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Performance Analysis and Implementation of Modified SEPIC Converter using Hybrid Source

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***Abstract*—In present era, the world is directed towards hybrid renewable energy system due to its environmental friendly and in reducing greenhouse gas emissions. It is a better alternative for conventional energy sources. Renewable energy is a natural source found anywhere with free of cost and its non-polluting behavior. However, these energy sources are intermittent in nature based on the weather condition, which shackles the stable power supply. To overcome this issue, a modified SEPIC converter using hybrid source is proposed. In this proposed system, open loop and closed loop with PI and FOPID controller has been discussed. In absence of hybrid source, grid connection can be used to supply and maintain constant voltage to the load.**

***Index Terms*— SEPIC converter, Renewable Energy, Hybrid renewable energy system.**

I. Introduction

In recent years, PV systems developed as never ending demand due to their enormous potential and in substitute for our diminishing fossil fuel energy sources. The Ultimate renewable source of energy is solar energy which is effective replacement and environment friendly alternative of electric power generation. Normally, a single PV cell generates a low voltage of typically 0.6V which is not feasible for electrical utility. And PV cell efficiency depends on different factors such as solar radiation, series resistor, shunt resistor, diode saturation current, ambient temperature etc. Due to variation of solar radiation, voltage and current and power is not constant. That's why, photovoltaic (PV) cell generates low dc voltage. Hence PV cells are connected in series and parallel combination for increasing voltage level, called PV module and it needs to be stepped up as per the load requirement. Since the output of solar photovoltaic module is dc, a dc-dc converter or ac-dc converter is used as per the needs. In that an isolated dc-dc converter is of four types namely: buck, boost, buck-boost, CUK converter. Buck converter only reduce voltage level. Boost converter only increase voltage level. Whereas buck-boost, CUK, SEPIC can increase or decrease voltage. The drawback of buck-boost converter is even though it is cheaper and require single L and C, these converter suffers from a high amount of input ripple current. These ripples can create harmonics. So it requires large C or LC filters. This make it expensive and they invert the voltage. The drawbacks of CUK converter can solve ripples and invert voltage by using an extra L and C. Both buck-boost and CUK cause large amount of electrical stress on device this results in device failure or overheating. To overcome this disadvantages, a non-isolated dc-dc converter with dual input is proposed in this paper.

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II. Proposed System

A Dual input voltage source based non-isolated Single-Ended Primary Inductor Converter (SEPIC) for constant voltage application is proposed. Solar photovoltaic (PV) panel and battery are the source of input voltage. SEPIC is a type of DC-DC converter that allows the electrical potential at its output to be greater than, less than, or equal to that at its input. Here SEPIC converter act as boost converter. PV module and battery is integrated with SEPIC converter where it is able to maximize and maintain the output voltage.

A. Open loop system

In this system, two input voltage sources solar PV and a battery were used. The output voltage varied with the variation of the input voltage sources. The converter proposed has high-quality output and high gain by making a small modification in the conventional SEPIC converter. The open loop of proposed system is shown as follows.

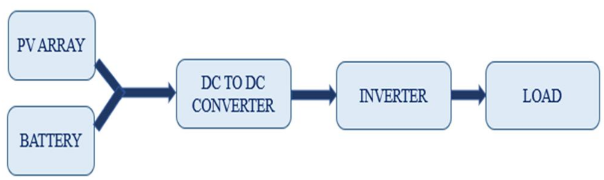

Fig. 1. Block Diagram of Open Loop System

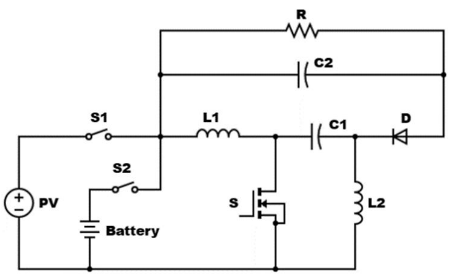

Fig. 2. Circuit Diagram of Proposed System

B. Modes of operation

Mode I:

When switch S1,S2,S is ON, then the diode D is forward biased. The inductor L1, output capacitor C2 gets charged by input voltage source and the coupling capacitor C1 gets discharged through the switch and charges the inductor L2.

Mode II:

When switch S1,S2 is ON and S is OFF then the inductor L1, L2 gets discharged and the coupling capacitor C1 starts charging through input source voltage. Due to the polarity of the inductor L2, the diode D is reverse biased and output capacitor C2 provides power to the load.

