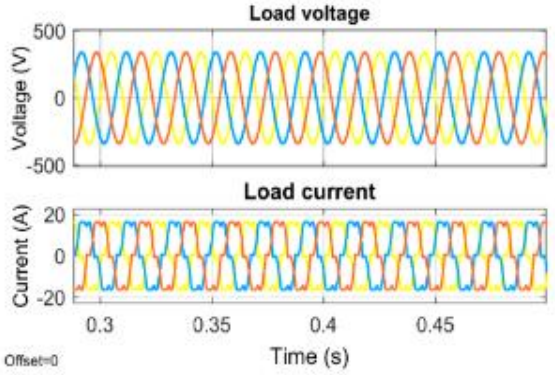

Figure 9: Voltage and Current Characteristics of the flyback converter to solar photovoltaic system

4.5. Analysis of the Zeta Converter

Efficiency of the solar PV system under multiple conditions such as steady-state and dynamic characteristics on employment of Zeta converter is analyzed on output voltage and output current is represented in the figure 10. Converter improves the power factor and response time.

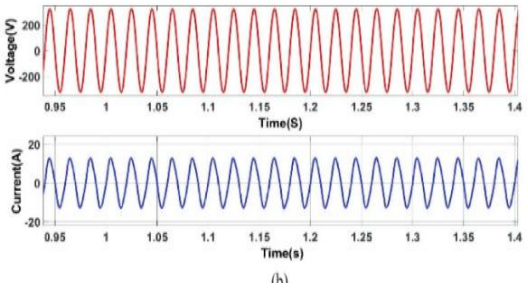

Figure 10: Voltage and Current Characteristics of the Zeta converter to solar photovoltaic system

4.CONCLUSION

In this paper, detailed performance and simulation analysis of the various types of modern converter design to photovoltaic cell towards power generation and power distribution to dynamic load conditions through utility grid

and battery storage is analyzed.. Based on the analysis, converter design of PV modules to grid connected system such as off grid system, on grid system, DC connected grid system and hybrid connected grid system has been evaluated on basis performance ratio and energy balance. Finally sepic converter design proves to be outperforming on compared with other types of converter design of PV modules connected to grid system on the simulation using Matlab Simulink software.

REFRENCES

[1] R. Wang, S. Yuan, C. Liu, D. Guo, and X. Shao, "A three-phase dual-output T-type three-level converter," IEEE Trans. Power Electron., vol. 38, no. 2,pp. 1844–1859, Feb. 2023
[2] Rengasamy, Mageswaran; Gangatharan, Sivasankar; Madurai Elavarasan, Rajvikram; Mihet-Popa, Lucian (2020). The Motivation for Incorporation of Microgrid Technology in Rooftop Solar Photovoltaic Deployment to Enhance Energy Economics. Sustainability, 12(24), 10365.
[3] S. Geraee, H. Mohammadbagherpoor, M. Shafiei, M. Valizadeh, F. Montazeri, and M. Feyzi, "Regenerative braking of electric vehicle using a modified direct torque control and adaptive control theory," Computers Electrical Engineering ., vol. 69, pp. 85–97, 2018.
[4] A. Riccobono and et al., "Stability of shipboard DC power distribution:Online impedance-based systems methods," IEEE Electrification Mag.,vol. 5, no. 3, pp. 55– 67, Sep. 2017.
[5] M. Mobarrez, S. Bhattacharya, and D. Fregosi, "Implementation of distributed power balancing strategy with a layer of supervision in a low-voltage dc microgrid," Applied Power Electronics Conference and Exposition (APEC), pp. 1248–1254, Mar. 2017.
[6] G. Zhang, Z. Wu, S. S. Yu, H. Trinh, and Y. Zhang, "Four novel embedded Z-source DC–DC converters," IEEE Trans. Power Electron., vol. 37, no. 1, pp. 607–616, Jan. 2022..
[7] Q. Huang, F. Wang, and J. A. Bolaghi, "Improved switched-capacitor switched-inductor Z-source inverter for increasing boost factor and decreasing voltage capacitors stress," IETE J. Res., vol. 69, no. 6, pp. 3887–3896, May 2021..
[8] C. W. Hansen et al., "Analysis of irradiance models for bifacial PV modules," 2016 IEEE 43rd Photovoltaic Specialists Conference (PVSC), Portland, OR, 2016, pp. 0138- 0143.
[9] A. Riccobono and et al., "Stability of shipboard DC power distribution: Online impedance-based systems methods," IEEE Electrification Mag., vol. 5, no. 3, pp. 55– 67, Sep. 2017.
[10] M. Mobarrez, S. Bhattacharya, and D. Fregosi, "Implementation of distributed power balancing strategy with a layer of supervision in a low-voltage dc microgrid," Applied Power Electronics Conference and Exposition (APEC), pp. 1248–1254, Mar. 2017.
[11] N. Patankar, H. Eshraghi, and J. Decarolis, "Effects of high renewable penetration on us energy system," in International Association for Energy Economics, Oct. 2018.
[12] H. Li, J. Lin, Y. Lin, and T. Jin, "A high step-up hybrid Y-source-quasi-Z source DC–DC converter for renewable energy applications," IEEE Trans. Ind. Electron., vol. 71, no. 9, pp. 10681–10692, Sep. 2024
[13] Manoj Kumar Nallapaneni, Impact of Clean Development Mechanism on Eco- friendly Energy Recovery Technology, In Procedia Technology, Volume 21, 2015, Pages 54-58,
[14] C. Zhao, C. Zhang, and Q. Jiang, "An H-bridge time-sharing multiplexing- based power electronic transformer," IEEE J. Emerg. Sel. Topics Power Electron., vol. 11, no. 5, pp. 4831–4840, Oct. 2023.
[15] V. Jayan and A. M. Y. M. Ghias, "Computationally-efficient model pre- dictive control of dual-output multilevel converter in hybrid microgrid," IEEE Trans. Power Electron., vol. 38, no. 5, pp. 5898–5910, May 2023..