iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** IV **Month of publication:** April 2018

DOI: http://doi.org/10.22214/ijraset.2018.4023

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

Comparison of Voltage and Efficiency of a Modified SEPIC Converter without Magnetic Coupling and with Magnetic Coupling

Rutuja Daphale[1], Vijaykumar Kamble[2]
[1]PG Student, [2]Assistant Professor
Power electronics and drives, Electrical Engg. Dept., AISSMS's IOIT, Pune.

Abstract: The objective of this paper is to compare and analyze the voltage and efficiency of a modified SEPIC converter without magnetic coupling and with magnetic coupling. A SEPIC converter is a DC-DC converter similar to a buck boost converter only with the advantage of non-inverted output. This paper focuses only on the boost part. SEPIC converter with magnetic coupling utilizes an isolation transformer to improve the gain which leads to higher output voltage and higher efficiency for low input voltage. Solar output voltage is given as an input to the converter and also P and O MPPT technique is applied to extract maximum power from the solar energy. The expected output voltage for SEPIC converter without magnetic coupling for an input voltage of 15V is 150V and efficiency of 91% approximately, while for SEPIC with magnetic coupling the expected output voltage is 300 V for 15 V input and efficiency near about 95%. The results are verified by simulating in MATLAB/SIMULINK software.
Keywords: Gain, magnetic coupling, SEPIC, boost, MPPT,etc

I. INTRODUCTION

Modernization and the need to reach every village with proper electricity supply have led to a demand for renewable energy sources. These renewable energy sources (RES) may be photovoltaic (PV) modules, wind or hydropower. These sources provide a clean energy and hence helps reduce the pollution that too at a very low maintenance cost. They act better as secondary sources rather than primary due to certain drawbacks like high capital investment, unreliability due to changing climate, power quality issues, etc. So, to turn the renewable energy sources more powerful and beneficial, efforts have been made and are still going on. Power electronics plays an important role in this regards, as the main challenge with RES is handling output voltage. Output voltage of RES varies over a wide range due to weather uncertainty. Even power quality and efficiency is improved with the help of power electronics. The power converters like rectifiers, voltage source inverters, buck boost converters, SEPIC, CUK, cyclo-converters, etc. majorly controls these variations of RES and provides an improved power supply. Our topic of interest amongst these all converters is the SEPIC converter and PV modules.

PV modules were costly in previous years, which was the major limitation for utilizing it. Continuous research in this field has shed the prices proving it beneficial for energy generation. Usually a number of PV modules are connected in series to obtain the desired voltage. There are 4 types of PV cells, monocrystalline silicon, multicrystalline silicon, amorphous silicon and hybrid. Of these, multicrystalline and monocrystalline cells are widely used on commercial basis. These two types have a maximum output power lower than 350W with maximum power point voltage range from 15 to 40V. In this paper a voltage of 15V is considered. 2 major responsibilities are expected from the converters which interface PV module to grid and those are, operating at maximum power point (MPP) and another is to inject sinusoidal current into the grid [1]. To achieve the responsibility of operating at MPP various techniques are used such as, incremental conductance, current sweep, constant voltage and perturb and observe (PO). The PO method is also known as hill climbing method. In this paper the PO method is used to extract the maximum power.

Fig. (1) depicts the two stage block diagram of the entire system from PV generation to supplying generated power to grid. This paper restricts the study up to second stage only, extracting maximum power from PV module and transferring it to DC-DC SEPIC. It compares the output voltage of modified SEPIC without magnetic coupling and modified SEPIC with magnetic coupling.

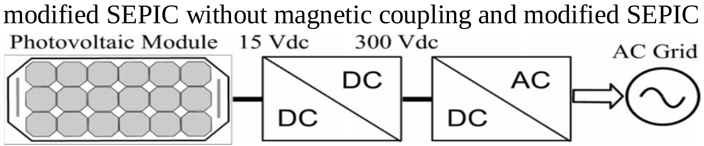

Fig.1- Two stage block diagram

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

SEPIC (Single Ended Primary Inductor Converter) is a DC-DC buck boost converter, whose output is controlled by controlling the duty cycle of the control transistor present in the circuit. SEPIC is different from the conventional buck-boost converter in terms of polarity of the output. The conventional buck boost converter has inverted output, while the SEPIC has advantage of non-inverted output. The circuit diagram for classical SEPIC converter is as shown in fig. (2).