C. Design parameters for simulation

The design parameters for the simulation can be calculated by the following equations,

The Duty Cycle, D can be determined by

$$D = V_o/(V_o+V_s) \qquad (1)$$

The inductor values L_1, L_2 can be determined by

$$L = (V_s*D)/(\Delta I_{L1}*f_s) \qquad (2)$$

The capacitor values C_1, C_2 can be determined by

$$C = /(R*(\Delta V_o/V_o)*f_s) \qquad (3)$$

D. Closed loop system

Closed loop system is to regulate and maintain the desired output voltage using feedback mechanism. The output voltage is compared with the reference voltage which generates an error signal. That error signal is processed in the controller and a pulse signal is generated using PWM generator. The pulse signal is given to the gate terminal of the MOSFET switch in the proposed converter. Two types of controller has been used in the proposed system. The controllers are PI and FOPID controller. PI controller helps to reduce the steady state error of the system without affecting stability of the system. Fractional-order PID(FOPID) controller is more flexible and provide improved performance. FOPID is the expansion of conventional PID controller but integral order and derivative order are fractional.

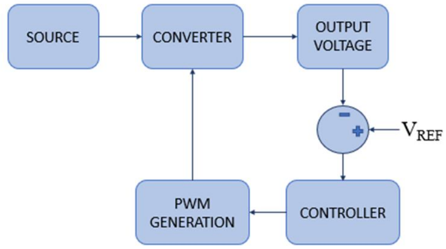

Fig. 3. Block diagram of closed loop system

III. SIMULATION AND PARAMETER

The simulation of the proposed system is done in the MATLAB environment with both open loop and closed loop control with PI and FOPID controller which is shown as follows.

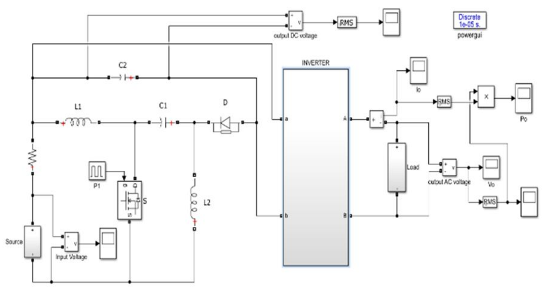

Fig. 4. Simulation diagram of proposed open loop system

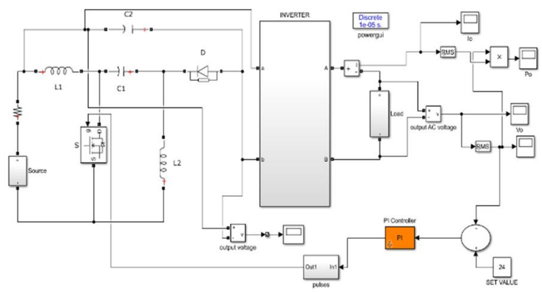

Fig. 5. Simulation diagram of proposed closed loop system with PI controller

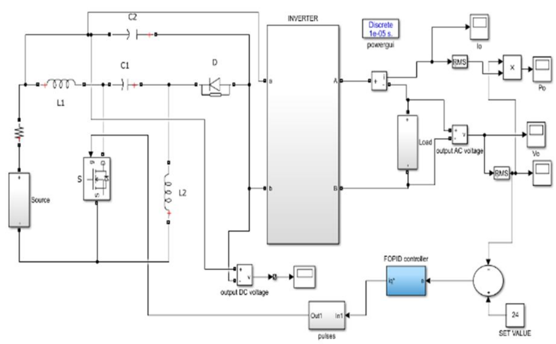

Fig. 6. Simulation diagram of proposed closed loop system with FOPID controller

The parameter values used in the simulation are tabulated as follows

TABLE I. PARAMETER VALUES OF SEPIC CONVERTER

PARAMETERS	VALUES
Switching Frequency	5kHz
Duty Cycle, D	0.5
Inductor, L_1, L_2	0.8μH, 10μH
Capacitors C_1,C_2	0.03F, 40mF
Ripple Voltage, ΔV	2%
Ripple Current, ΔI	40%
Resistor, R	50Ω

IV. Simulation Result Analysis

Fig 7(a) shows the output voltage from PV and battery and input voltage to the converter. Fig 7(b) shows the output voltage of the inverter. Initially irradiance is 1000W/m3 at time 0seconds the voltage obtaining from the solar is 12V. Since pv and battery are of same voltage level 12V is maintained. At time 0.5seconds, assuming irradiance is reduced so does the pv voltage. Hence sum of pv and battery voltage is obtained at the input terminal. Fig 8(a) shows the output voltage of the converter and Fig 8(b) shows the output voltage of the inverter of a closed loop system with PI controller. The gains of PI controller are proportional gain, KP=0.05 and Integral gain, Ki=1.5. The rise time and settling time of a PI controller is 0.54seconds and 5.15seconds respectively. After settling time the system reaches the steady state.

