Effective Design and Implementation of Three Port Hybrid Converter for Hybrid Power Sources

K. Soumiyaa¹, D. Aruna²
¹Assistant Professor, Department of EEE, IFET College of Engineering, Villupuram
²UG Scholar, Department of EEE, IFET College of Engineering, Villupuram
soumiyaakannadhasan@gmail.com, arunadevan1998@gmail.com,

Abstract: With the improvement in the power electronics innovations, a bigger amount of PV panels are integrated as power energy sources into distributed power generations systems leads to the betterment of hybrid renewable energy systems. Enhancement in a renewable hybrid generation system is required because it is the future origin of power where we are expected to produce a lot of yield voltage. It tends to be finished by utilizing the plan of the converter design. In recent days, the developing method on hybrid power generation systems makes it more beneficiaries on the power systems domain. So, an integrated three port converter with combinations of PV cell/ fuel cell/ battery systems is proposed here. We need to effectively increase the generation to meet up with the power demand by boosting output power. To build the effective yield power by a blend of photovoltaic (PV)/Fuel cell energy unit with the assistance of the structure strategies of the three-port converter dependent on five switches connect DC-DC support converter. Along these lines, we could accomplish a superior productivity is verified with MATLAB/SIMULINK simulation results and scale down the model is developed.

Keywords
Hybrid power generation systems, converter design and a blend of photovoltaic (PV)/Fuel cell, DC-DC boost converter, five switches

1. Introduction
These days power is an essential requirement throughout everyday life, such the increase in demand leads to researches on generations of power. The hybrid renewable energy generation is the booming trends on the power system in order to provide the proper, boosted voltage of the energy generated [1]. The hybrid renewable energy typically consists of two or more renewable energy sources used together to produce increased system efficiency additionally as an energy supply to produces more generated power. Example Models for the hybrid sustainable power source framework are blending of the photovoltaic and battery [1], photovoltaic with super capacitor [3] and so on. Right now, the proposed framework has a mix of the photovoltaic cell and a fuel cell as a power device to expand the design of more effective converter configuration to create an enormous boost of DC voltage [4].

As we all know that solar energy is the major key solution for renewable energy sources. We need to integrate numerous PV cell to generate a huge power by using a converter (i.e. boost converter) [2]. Along with the PV cell in this proposed system we use the fuel cell technology for the continuous constant output design to
the DC microgrids. A PV/fuel cell hybrid system acting as a source which includes an MPPT controller to find and use the maximum energy output voltage from each PV array. Energy storage systems using the fuel cell is the major recent technologies to overcome the need for electricity at times of the demand. Power generation techniques from the sources are sun based, wind-based, small hydro and daily load cycles [2]. The storage of energy uses nickel-metal hydride, lead-acid battery, and a super capacitor [5].

2. Proposed systems

This project proposal focuses on boosting of voltage using DC/DC power converter to increase the output power of the solar panel [9]. Since the solar panel power generated is always less in magnitude and they must be increased to have a large amount of power generation[7]. This converter utilizes five MOSFET switches connect the controller to control the energy production to produce a continuous output voltage.

The integration of the PV/fuel cell with the simple modified three-port converters to increase the power density[5]. Such the design of the converter involves the maximum increase in the reliability and dynamic response of the output of the converter [8]. Various five-switch bridges involve the different four modes of operations that include the integrated half-bridge, half-bridge, hybrid bridge and full bridge modes.

Fig.1a: Block Diagram of Hybrid Systems

Case 1: Converter Design for Voltage Boosting With PV and Fuel Cell

Fig.1a shows that the block diagram of hybrid systems converter design for voltage boosts with PV and FUEL CELL with the proposed system methodologies using MPPT technique and high working efficient converter design topologies being involved in order to increase the input voltage and make it sufficient for loads to compensate high demands in the near future. Similarly Fig.1b shows that the block diagram of hybrid systems converter design for voltage boosts with PV and battery with the proposed system methodologies using MPPT technique and high working efficient converter design topologies being involved using a battery backup with more numbers of inputs from renewable energy sources.
The main contribution of the work is as follows:

- The Hybrid energy system is combinations of the fuel cell and a series of a photovoltaic cell to produce a constant output out of the converter.
- The Design of the DC-DC boost converter with a minimum number of switches and different modes of operations using bridge controls.
- By improvising the DC output leads to increase the efficiency of power outcome and to improve the power density.
- It can apply to both the AC and DC loads. The output voltage is connected to the DC microgrid where DC loads can be supplied and for AC loads, we need a separate DC-AC inverter.

