A Modified Sepic Converter With Pv Module And Mppt Technique

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ABSTRACT- Solar-electric-energy system has grown consistently over the years. The core of solar power generation system is a solar cell. Modeling the solar cell is required for study of photovoltaic systems. In this paper utilization of a modified Single Ended Primary Inductance Converter (SEPIC) for control of photovoltaic power using Maximum Power Point Tracking (MPPT) control mechanism is presented. The SEPIC is designed to make the power flow from PV module to load effectively and maintain constant output voltage. The model is developed using basic circuit equations of the photovoltaic (PV) solar cells including the effects of solar irradiation and temperature changes. The preferred topology presents low switch voltage with high efficiency for low input and high output voltage applications. This converter topology is the combination of a classical boost converter and a conventional SEPIC converter. The input voltage of the converter is chosen to be 15 V and an output voltage of 120 V is obtained. The output power obtained is of 30W.

KEYWORDS- Continuous Conduction Mode (CCM), Maximum Power Point Tracking (MPPT), Photo Voltaic module (PV), Single Ended Primary Inductance Converter (SEPIC).

1. INTRODUCTION

1.1 Motivation:

The energy which is harvested from the natural resources like sunlight, wind, tides, geothermal heat etc. is called Renewable Energy. As these resources can be naturally replenished, for all practical purposes, these can be considered to be limitless unlike the tapering conventional fossil fuels. The global energy crunch has provided a renewed impulsion to the growth and development of Clean and Renewable Energy sources. Clean Development Mechanisms (CDMs) are being adopted by organizations all across the globe. Another advantage of utilizing renewable resources over conventional methods is the significant reduction in the level of pollution associated. The cost of conventional energy is rising and solar energy has emerged to be a promising alternative. They are abundant, pollution free, distributed throughout the earth and recyclable. PV arrays consist of parallel and series combination of PV cells that are used to generate electrical power depending upon the atmospheric specifies (e.g. solar insolation and temperature).

1.2 Historical Development:

Photovoltaic technology in reality goes back over 160 years. The basic science first came upon in 1839 but the pace of advancement really hastened in two major drives in the 20th century. Bell Laboratories, discovered silicon photoelectric attributes and quickly developed Si solar cells, achieving 6% efficiency and former satellites were the elemental use for these first solar 11 cells. To spur acceptance, Germany and then Japan initiated appreciable subsidy programs and now those markets exist largely without grants. In 2007, California leads the US with a similar 10-year program.

1.3 Application:

Solar technologies are broadly qualified as either passive or active depending on the way they catch, change over and distribute sunlight. Active solar proficiencies use photovoltaic arrays, pumps, and fans to convert sunlight into executable outputs. Passive solar techniques include selecting materials with favorable thermal attributes, and citing the position of a building to the Sun. The standalone PV Systems have been used for solar street lighting, home lighting system, SPV water pumping system. A hybrid system installed with a backup system of diesel generator can be used in remote military installations, health centres and tourist bungalows. In grid connected system the major part of the load during the day is supplied by the PV array and then from the grid when the sunlight is not sufficient.

1.4 Work Summary:

Different forms of renewable energies have been discussed along with the most important one, the solar energy. The concepts of a PV cell and its characteristics have been studied and obtained through its characteristic equation. SEPIC and Boost converter has been studied under both open loop and closed loop conditions. An MPPT model has been designed to extract maximum power from the photovoltaic array.

2. PV MODEL

The model is developed using basic circuit equations of the Photovoltaic (PV) Solar cells including the effects of solar irradiation and temperature changes. A PV cell can be represented by a current source connected in parallel with a diode, since it generates current when it is illuminated and acts as a diode when it is not. The equivalent circuit model also includes a shunt and series internal resistance that can be represented by resistors R_s and R_{sh} as shown in Fig. 1.

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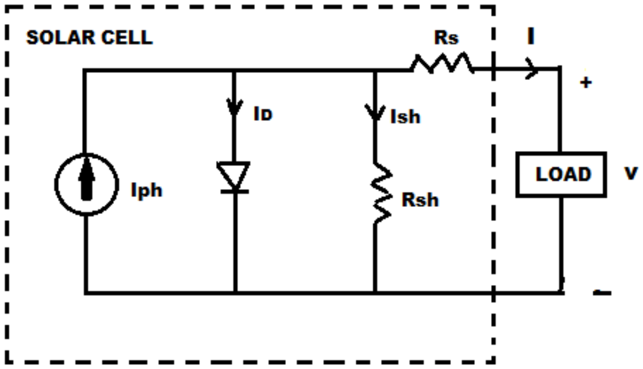

Figure 1: Simplified circuit diagram of a solar PV cell

The cell presents a voltage called (Voc) expressed analytically using eq. 1

$$V = \left(\frac{A * K * T_c}{q}\right) \ln\left(\frac{I_{ph}}{I_o}\right) \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The terminals of the cell are short circuited, through which flows a current called (Isc). In this situation, the voltage between cell terminals is zero.

$$I_{sc} = I_{ph} = C * G \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, C is a constant.