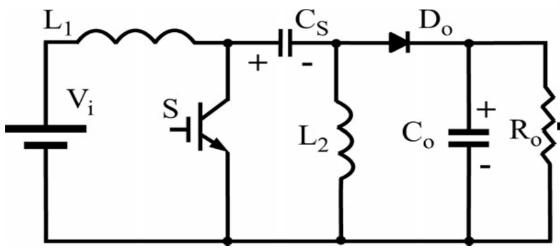

Fig. 2 – Circuit diagram of classical SEPIC.

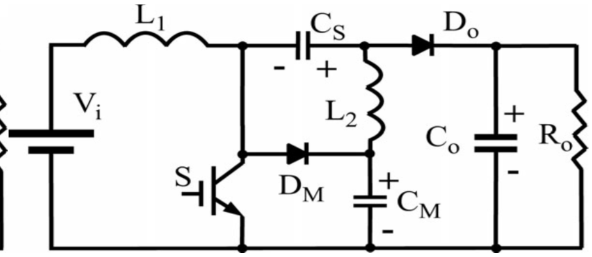

Fig. 3 – Circuit diagram of Modified SEPIC.

The classical SEPIC consists of 2 identical inductors, a control transistor (switch) 2 capacitors and a diode. The inductors L_1 and L_2 are coupled inductors. These inductors are selected on the basis of peak to peak ripple current, it should be approximately equal to 38%-40% of the maximum input current at maximum input voltage [2]. C_S is the coupled capacitor, and isolates the input from output protecting against shorted load. C_S is such selected that RMS current though it must be very small [2].The control transistor can be FET or MOSFET, in this project MOSFET is used. In case of power MOSFET selection, minimum threshold voltage, the on resistance, gate-drain charge, and the maximum drain to source voltage are considered. The output diode should be able to handle peak current and reverse voltage, hence it should be selected accordingly [2]. The output capacitor C_O, is charged with inductor current L_2, hence must sustain maximum RMS current [2].

The modified SEPIC overcomes certain drawbacks of classical SEPIC as higher input ripple current, higher switch voltage, losses due to diode reverse recovery current, etc. This project majorly focuses only on improvement of gain to increase the output voltage and efficiency improvement. The circuit diagram for modified SEPIC is shown in Fig.(3) below.

In modified SEPIC converter, a voltage multiplier circuit is applied to the classical boost converter, for higher output voltage, improved efficiency and low switch voltage [3]. This is done by adding diode D_M and Capacitor C_M to the classical SEPIC as shown in fig.(3). Capacitor C_M of the modified SEPIC is charged with the output voltage, hence when the switch is conducting the voltage applied to inductor L_2 is higher than that in traditional SEPIC. In case of modified SEPIC converter, the losses due to diode reverse recovery current are reduced and soft commutation is obtained with regenerative snubber circuit. The static gain of modified SEPIC is higher than classical boost converter for high values of duty cycle, and low input voltage[3].A gain up to 5 is considered as standard static gain, gain larger than 10 is high static gain and that larger than gain=20 is considered as very high static gain [4]. If compared with other converters for high gain, modified SEPIC utilizes lesser number of switches and less passive components than those converters.

The main purpose of magnetic coupling in modified SEPIC is to increase the voltage gain leading to boost in the output voltage. In past various other techniques like voltage multiplier[6], interleaved boost converter[7],zero voltage switching boost integration technique[8], etc. each of them have certain advantages and disadvantages and can be implemented as per application. The theoretical explanation, working and simulation results of modified SEPIC without magnetic coupling and modified SEPIC with magnetic coupling are explained in following sections. For magnetic coupling an inductor operating as a fly back transformer is used.

II. MODIFIED SEPIC WITHOUT MAGNETIC COUPLING

As stated above a modified SEPIC is built by adding only 2 components diode D_M and capacitor C_M to the classical SEPIC circuit. The circuit diagram for modified SEPIC without magnetic coupling is in fig (3). Modified SEPIC operates in continuous conduction mode and discontinuous conduction mode. For continuous conduction mode modified SEPIC operates in two stages depending upon the on and off condition of switch.

A. Stage 1. When the switch is in off state.

At time to, the switch is turned off; the input energy stored in inductor L_1 is passed on to the output through C_S and output diode D_O, and also to C_M through diode D_M. Here the switch voltage is same as the voltage across C_M, $V_S = V_{CM}$. The energy stored in inductor L_2 is passed on to output through diode Do.

