# Performance Evaluation of Modified SEPIC converter for Renewable Applications

Ch.Venkata Krishna Reddy[1], T.R.Vijaya Lakshmi[2*], P. Venkata Prasad[3] and M.Thirupathaiah[4]
[1, 3,4] Chaitanya Bharathi Institute of Technology
[2*] Mahatma Gandhi Institute of Technology

***Abstract:*** In most of the power electronics applications, DC to DC converts have their importance in providing better regulated output for renewable application. The converters like boost and classical SEPIC converters provide limited voltage gain. The new DC to DC converter is Modified SEPIC converter and is designed and developed in MATLAB/SIMULINK to have better regulated voltage and their performance was estimated in terms of output voltage, output current, gain and efficiency.

*Keywords:* **Converter, Modified SEPIC converter, Efficiency, Gain etc.**

## 1. INTRODUCTION

We know that the non-renewable energy resources are the new trend in generating electricity. Out of these, solar energy is the most popular and efficient method of electricity generation. For this, special devices called solar cells are installed. The semiconductor material emits electrons when light energy is incident on a solar panel. However, this method has its own disadvantages. Sunlight is Earth's primary source of energy. Solar PV is a semiconductor device which converts sunlight directly into electricity. The electricity generated by a PV module is of the DC (direct current) type. The amount of electricity produced by a PV module is proportional to its size; the larger the module, the more electricity it produces and the higher the cost of electricity. To overcome this problem, power converters which steps up the input electrical energy to the desired level are developed. To step up the energy generated from a PV module, we generally use a DC to DC converter like Boost, Buck-Boost, SEPIC converter and Modified SEPIC converter [1,2].

But Classical converters (Boost and Buck-Boost) gives limited voltage gain of about G=5 with duty ratio of 0.8 and normally can operate with an adequate static and dynamic performance. SEPIC converter also generates limited gain same as boost converter, also has high input ripple current. To overcome these drawbacks, some modifications have been done to the SEPIC converter. Modified SEPIC converter has less passive components, high static gain, high efficiency, low input ripple current, soft switching and good dynamic response. Modified SEPIC converter has two topologies: Without Coupling and With Coupling [3,4].

This paper aims to build a converter which steps up the energy generated by a low power DC source. The main objective is to build modified SEPIC converter to improve the converter static gain, enable soft switching, and obtain better efficiency. The analysis was carried out in MATLAB/SIMULINK environment.

## 2. MODIFIED SEPIC CONVERTER

### 2.1 Modified SEPIC converter

The Classical SEPIC converter has been modified to achieve high static gain, low switch voltage, low input current ripple, reduced weight and volume, and high performance. This modified SEPIC converter has two topologies:

- Modified SEPIC converter without coupling
- Modified SEPIC converter with coupling

#### 2.1.1 Modified SEPIC converter without coupling

The static gain of the Modified SEPIC converter without coupling is nearly twice that of the classical Boost converter, and the switch voltage is half that of the classical Boost converter. With this alteration, many operational characteristics of the Classical SEPIC converter are altered, such as the elevation of converter static gain. The capacitor $C_M$ is charged with the current in this topology. It's operation can be explained in two stages. Assume all the capacitors to be voltage sources and the semiconductors to be ideal for theoretical analysis [5,6]. The Basic circuit diagram of Modified SEPIC converter, without coupling and with coupling when switch is ON and OFF is shown in Figure 1, Figure 2 and Figure 3.

First stage (switch is turned off): When the switch S is switched off, the energy stored in the inductor $L_1$ is transferred to the load via the capacitor $C_S$ and diode $D_0$, as well as to the capacitor $C_M$ via the diode $D_M$. The capacitor $C_M$ voltage is equal to the switch voltage at this point. The diode $D_0$ is used to transfer energy to the load [7, 8].