Maximum power point (MPP) is the operating point on the I-V curve that gives the maximum output power from the solar cell at different operating conditions. Here voltage versus current product which produce maximum values of power points. V_{MP} is related to VOC through the relation in eq. (3):

$$V_{MP} \approx 0.8 * V_{oc} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

And I_{MP} is related to Isc through the relation in eq. (4):

$$I_{MP} \approx 0.8 * I_{sc} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The best conditions are the "standard operating conditions" happen at Irradiance equal to 1000W/m², cells temperature equals to 25°C, and spectral distribution (Air Mass) AM is equal to 1.5. For accurate modeling of the solar panel, two diode circuit could have been used. But our scope of study is limited to single diode model

3. PV FED MODIFIED SEPIC CONVERTER USING MPPT TECHNIQUE

3.1 Power Circuit With Magnetic Coupling

The modified SEPIC converter without magnetic coupling can operate with the double of the static gain of the classical boost converter for a high duty-cycle operation. However, a very high static gain is necessary in some applications. A practical limitation for the modified SEPIC converter in order to maintain the converter performance is a duty cycle close to $D = 0.85$, resulting in a maximum static gain equal to $q = 12.3$. A simple solution to elevate the static gain without increases the duty cycle and the switch voltage is to include a secondary winding in the L_2 inductor. The L_2 inductor operation is similar to a buck–boost inductor and a secondary winding can increases the output voltage by the inductor windings turns ratio (n), operating as a fly-back transformer. Fig.3 shows this alternative circuit. However, this converter structure presents the problem of overvoltage at the output diode D_o due to the existence of the coupling winding L_2 leakage inductance. The energy stored in the leakage inductance, due to the reverse recovery current of the output diode, results in voltage ring and high reverse voltage at the diode D_o. This overvoltage is not easily controlled with classical snubbers or dissipative clamping.

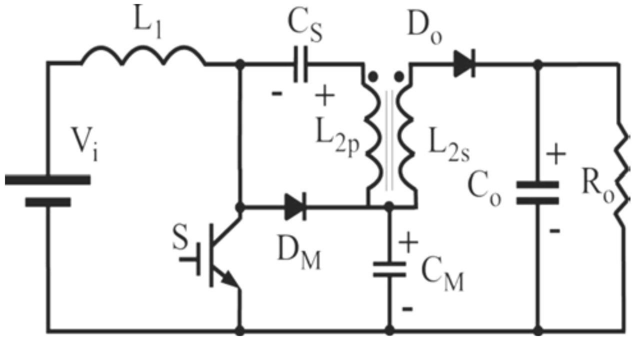

Figure 3: **SEPIC converter with magnetic coupling**

A simple solution for this problem is the inclusion of a voltage multiplier at the secondary side as presented in Fig.4. This voltage multiplier increases the converter static gain, the voltage across the output diode is reduced to a value lower than the output voltage and the energy stored in the leakage inductance is transferred to the output. Therefore, the secondary voltage multiplier composed by the diode D_{M2} and capacitor C_{S2} is also a non dissipative clamping circuit for the output diode. The solutions based on the classical boost converter with magnetic coupling or the integration of the magnetic coupling and the voltage multiplier cell can present very high voltage gain and an excellent performance. However, as the magnetic coupling is accomplished with the input inductor in the boost-based solutions, the input current ripple is significantly increased and depends on the inductor winding turns ratio. Increasing the inductor turns ratio and the static gain, the input current ripple rises. The input current ripple increment is a non desirable operation characteristic for some applications as the fuel cell power source. As the magnetic coupling is not accomplished with the input inductor in the proposed topology, the input current ripple is low and is not changed by the magnetic coupling.