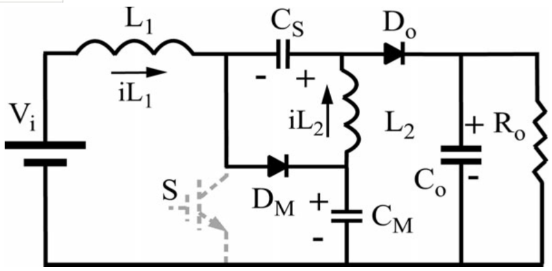

Fig 4 –Stage 1-Switch is off

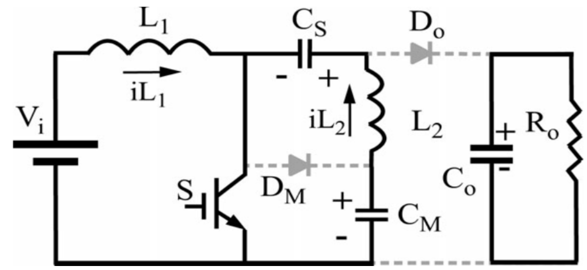

Fig. 5 – Stage 2 –Switch is on

During this time period, the current in inductor 1 is equal to input current i.e. $i_{L1} = i_{In}$. As the diode is in conducting state voltage across it is zero, while current through it is in decaying state. The waveforms to understand these operations are shown in fig. 6

B. Stage 2 – When switch is in on state.

At t_1, the switch is turned on and the circuit is as shown in fig(5). In this mode the inductors instead of transferring energy, they store it. The input energy is applied to L_1, i.e. $Vi = \frac{di_{L1}}{dt}$. Voltage V_{CS}-V_{CM} is applied to inductor L_2.The diodes D_M and D_O are reverse biased. The current through inductor L_2 is equal to output current. Switch is in conducting state so voltage across it is zero, while current flowing through switch is equal to addition of current flowing through both the inductors. i.e. $i_s = i_{l1} + i_{l2}$ .Voltage across diode $D_O = V_{CM}$, and $V_{DM} = V_{CM}$. The waveforms to understand these operations are shown in fig. 6

From above observations, three equations can be derived.

Static gain $\frac{V_0}{V_{in}} = \frac{\left(1+\frac{Ton}{T}\right)}{1-\frac{Ton}{T}}$

$$\frac{V_o}{V_{in}} = \frac{1+D}{1-D} \qquad (1)$$

The voltage across Cm , $V_{CM} = \frac{V_{in}}{1-D}$ (2)

The voltage across Cs, $V_{CS} = \frac{V_{in}D}{1-D}$ (3)

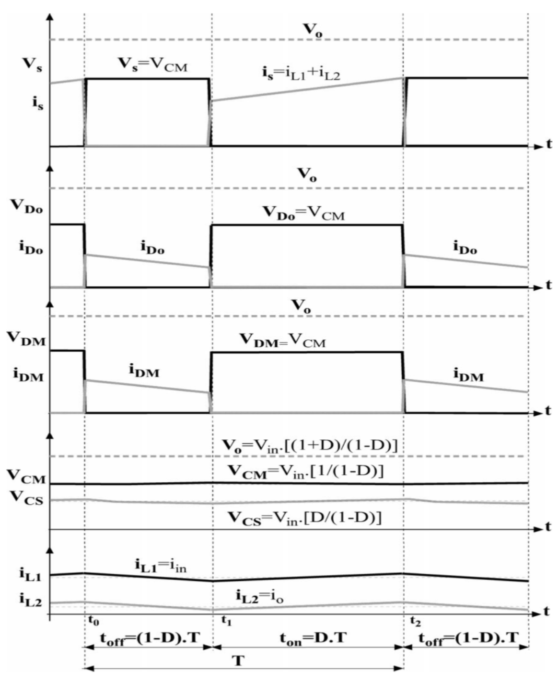

Fig.6 – Waveforms for without magnetic coupling

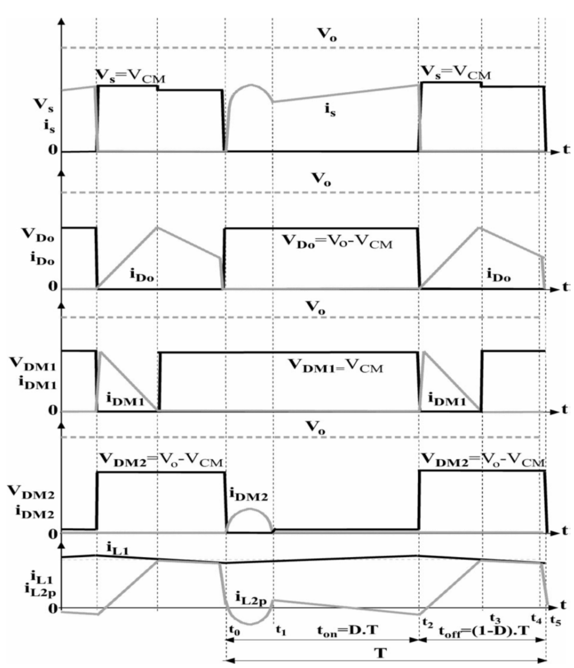

Fig.7– Waveforms for with magnetic coupling

Following equations can be useful for selection of parameters and components of Modified SEPIC without magnetic coupling.