Second stage (switch is turned on): When switch 'S' is switched on, the diodes $D_M$ and $D_0$ are blocked, and the energy is stored in the inductors $L_1$ and $L_2$. The inductor $L_1$ receives the input voltage $V_i$, while the inductor $L_2$ receives the voltage $V_{CS} – V_{CM}$. The $V_{CM}$ voltage is higher than the $V_{CS}$ voltage. No energy will be passed to the load because the diodes are blocked [9].

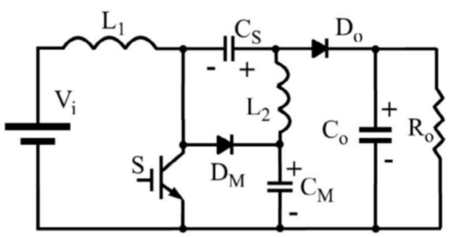


Figure 1. Modified SEPIC converter coupling without coupling

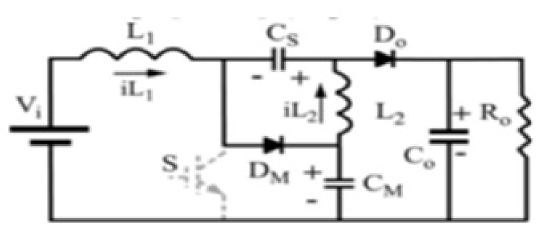


Figure 2. Modified SEPIC without when switch is turned off

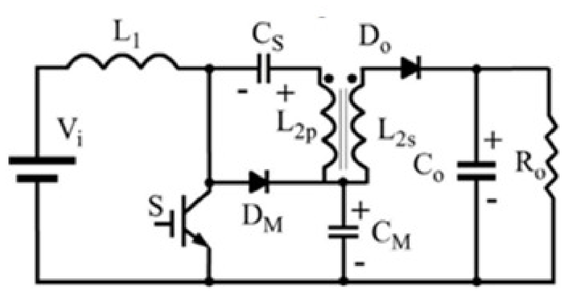

**Figure 3. Modified SEPIC without coupling when switch is turned on**

### 2.1.2. Modified SEPIC converter with coupling

The modified SEPIC converter with coupling gives a static gain close to twice of the modified SEPIC converter without coupling. This topology is accomplished by adding an inductor auxiliary winding that functions as a flyback transformer to a modified SEPIC converter without a coupling circuit in order to increase static gain by increasing the transformer turns ratio (n) while keeping the switch voltage low. Due to the presence of coupling winding $L_2$ leakage inductance, this topology has the issue of overvoltage at the diode $D_0$. Some energy is retained in the leakage inductance due to the diode $D_0$'s reverse recovery current, resulting in a voltage ring and a high reverse voltage across $D_0$. The overvoltage problem cannot be solved with conventional snubbers or dissipative clamping. A voltage multiplier on the secondary side of the fly back transformer is a simple solution to this problem. The voltage across $D_0$ is reduced to a value lower than the output voltage by this voltage multiplier, which increases the static gain. Energy stored in the leakage inductance due to the reverse recovery current of the diode $D_0$ is transferred to the load through this voltage multiplier cell. However, since magnetic coupling is not achieved with the input inductor in this topology, the input current ripple is poor and is unaffected by magnetic coupling. However, this topology also has some disadvantages like Pulsating input current, Increases the converter complexity [10].

The modified SEPIC converter operation with coupling can be explained in FIVE stages. Assuming all the capacitors to be voltage sources and the semiconductors to be ideal for theoretical analysis.

First stage (switch is turned on): At the instant when switch S is turned on, inductor $L_1$ stores the energy and diode $D_0$ is blocked. Capacitor $C_{S2}$ is charged by the secondary winding $L_{2s}$ and diode $D_{M2}$. When the capacitor $C_{S2}$ is completely charged, diode $D_{M2}$ is blocked. Second stage: From the time the diode $D_{M2}$ is blocked to the time the switch S is switched off, the energy is stored in inductors $L_1$, $L_{2s}$, and $L_{2p}$, and the currents increase linearly. Third stage (switch is switched off): Energy stored in the inductor $L_1$ is transferred to the capacitor $C_M$ at the moment the switch S is turned off. Energy is also transferred to the load via $C_{S1}$, $L_{2p}$, $L_{2s}$, $C_{S2}$ and $D_0$. The diode $D_{M1}$ is blocked when the capacitor $C_M$ is fully charged. The energy transference to the load is kept constant until the switch S is switched on. Fifth stage (switch is turned on): When the switch S is triggered, current at the diode $D_0$ decreases linearly, and di/dt is limited by the transformer leakage inductance, reducing diode reverse recovery current problems. When the diode $D_0$ is blocked, the converter returns to the first stage of operation [11].