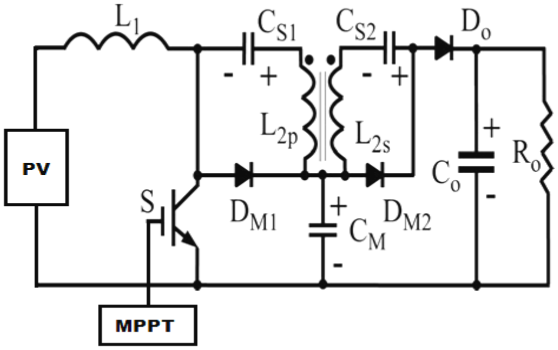

Figure 4: PV Fed Modified SEPIC Converter

The CCM operation of the PV fed modified SEPIC converter with magnetic coupling and output diode clamping presents five operation stages. All capacitors are considered as a voltage source, and the semiconductors are considered ideals for the theoretical analysis.

4. ANALYSIS OF PROPOSED CONVERTER

1) First Stage [t_0–t_1] (Fig. 5*):* The power switch *S* is conducting and the input inductor L_1 stores energy. The capacitor C_{S2} is charged by the secondary winding L_{2S} and diode D_{M2}. The leakage inductance limits the current and the energy transference occurs in a resonant way. The output diode is blocked, and the maximum diode voltage is equal to (V_o–V_{CM}). At the instant t_1, the energy transference to the capacitor C_{S2} is finished and the diode D_{M2} is blocked.

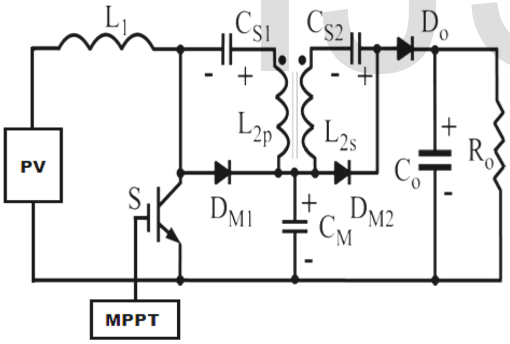

Figure 5: First Stage Operation

2) Second Stage [t_1–t_2] (Fig. 6): From the instant t_1, when the diode D_{M2} is blocked, to the instant t_2 when the power switch is turned OFF, the inductors L_1 and L_2 store energy and the currents linearly increase.

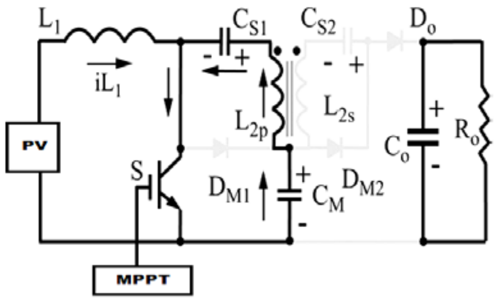

Figure 6: Second Stage Operation

3) Third Stage [t_2–t_3] (Fig. 7): At the instant t_2 the power switch S is turned OFF. The energy stored in the L_1 inductor is transferred to the C_M capacitor. Also, there is the energy transference to the output through the capacitors C_{S1}, C_{S2} inductor L_2 and output diode D_o.

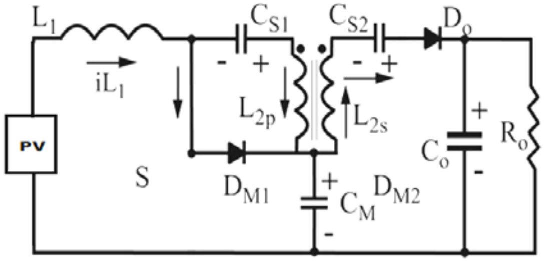

Figure 7: Third Stage Operation

4) Fourth Stage [t_3–t_4] (Fig. 8): At the instant t_3, the energy transference to the capacitor C_M is finished and the diode D_{M1} is blocked. The energy transference to the output is maintained until the instant t_4, when the power switch is turned ON.

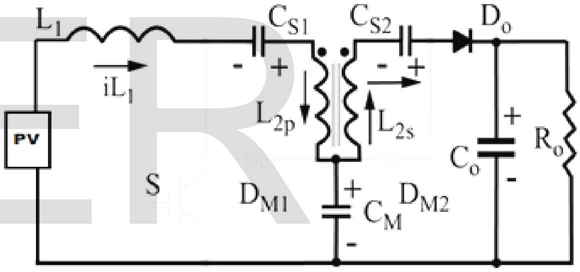

Figure 8: Fourth Stage Operation

5) Fifth Stage [t_4–t_5] (Fig. 9): When the power switch is turned ON at the instant t_4 , the current at the output diode D_o linearly decreases and the di/dt is limited by the transformer leakage inductance, reducing the diode reverse recovery current problems. When the output diode is blocked, the converter returns to the first operation stage.