1.Duty cycle = $\frac{V_o - V_{in}}{V_o + V_{in}}$ … from (1) (4)

2. L_1 *and* L_2– Both are identical inductors and can be designed with the help of following equation. Δi_L is the current ripple.

$$L_1 = L_2 = \frac{V_i \cdot D}{(\Delta i_{L} \cdot f)} \text{ …. [5]} \qquad (5)$$

3. C_S and C_M – Both the capacitors have same voltage ripple and are calculated considering capacitor charge variation with zero equivalent capacitor resistances.

$$C_S = C_M = \frac{I_o}{\Delta V_c \cdot f} \text{ …… [5]} \qquad (6)$$

4.The average current through diode D_m and diode D_o is equal to output current.

$$I_o = \frac{P_O}{V_O} \qquad (7)$$

III. PROPOSED MODIFIED SEPIC WITH MAGNETIC COUPLING

The gain of the converter can be increased with the help of high duty cycle, but this is a limitation in modified SEPIC. Inclusion of secondary winding to the inverter L_2 can be of help to increase the gain. This inductor works as a transformer, and the increase in gain depends upon the turns ratio. Another benefit achieved from proposed system is output diode voltage clamping. The circuit diagram for proposed system is as shown in fig.(8).

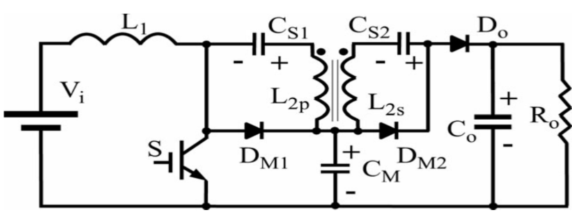

Fig.8- Proposed Modified SEPIC with magnetic coupling

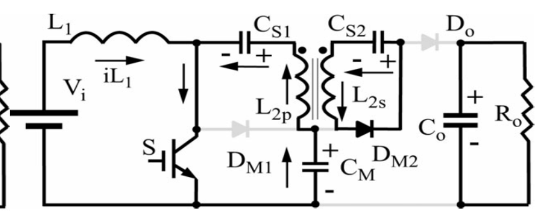

Fig.9 – Mode 1 operation

Diode D_{M2} and capacitor C_{S2} are added to the circuit for the purpose of output diode voltage clamping, to avoid leakage inductance and avoid high input ripple current [5]. The continuous conduction mode of proposed modified SEPIC with magnetic coupling works in 5 modes of operation.

A. Mode 1- Time duration t_O to t_1.

At t_0, the input energy is transferred to inductor L_1 and it stores that energy. The voltage is induced in secondary winding of inductor 2 L_{2s} due to mutual induction. This energy charges the capacitor C_{s2} through diodeD_{M2}. Diode D_o is reverse biased and the maximum diode voltage is $V_O - V_{CM}$. Att_1, capacitor charging stops and diode D_{M2} is blocked. The circuit diagram for first stage operation is as shown in fig.(9).

B. Mode 2 – Time duration t_1 to t_2.

At time t_1, switch is in ON state hence, diode D_{M2} is blocked. At t_2, the switch is turned off and, inductors L_1 and L_2 store energy.The current rises linearly .Fig. 10 shows the operation of mode 2. The diode voltage of D_{M1},is equal to V_{CM}.

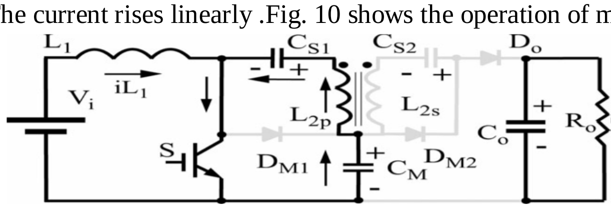

Fig.10 –Mode 2 operation

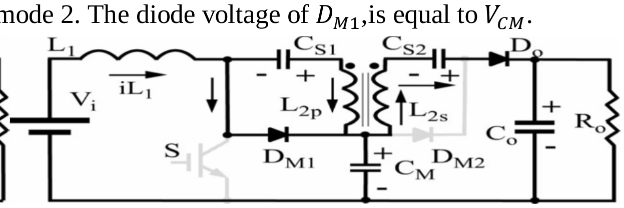

Fig.11-Mode 3 operation

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

Voltage across the output diode D_o is $V_O - V_{CM}$.