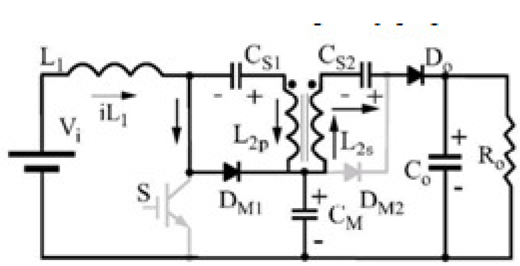


**Figure 4. Modified SEPIC converter with coupling and a voltage multiplier cell**

## 3. SIMULATION RESULTS AND DISCUSSIONS

The modified SEPIC converter without coupling is implemented and simulated in MATLAB/SIMULINK and its related circuits are depicted from Figure 5 to Figure 11. Similarly modified SEPIC converter with coupling also implemented and simulated in MATLAB/SIMULINK and its related circuits are depicted from Figure 12 to Figure 18.

### 3.1 Modified SEPIC converter without coupling

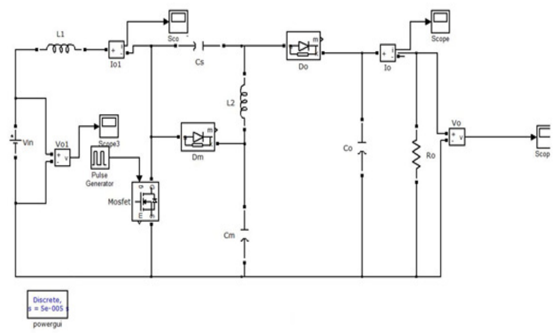


**Figure 5. Modified SEPIC converter without coupling in open loop configuration**

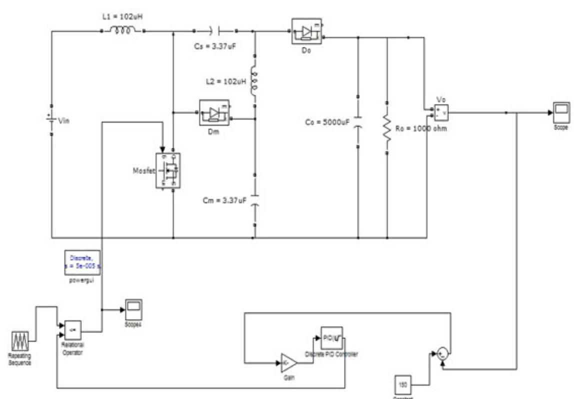


**Figure 6. Modified SEPIC converter without coupling in closed loop configuration**

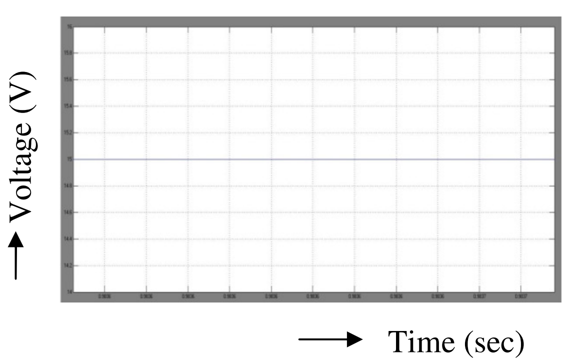


**Figure 7. Input voltage waveform of Modified SEPIC converter without coupling in closed loop configuration**

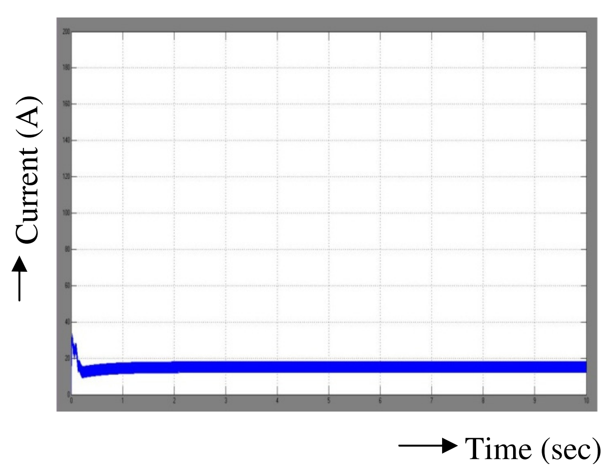