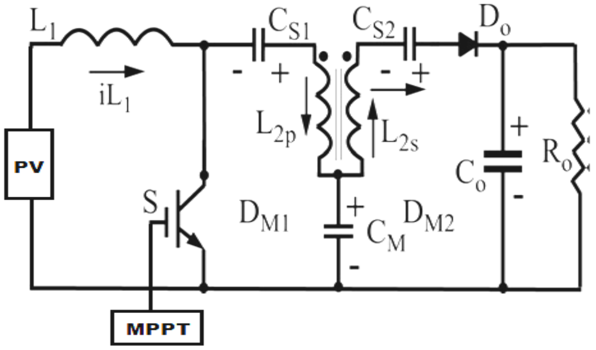

Figure 9: Fifth Stage Operation

The main theoretical waveforms of the modified SEPIC converter with magnetic coupling and with the voltage multiplier at the secondary side are presented in Fig. 18. The switch voltage and the voltage across all diodes are lower than the output voltage. The power switch turn-on occurs with almost zero current reducing significantly the switching losses. The current variation ratio (*di*/*dt*) presented by all diodes is limited due to the presence of the coupling inductor leakage inductance, reducing the negative effects of the diode reverse recovery current.

The static gain of the modified SEPIC converter with magnetic coupling and voltage multiplier is calculated by (1). The static gain can be increased by the windings turns ratio (*n*) without increasing the switch voltage

$$\frac{V_o}{V_i} = \frac{1}{1-D} * (1+n) \ldots\ldots (1)$$

Where, the inductor windings turns ratio (*n*) is calculated by

$$n = \frac{N_{L2s}}{N_{L2p}} \ldots\ldots\ldots\ldots (2)$$

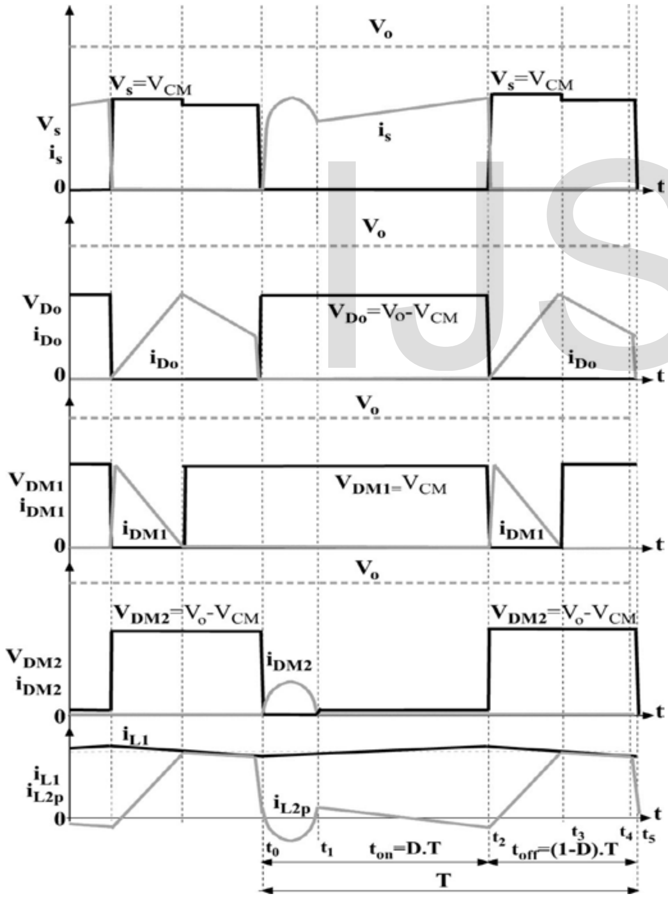

Figure 10: Theoretical Waveforms

Considering a duty cycle equal to 0.8, a static gain equal to *q* = 10 is obtained for *n* = 1, *q* = 15 for *n* = 2 and *q* = 20 for *n* = 3 and the switch voltage is equal to five times the input voltage for all cases.