3. Working of the proposed converter systems
The sum of generated power from a PV cell is equal to the sum of the loads, no storage or charging does not take place in the fuel cell. But when the demand exceeds the generating power in the PV cells then fuel cell supply the energy stored to the grid or load that’s the process of the discharging the fuel cell [8]. Similarly, when the voltage generated from the PV panel is high and the load demand is less than the fuel cell is controlled to do the charging of ions i.e. the reverse electrolysis to get back hydrogen for the storage [3]. The Fig.2 shows the circuit diagram of the proposed system that cleanly explains about the working of the converter with the help of the table shown below i.e. Table.1 by means the entire working is done by comparison of voltage of the PV panel and the load voltage. When the output voltage and the demand voltage decides the fuel cell or battery working conditions and time periods for the efficient working using MPPT algorithms.
3.1 Sunlight based cell (Solar cell)
A sunlight based cell is an electronic gadget that converts the energy of sunshine directly into electricity by the photovoltaic effect which changes over light radiation into power [6]. Light vitality that falls on the sunlight based cell produces both current and voltage. This procedure requires light which raises an electron to a higher vitality state, and afterward development of the electron from the sun oriented cell into an outer circuit [2].

### Table 1. Operations of Systems

| Voltage Conditions | Working |
|--------------------|---------|
| $V_{PV} < V_L$     | Fuel cell is discharging to load, PV cell generates less voltage |
| $V_{PV} = V_L$     | Fuel cell does not operates, PV cell generation = power demand |
| $V_{PV} > V_L$     | Fuel cell is charging from PV cell generations, PV cell generates more voltage |

![Circuit Diagram](image)
Fig.3: Solar cell

The electron at that spot scatters its energy in the outer circuit and move towards the sun powered cell. All photovoltaic cell make use of semiconductor materials as a PN intersection diode [5].

3.2 Fuel cell
The fuel cell is a production of electrical energy from the chemical reaction, i.e. oxidation and reduction process with the hydrogen as its sources [6]. The fuel cell technology is major sources in the electrical vehicles [4].

3.3 Battery
A battery is a device consisting of electrochemical cells with external connections [1] for powering electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode [2]. It is also a storage device.

3.4 PIC Micro Controller
PIC Micro Controller is used to produce pulses employed PWM technique for production of MOSFETS devices to activate and organize. PWM technique is used for dropping the harmonic in the circuit. This project proposal uses PIC16F877a Microcontroller

3.5 MPPT algorithm
Maximum power point tracking (MPPT) is a calculation executed in PV inverters to continually modify the sunlight based PV system operating at the peak power point of the PV board under fluctuating conditions, such irradiance, temperature and load [9]. This MPPT uses Perturbation and observation (P&O) calculation is to find the working voltage to guarantee most extreme power.

4. Calculation for the PV cell
\[
\text{Power} = V \times I
\]
\[
\text{Fill factor (FF)} = \frac{(V_{mp} \times I_{mp})}{(V \times I)}
\]
\[
\text{P}_{\text{max}} = V_{oc} \times I_{sc} \times \text{FF}
\]
\[
\eta = \frac{\text{P}_{\text{max}}}{\text{Pin}}
\]

5. Simulations and results
Fig. 4a: MATLAB circuit of THREE PORT Converter with fuel cell

Fig. 4b: MATLAB circuit of THREE PORT Converter with battery
Fig. 5a: Gate Signal To The Converters

Fig. 5b: Gate Signal To The Converters

Fig. 6: Voltage at the Solar Panel

Fig. 7: Current At The Solar Panel
Fig. 8: Current In Battery

Fig. 9: Output Voltage of PV without Converter Boosting

Fig. 10: Output Voltage after Converter Boosting With Battery

Fig. 11: Output voltage after converter boosting with fuel cell
6. Simulations results
The input voltage is raised from the 8V to approximately 100V as the output voltage using this type boost the voltage 12 times. The simulations detail explains about the various values of the solar related systems. The gate signals, input and output voltages of solar and fuel cell are shown.

7. Hardware

![Hardware Image](image_url)

Fig.12: Hardware

7.1 Solar panel
Maximum power: 3W
Maximum power voltage: 8.97V
Maximum power current: 0.34A
Open circuit voltage: 11.12V
Short circuit current: 0.37A

The fig.12 describes the hardware of the three port converter design for the combinations of PV cell and battery setup consists of two inputs ports one for the PV cell and other port for battery, one output port for load connections. This hardware proves the proposed system is successful done its boosting of voltage level to increase the high power density. In case 1: The input voltage is raised from the 8.75V to approximately 400V as output voltage using this boosting of the voltage 45 times more by using fuel cell. In case 2: The input voltage is raised from the 8.75V to approximately 100V as the output voltage by boosting the voltage 12 times using battery. The effective increase in the generation of power to meet up with the power demand by boosting output power is done by the proposed system.