C. Mode 3 – Time duration $t_2 - t_3$

At t_2, the switch is turned off, energy stored in inductors is transferred to C_M through diode D_{M1} and also to output, through C_{s1},C_{s2} and diode D_o. The current in L_1 falls and current in L_2 suddenly rises through this period. Voltage across switch is equal to V_{CM}.This mode has the maximum switch voltage than other stages. A reverse current flows through D_{M2} hence it is blocked. Voltage across $D_{M2} = V_O - V_{CM}$.

D. Mode 4 –Time duration $t_3 - t_4$

At t_3 energy transfer to C_M is completed and now D_{M1} gets blocked because both the inductor currents are equal. The voltage across D_{M1} becomes equal to voltage across C_M. The operation diagram of this mode is as shown in fig. 12

E. Mode 5- Time duration $t_4 - t_5$

The output diode current linearly decreases at t_4, when the switch is turned on. Transformer leakage inductance controls $\frac{di}{dt}$, reducing the diode reverse recovery current problems. The converter returns to mode 1 when the output diode is blocked.

Waveforms depicting these operations of five modes are shown in figure, 7. In the proposed system, switching losses are less as compared to other converters because of the zero current switching of power switch.

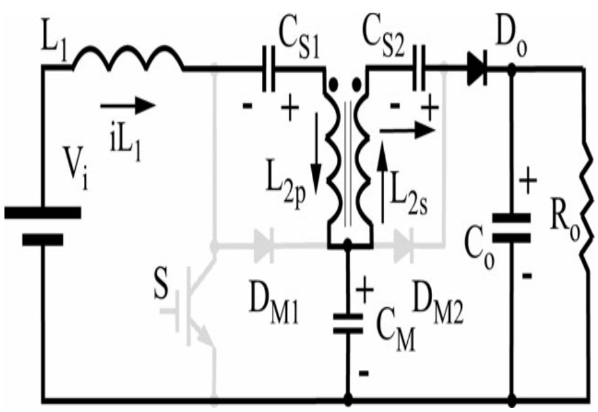

Fig.12-Mode 4 operation

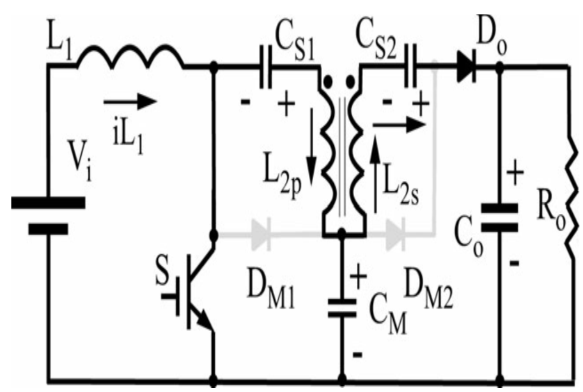

Fig.13-Mode 5 operation

Static gain of the proposed converter is given by equation (8)

$$\frac{V_O}{V_{in}} = \frac{1+n}{1-D} \qquad (8)$$

Where n, is inductor turns ratio and D is the duty cycle.

n is calculated by following formula.

$$n = \frac{N_{L2s}}{N_{L2p}} \qquad (9)$$

By increasing the turns ratio, static gain can be increased.

The duty cycle is calculated from the below formula.

$$D = 1 - \frac{V_i}{V_O}(1 + n) \qquad (10)$$

The leakage inductance required for the zero current switching of switch is a key parameter of transformer and is considered in series with the L_{2p} inductor. It is also important of the reverse recovery current of the output diode. It can be calculated as follows;

$$Lr = \frac{Vi}{(1-D)\frac{di}{dt}n} \qquad (11)$$

IV. SIMULATION RESULTS

Both the systems, the one without magnetic coupling and one with magnetic coupling are simulated in MATLAB/SIMULINK for comparing their output voltages and efficiency. The ratings used for circuit parameters are as shown in tables below.