5. DESIGN PROCEDURE

The main equations to design the modified SEPIC converter with magnetic coupling are shown with an example, considering the following specifications:

- Output power: P_o = 26 W
- Input voltage: V_i = 15-19 V
- Output voltage: V_o = 115 V
- Switching frequency: f = 24 kHz

5.1 Prototype Parameters

TABLE I

PARAMETER	PROPOSED CONVERTER
Input Voltage	15-19V(PV MODULE)
Output Voltage	115V
Output Power	27W
Duty Ratio	0.8
Switching Frequency	24KHz
Gain	8

5.2 Prototype Components

TABLE II

COMPONENTS	PROPOSED CONVERTER
S	IRFP250
D_O	BYQ28E
D_{M1}	BYQ28E
D_{M2}	BYQ28E
C_M	$4.7\mu F$/250V
C_{S1}	$4.7\mu F$/250V
C_{S2}	$4.7\mu F$/250V
n	2.6
C_O	$100\mu F$/250V

The prototype is fed from a PV module BPSX150 providing a maximum power of 30W and a maximum voltage of 19V. Maximum power is tracked by using MPPT technique using P & O algorithm. This is attained by using dsPIC30F2010 which is a 28 pin high performance digital signal controller. This provides the switching pulse. The switch used is IRFP250N, a power MOSFET having fast switching property. The diodes used are BYQ28E which are dual ultrafast soft recovery rectifiers. The capacitors, except the output capacitor C_o are non polarity capacitors. Opto-couplers TLP250 and 4N25 are used for isolation purposes. The opto-coupler, TLP250 serves the purpose of providing gate drive for the power MOSFET also. In the prototype, regulators are provided for step down of the voltage level, i.e; in the case of microcontroller as well as the opto-coupler, which need only lesser voltage. The regulator used is LM317, which is a 3 terminal positive adjustable regulator.

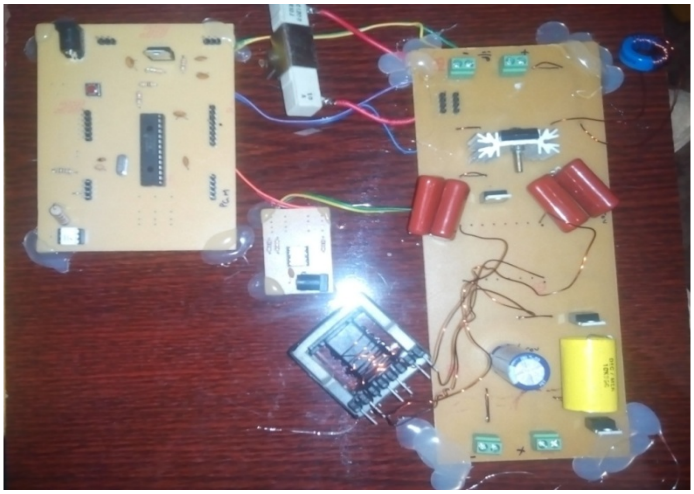

Figure 11: Prototype Of Proposed Converter.

The results obtained with the proposed converter with magnetic coupling and voltage multiplier are presented from Figs. 12 to 15 operating with a resistive load equal to 100 W. Fig. 12 shows the input current and the input voltage of the PV fed modified SEPIC converter with magnetic coupling and MPPT technique. The output voltage and output current is shown in fig. 13 and is equal to 115V, and 239mA respectively. The switch voltage waveform is shown in the fig. 15. The experimental results are similar to the theoretical waveforms presented in Fig. 10. The voltage waveform of the output diode is shown in Fig. 14. The diode voltage is found to be 78V.

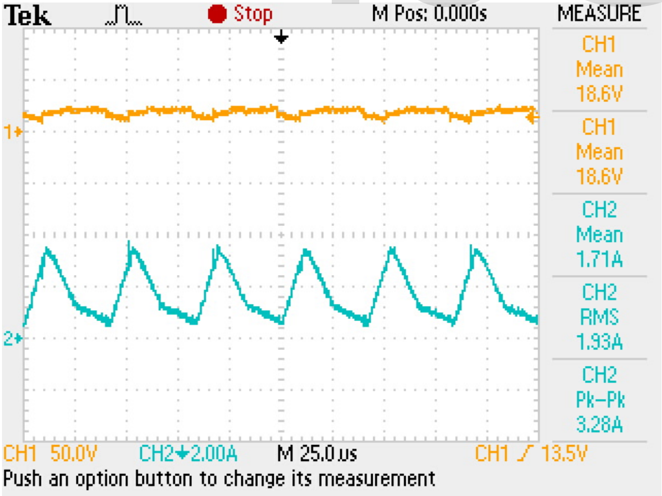

Figure 12: Waveforms of input voltage and input current.