**Figure 9.Input current waveform of Modified SEPIC converter without coupling in closed loop configuration**

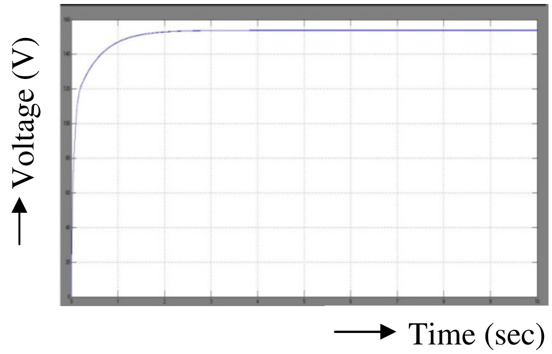


Figure 8. Output voltage waveform of Modified SEPIC converter without coupling in closed loop configuration

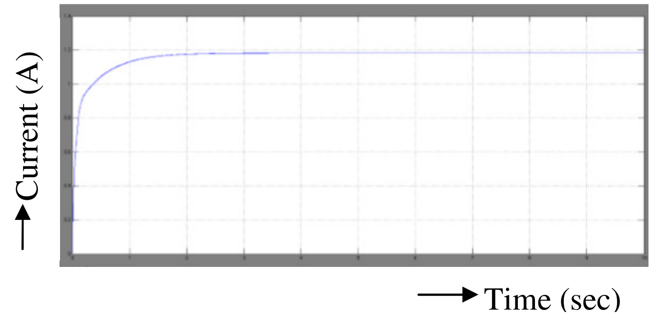


Figure 10.Output current waveform Modified SEPIC converter without coupling in closed loop configuration

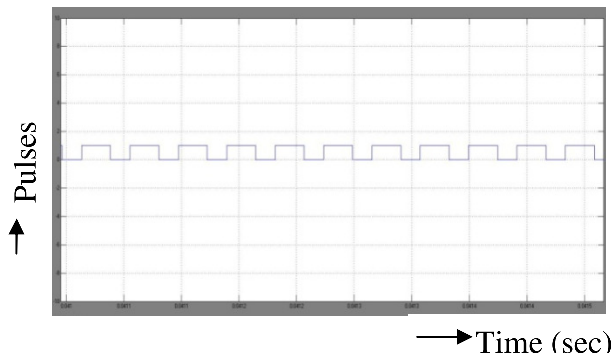


Figure 11.Switching pulses given in configuration Modified SEPIC converter without coupling in closed loop configuration

From the above figures, it is evident that

Input voltage, Vin = 15 V, Output voltage, Vout = 150 V, Input current, Iin = 13 A , Output current, Iout = 1.2 A, Input power, Pin = Vin * Iin = 15*13 = 195W, Output power, Pout = Vout*Iout = 150*1.2 = 180W

Hence, Gain = output voltage/input voltage = 150/15 = 10, Efficiency = output power/input power = 180/195 = 92.3%