Table I- Ratings of circuit parameters for simulation

Parameters	Modified SEPIC without magnetic coupling	Modified SEPIC with magnetic coupling.
Input Voltage	15V	15V
Inductors L_1 and L_2	102µH,102µH	102µH,0.08PU
Capacitor C_s	2.9µF	2.9µF
Capacitor C_m	2.9µF	2.9µF
Duty cycle	0.8	0.8
Switching frequency	24KHz	24KHz

A. *Simulation of Modified SEPIC without magnetic coupling*

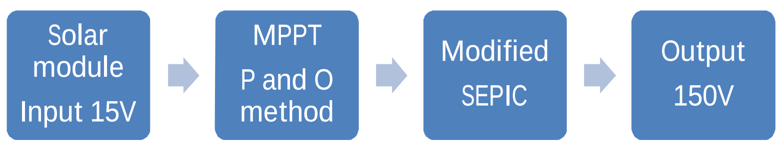

Fig.14 – Block diagram of simulation of modified SEPIC without magnetic coupling

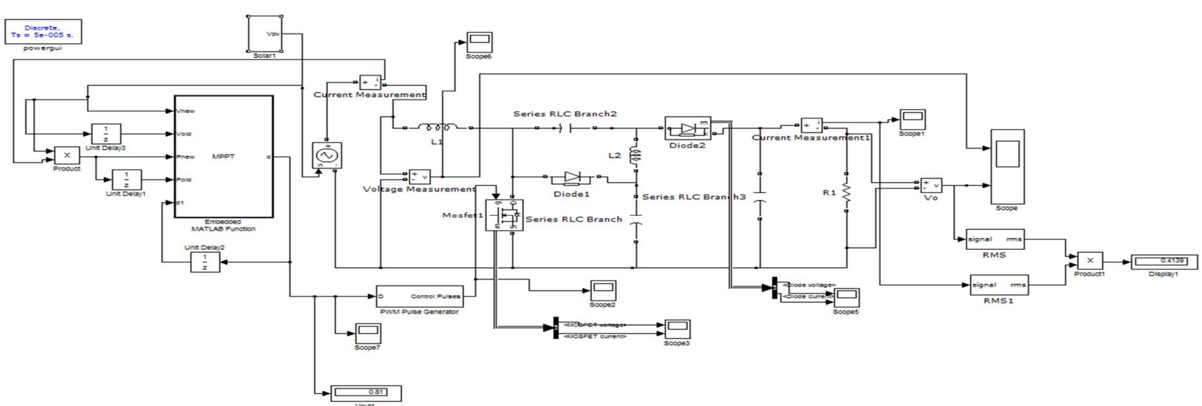

Fig.15 Simulation of modified SEPIC without magnetic coupling

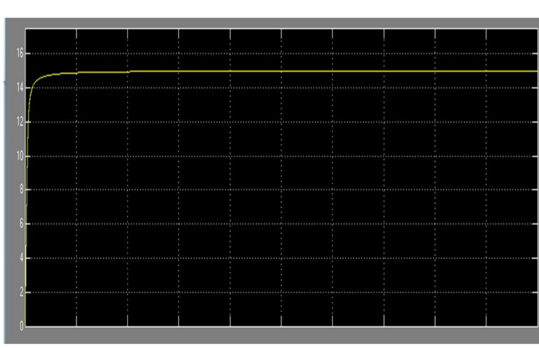

Fig.16- Input voltage of modified SEPIC Without magnetic coupling.

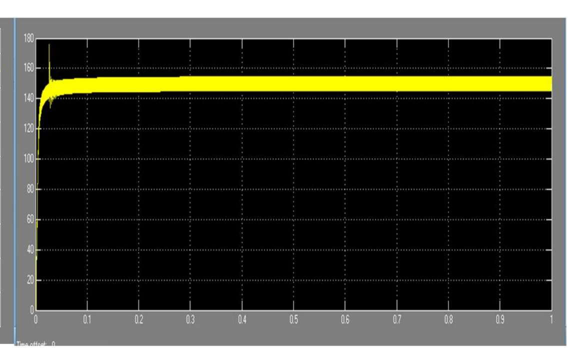

Fig.17- Output voltage of modified SEPIC without magnetic coupling.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

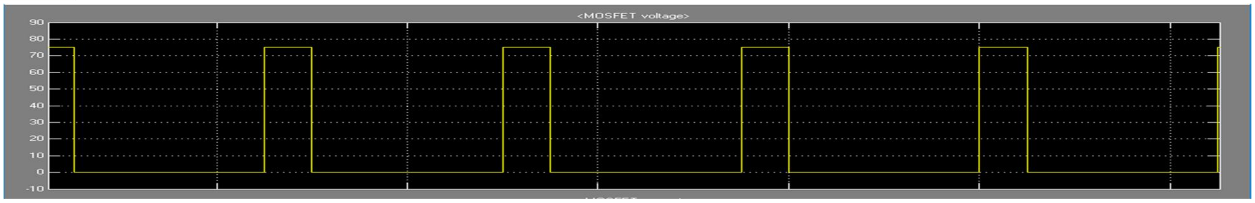

Fig.18- Voltage of switch of modified SEPIC without magnetic coupling

The complete simulation of modified SEPIC without magnetic coupling is as shown in figure 15. P and O method of MPPT is applied using coding. All the parameters are according to the ratings provided in table 1.Fig. 16 shows the input voltage of the system, this voltage is acquired from the solar module. The solar cells are connected in series to seek this voltage. Fig. 17 shows the output voltage as 150V. The voltage of MOSFET is nearly equal to 75V. Efficiency of this system is calculated as 91.1%