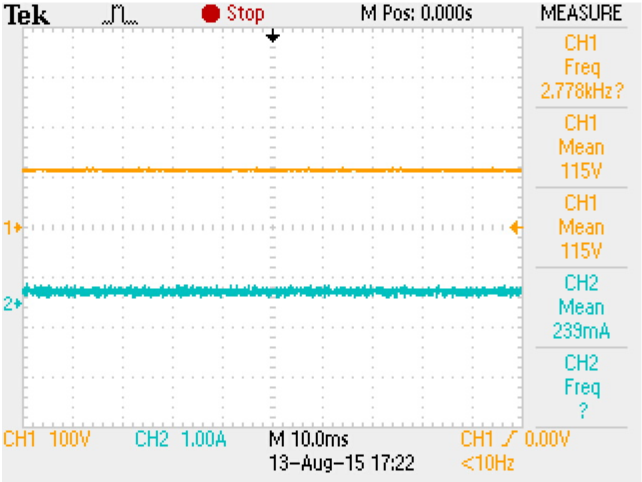

Figure 13: Waveforms of output voltage and output current

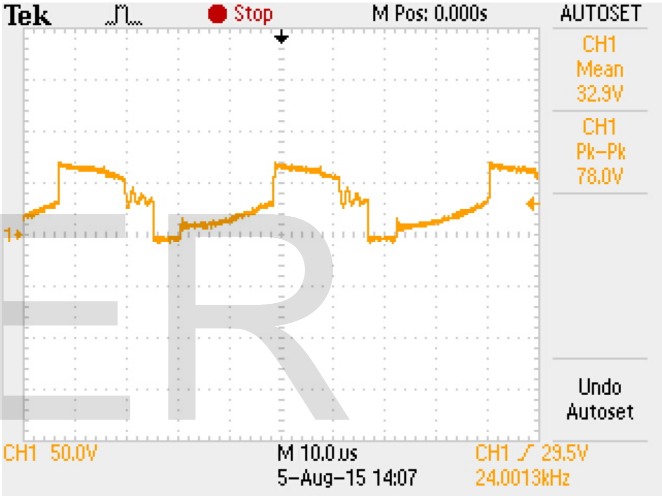

Figure 14: Waveform of voltage across output diode.

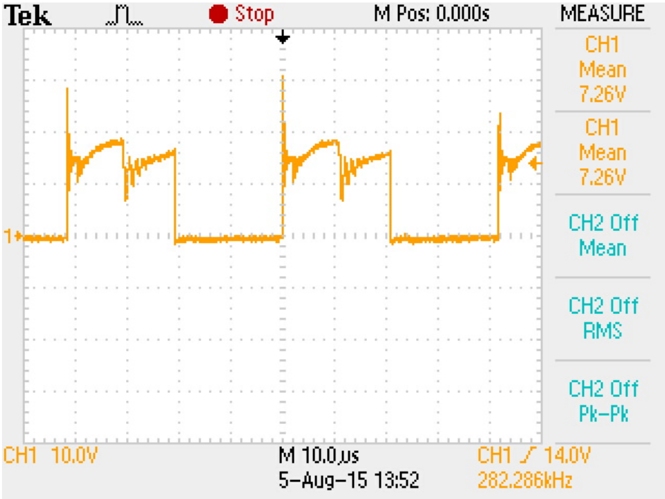

Figure 15: Waveform of voltage across the switch, V_s

From the experimental results it is evident that the conduction losses are reduced and also the presence of high voltage at the output diode is also eliminated. The voltage across the output diode is less than the output voltage obtained, also is the switch voltage.

6. CONCLUSION AND FUTURE SCOPE

6.1 Conclusion:

A SEPIC converter using low cost control circuit has been designed for PV system. The converter maintains constant output voltage even though the output voltage from PV system changes. A prototype of about 30W SEPIC converter is constructed and the results are also verified experimentally. Modified SEPIC converter with magnetic coupling is the most advanced scheme in order to achieve a very high static gain for low input voltage and high output voltage applications. Inclusion of voltage multiplier cell at the secondary side will not affect the complexity of converter. Furthermore, it increases the converter static gain. The commutation losses of the suggested converter with magnetic coupling are reduced due to the existence of the transformer leakage inductance. The main advantage of modified SEPIC converter circuit is that it has a standard gain for a given duty cycle.

6.2 Future Scope:

The proposed topology can find application in systems with low input and high output voltage. This topology can also be applied in the applications which require reduced losses, high power density, low weight, and volume. Since the system uses renewable energy source it can be effectively used in wide range of applications, including the ups system.

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