### 3.2 Modified SEPIC converter with coupling

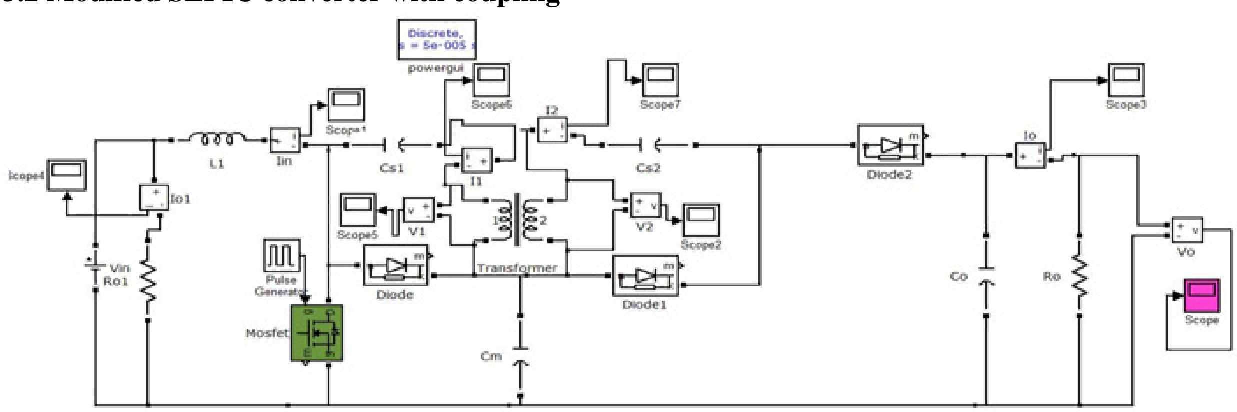


Figure 12. Modified SEPIC converter with coupling in open loop configuration

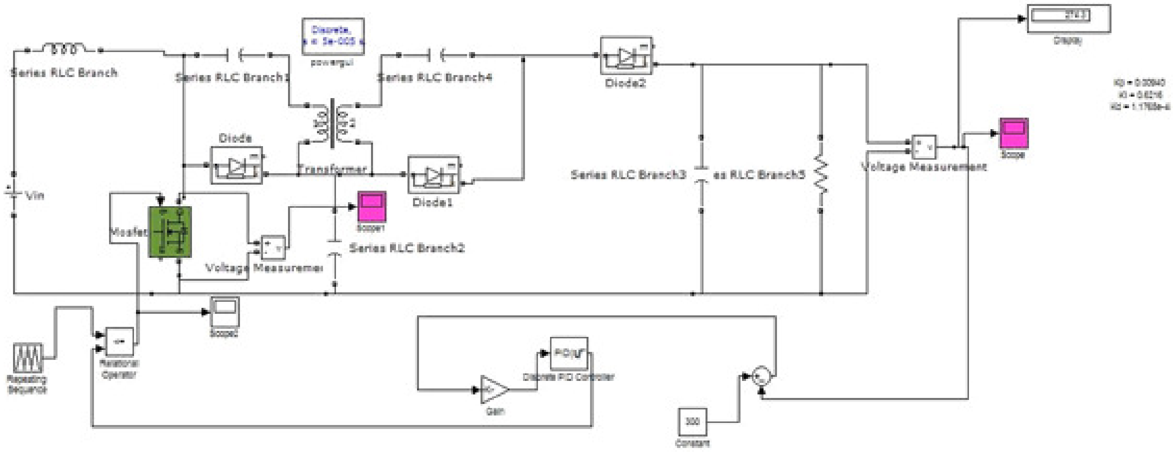


**Figure 13. Modified SEPIC converter with coupling in closed loop configuration**

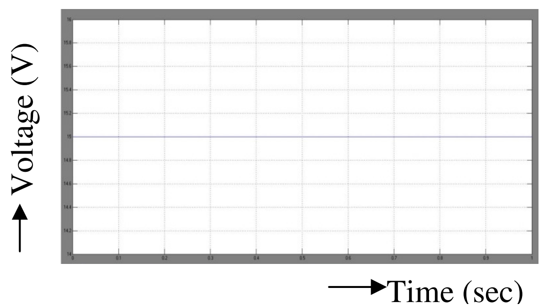


**Figure 14. Input voltage waveform of Modified SEPIC converter with coupling in closed loop configuration**


**Figure 16. Input current waveform of Modified SEPIC converter with coupling in closed loop configuration**

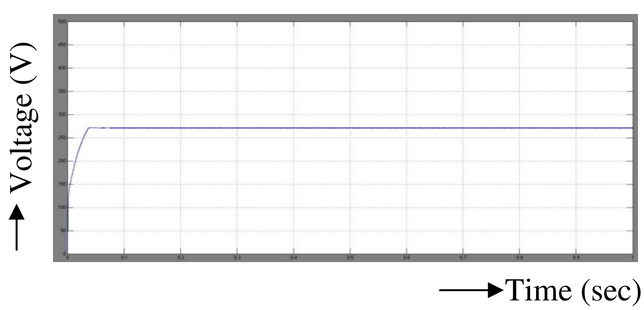


**Figure 15. Output voltage waveform of Modified SEPIC converter with coupling in closed loop configuration**

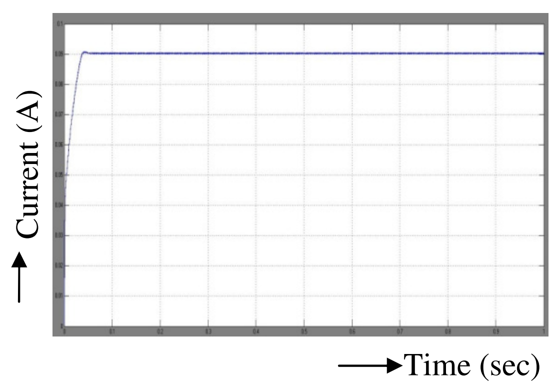


**Figure 17. Output current waveform of Modified SEPIC converter with coupling in closed loop configuration**

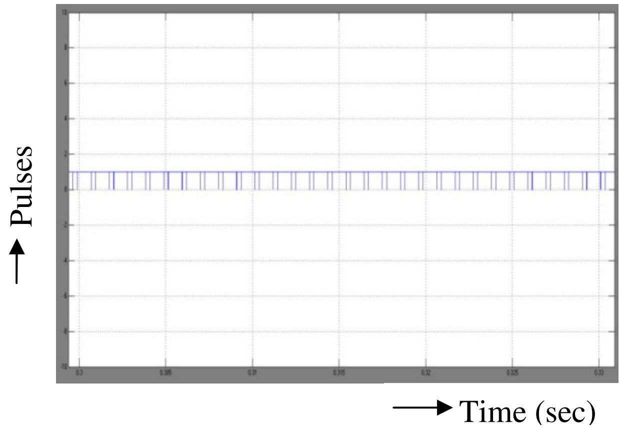


**Figure 18. Switching pulses in closed loop configuration Modified SEPIC converter with coupling**

From the above
Input voltage, Vin = 15 V, Output current, Iout = 0.09 A, Input current, Iin = 1.7 A, Output voltage, Vout = 271 V, Input power, Pin = Vin * Iin = 15*1.7 = 25.5W, Output power, Pout = Vout*Iout = 271*0.09 = 24.39W
Hence, Gain = output voltage/input voltage = 271/15 = 18.1, Efficiency = output power/input power = 24.39/25.5 = 95.65%
Thus, Boost, Classical SEPIC, Modified SEPIC (without and with coupling) converter circuits have been designed, constructed in MATLAB SIMULINK and the following results have been obtained and are depicted in Table.

**Table: Comparison of Different Converters**

| Converter / Parameter | Modified SEPIC without coupling | Modified SEPIC with coupling |
|---|---|---|
| Output Voltage | 150 V | 271 V |
| Output current | 1.2 A | 0.09 A |
| Gain | 10 | 18.1 |
| Efficiency | 92.3% | 95.65% |

Hence, it can be concluded that the highest gain and efficiency are being obtained by using a modified SEPIC converter with coupling, their values being 18.1 and 95.65% respectively.