8. Applications
- Islanded framework (remote zones)
- Hybrid vehicle (fuel less)
- Industrial force saver
- Distributed force age

9. Points of interest
- Green, condition inviting
- Efficiency improvement
- Higher yield power
- Economical advantages
Maximum peak efficiency over the full charging range.

The Fuel cell is broadly used in plug-in electric vehicles (PEVs) as the chief energy storage division and Ultra wide voltage range operation.

10. Conclusion
The Renewable hybrid generation system has brought the effective output power by a combination of photovoltaic (PV)/Fuel cell energy system with the support of the configuration of the three-port converter dependent on five switches connect DC-DC boost converter. The proposed converter could operate in four different modes with scaled voltage gain. The proposed systems produce a high amount of yield voltage by utilizing the strategies of the converter design. The proposed converter is also suitable for other wide input/output voltage range applications. These are proved with the simulation results in MATLAB software.

11. Future Scope
In this project work a new and fast response boost converter topologies to generate high voltage gain from photovoltaic system integrate with battery and fuel cell have been proposed.

- Coordinated hybrid converter (DC-DC-AC) can be developed & tested.
- Hybrid Maximum Power Point Tracking methods can be used to track the optimum point during varying environmental conditions.
- Coordinate controller may be developed to operate the overall PV integrated grid system.

12. References
[1] Cheng Li, Student Member, IEEE, Haoyu Wang, Member, IEEE, and Ming Shang “A Five-Switch Bridge Based Reconfigurable LLC Converter for Deeply-Depleted PEV Charging Applications” IEEE Trans. Power Electron, 2018
[2] A Five-Switch with Low Output Voltage boosts THD for Photovoltaic Applications 2018.
[3] F. Blaabjerg, Z. Chen, and S. B. Kjaer, “Power electronics as efficient interface in dispersed power generation systems,” IEEE Trans. Power Electron., vol. 19, no. 5, pp. 1184–1194, Sep. 2004.
[4] J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz, E. Galvan, R. Potillo, M. Prats, J. I. Leon, and N. Moreno-Alfonso, “Power-electronic systems for the grid integration of renewable energysources: A survey,” IEEE Trans. Ind. Electron., vol. 53, no. 4, pp. 1002–1016, Jun. 2006.
[5] BP Statistical Review of World Energy, British Petroleum, London, U.K., Jun. 2018.
[6] J. P. Barton and D. G. Infeld, “Energy storage and its use with intermittent renewable energy,” IEEE Trans. Energy Convers., vol. 19, no. 2, pp. 441–448, Jun. 2017.
[7] M. S. Whittingham, “History, evolution, and future status of energystorage,” Proc. IEEE, vol. 100, pp. 1518–1534, May 2012.
[8] AC/DC microgrid using hybrid energy storage,” IEEE Trans. Ind. Appl., vol. 54, no. 1, pp. 526–538, Jan./Feb. 2018.
[9] I. Atawi and A. Kassem, “Optimal control based on maximum power point tracking (MPPT) of an autonomous hybrid photovoltaic/storage system in micro grid applications,” Energies, vol. 10, no. 5, p. 643, May 2015.
[10] Y. P. Siwakoti, “A new six-switch five-level boost-active neutral point clamped (5L-Boost-ANPC) inverter,” 2018 IEEE Applied Power Electronics Conference and Exposition (APEC), San Antonio, TX, 2018, pp. 2424–2430
[11] S. H. Choung and A. Kwasinski, “Multiple-input DC-DC converter topologies comparison,” in
Proc. 34th Annu. Conf. IEEE Ind. Electron., 2008, pp. 2359–2364

[12] L. Solero, A. Lidozzi, and J. A. Pomilio, “Design of multiple-input power converter for hybrid vehicles,” in Proc. IEEE Appl. Power Electron. Conf., 2014, pp. 1145–1151

[13] L. Chen and S. Mei, “An integrated control and protection system for photovoltaic microgrids,” CSEE J. Power Energy Syst., vol. 1, no. 1, pp. 36–42, Mar. 2015.

[14] Y. Xu, W. Zhang, G. Hug, S. Kar, and Z. Li, “Cooperative control of distributed energy storage systems in a microgrid,” IEEE Trans. Smart Grid, vol. 6, no. 1, pp. 238–248, Jan. 2015.

[15] N. L. Díaz, A. C. Luna, J. C. Vasquez, and J. M. Guerrero, “Centralized control architecture for coordination of distributed renewable generation and energy storage in islanded AC microgrids,” IEEE Trans. Power Electron., vol. 32, no. 7, pp. 5202–5213, Jul. 2017.