B. Simulation of Modified SEPIC with magnetic coupling

Simulation of modified SEPIC with magnetic coupling are as shown in fig. 20. All the parameters are according to the ratings provided in table 1.The input voltage for proposed system is 15V and is shown in fig.21. The output voltage is boosted and reaches 300V, fig. 22 shows the waveform. The switch voltage is reduced to nearly 72V, it is shown in figure 23. Efficiency of the proposed system is 95.9%.

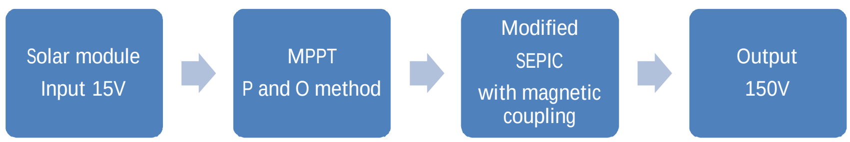

Fig.19- Block diagram of simulation of proposed modified SEPIC with magnetic coupling

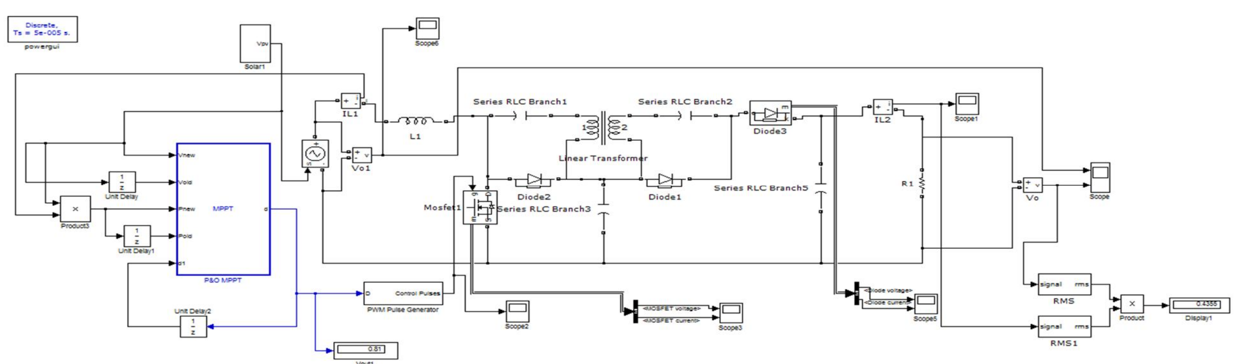

Fig.20 – Simulation of proposed modified SEPIC with magnetic coupling

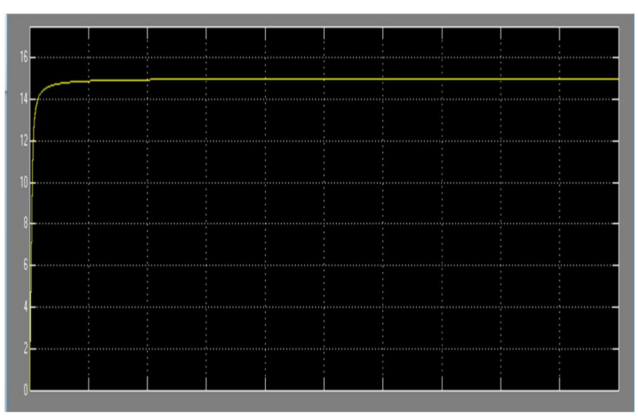

Fig.21 - Input voltage of modified SEPIC with magnetic coupling

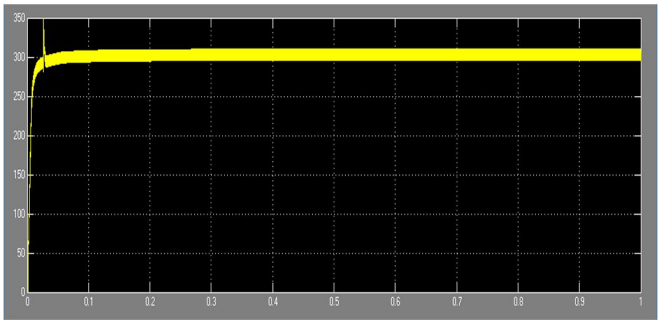

Fig.22 - Output voltage of modified SEPIC with magnetic coupling

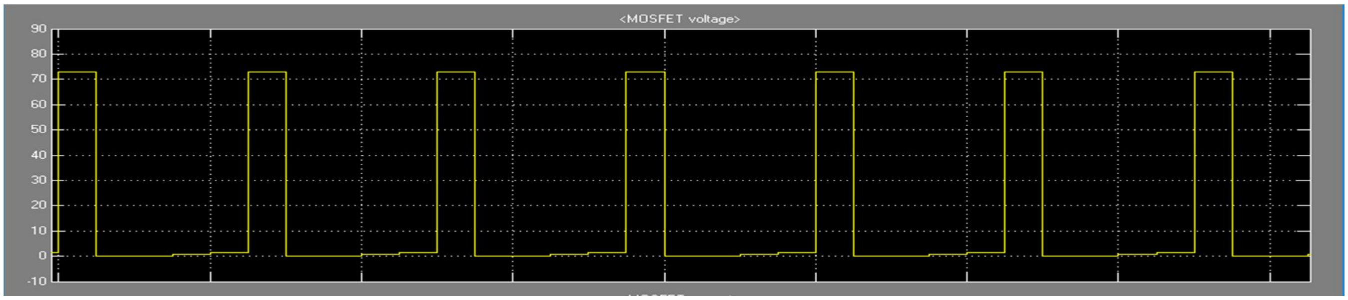

Fig 23 – Switch voltage of modified SEPIC with magnetic coupling

V. COMPARISON BETWEEN MODIFIED SEPIC WITHOUT MAGNETIC COUPLING AND MODIFIED SEPIC WITH MAGNETIC COUPLING.

The comparison between two systems is presented in table below. Comparison is majorly done based on output voltage and efficiency. The proposed modified SEPIC is much more efficient than conventional.

Table 2. Comparison of both systems.

Parameters	Modified SEPIC without magnetic coupling	Modified SEPIC with magnetic coupling.
Input voltage	15V	15V
Output Voltage	150V	300V
Efficiency	91.1%	95.9%
Switch voltage	75(approximately)	72(approximately)

VI. CONCLUSION

Two systems of modified SEPIC were presented and explained in this paper. The first system modified SEPIC without magnetic coupling boost the input voltage of 15V to 150V, and the proposed system with magnetic coupling boosts the voltage of 15V input to 300V output. The proposed system used zero current switching that reduces the losses and efficiency is improved. The first system has an efficiency of 91.1% while the second system has 95.9%. The switch voltage is also reduced in second system. Hence, this proposed system is very useful for applications which need high output voltage like solar panel, SMPS, portable power electronics equipment, etc.