## 4. CONCLUSIONS

The basics, mathematical analysis and simulation results of Modified SEPIC with and without coupling converter is presented in this report. Modified SEPIC converter without coupling can operate with static gain 10 with an efficiency of 92%. Modified SEPIC converter with coupling can operate with static gain 18 with improved efficiency of 96%. Modified SEPIC converter with coupling has high static gain. This is because; the commutation losses in this topology are reduced due to the presence of transformer leakage inductance.

## REFERENCES

*[1] Wuhua Li, "Review of Non isolated High-Step-Up DC/DC Converters in Photovoltaic Grid-Connected Applications". IEEE Transactions on Industrial Electronics, 58(4), **(2011)**, 1239-1250.*

*[2] C. S. B. Kjaer, J. K. Pedersen and F. Blaabjerg, "A Review of Single-Phase Grid Connected Inverters for Photovoltaic Module". IEEE Transactions on Industry Applications, 41(5), **(2005)**, 1292-1306.*

*[3] D. Meneses, F. Blaabjerg, O. Garcia and J. A. Cobos, "Review and Comparison of Step Up Transformerless Topologies for Photovoltaic AC-Module Application". IEEE Transactions on Power Electronics, 28(6), **(2013)**, 2649- 2663.*

*[4] D. Zhou, A. Pietkiewicz and S. Cuk, "A Three-Switch High-Voltage Converter". IEEE Transactions on Power Electronics, 14(1), **(1999)**, 177-183.*

*[5] M. Prudente, L. L. Pfitscher, G. Emmendoerfer, E. F. Romaneli and R. Gules, "Voltage Multiplier Cells Applied to Non-Isolated DC–DC Converters". IEEE Transactions on Power Electronics, 23(2), **(2008)**, 871-887.*

*[6] B. Axelrod, Y. Berkovich and A. Ioinovici, " Switched Capacitor/Switched-Inductor Structures for getting Transformerless Hybrid DC–DC PWM Converters" . IEEE Transactions on Circuits and Systems - I: Regular Papers, 55(2), **(2008)**, 687-696.*

*[7] A. Kalaivani and S. K. Nandha Kumar, "Modifiedhigh Step-Upnon-Isolated Single Endedprimary Inductor Converter (SEPIC) For PV Applications," 2018 National Power Engineering Conference (NPEC), Madurai, India, **(2018)**, pp. 1-5.*

*[8] Pandav Kiran Maroti, Rashid Al-Ammari, Atif Iqbal, Lazhar Ben-Brahim, Sanjeevikumar Padmanaban, Haitham Abu-Rub, "A Novel High Gain Configurations of Modified SEPIC Converter for Renewable Energy Applications. Industrial Electronics (ISIE) IEEE 28th International Symposium, **(2019),** pp. 2503-2508.*

*[9] Mahajan Sagar Bhaskar, P. Sanjeevikumar, John K. Pedersen, Jens Bo Holm-Nielsen, Zbigniew Leonowicz, "XL Converters- New Series of High Gain DC-DC Converters for Renewable Energy Conversion". Environment and Electrical Engineering and 2019 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe) IEEE International Conference, **(2019),** pp. 1-6.*

*[10] Neeraj Priyadarshi, Sanjeevikumar Padmanaban, Jens Bo Holm-Nielsen,Vigna Ramachandaramurthy,Mahajan Sagar Bhaskar, "An AN-GA Controlled SEPIC Converter for Photovoltaic Grid Integration". Compatibility Power Electronics and Power Engineering (CPE-POWERENG) IEEE 13th International Conference, **(2019)**, pp.1-6.*

*[11] B. Axelrod, Y. Berkovich, Y. Beck, "A Family of Modified Zeta-Converters with High Voltage Ratio for Solar-PV Systems". Power Electronics and Applications (EPE '19 ECCE Europe) 21st European Conference, **(2019)**, pp. 1-9.*