VII. ACKNOWLEDGEMENT

The authors would like to thank teaching and non-teaching staff of AISSM'S IOIT, for providing technical support and other requirements needed for completion of this project.

REFERENCES

[1] C. S. B. Kjaer, j. K. Pedersen, and f. Blaabjerg, "a review of single phase grid-connected inverters for photovoltaic modules," ieee trans. Ind. Appl., vol. 41, no. 5, pp. 1292–1306, sep. 2005.

[2] dongbing zhang texas instruments an-1484 designing a sepic converter snva168e–may 2006–revised april 2013

[3] priscila facco de melo, roger gules "a modified sepic converter for high-power-factor rectifier and universal input voltage applications," 310 ieee transactions on power electronics, vol. 25, no. 2, february 201
[4] Krunalkumar patel, aditi hajari, "modified sepic converter for high static gain" issn (online): 2395-6151, volume-1, issue-3, 201
[5] Roger gules, walter meneghette dos santos, flavio aparecido dos reis, "a modified sepic converter with high static gain for renewable applications"ieee transactions on power electronics, vol. 29, no. 11, november 2014
[6] M. Prudente, l. L. Pfitscher, g. Emmendoerfer, e. F. Romaneli, and r. Gules, "voltage multiplier cells applied to non-isolated dc–dc converters," ieee trans. Power electron., vol. 23, no. 2, pp. 871–887, mar.2008.
[7] Li and x. He, "an interleaved winding-coupled boost converter with passive lossless clamp circuits," ieee trans power electron., vol. 22, no. 4, pp. 1499–1507, jul. 2007.
[8] High step-up dc-dc converters using zero-voltage switching boost integration technique and light-load frequency modulation control ieee transactions on power electronics, vol. 27, no. 3, march 2012 1383