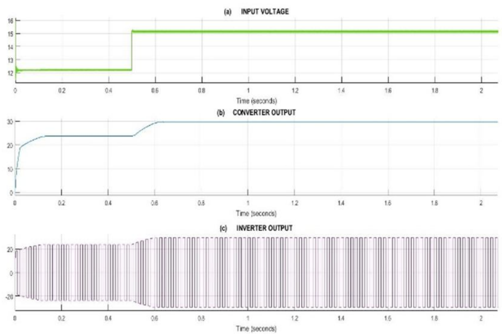

Fig. 7. Waveforms of open loop system (a) Input voltage (b)Converter output voltage (c) Inverter output voltage

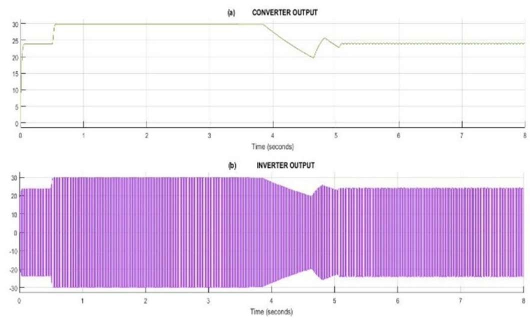

Fig. 8. Waveforms of closed loop system with PI controller (a) Converter output voltage (b) Inverter output voltage

Fig 9(a) shows the output voltage of the converter and Fig 9(b) shows the output voltage of the inverter of a closed loop system with FOPID controller. The gains of FOPID controller are proportional gain, K_P=0.05, Integral gain, K_I=1.5, Derivative gain, K_D=0.00000009 and K_S=0.9. The rise time and settling time of a FOPID controller is 0.52seconds and 2.88seconds respectively. After settling time the system reaches the steady state. Table II represents the comparison of time domain parameters of the PI and FOPID controller. It shows the rise time(T_r), peak time(T_p), settling time(T_s), and steady state error(E_{ss}) value of the PI and FOPID controller. As per the table II, FOPID controller has shown faster settling time and less steady state error when compared with the PI controller. Thus the system reaches stability faster and improves the system performance.

TABLE II. Comparison of Time Domain Parameters

TYPE OF CCONTROLLER	T_R	T_P	T_S	E_{SS}
PI	0.54	2.78	5.15	2.56
FOPID	0.52	1.65	2.88	1.84

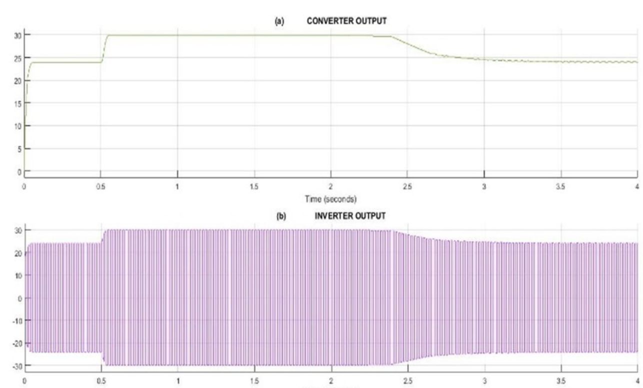

Fig. 9. Waveforms of the closed loop system with FOPID controller (a) Converter output (b) Inverter output

V. HARDWARE

Fig 10 shows the hardware setup of proposed open loop system. It consists of PV, Battery, converter, inverter, load and a controller. The controller consists of transformer, rectifier, 12V and 5V regulator, PIC controller and driver circuit. There are three driver circuit one for MOSFET switch in the converter and other two for MOSFET switches in the inverter. Fig 11 shows the hardware output waveform of the proposed open loop system. The switching frequency of the gate pulse is 5kHz. The output voltage of the converter shows 26.1V in the Fig 10 which is closer to the simulation results. Thus hardware implementation of the modified SEPIC converter is verified and analysed with the design parameters and simulation results.

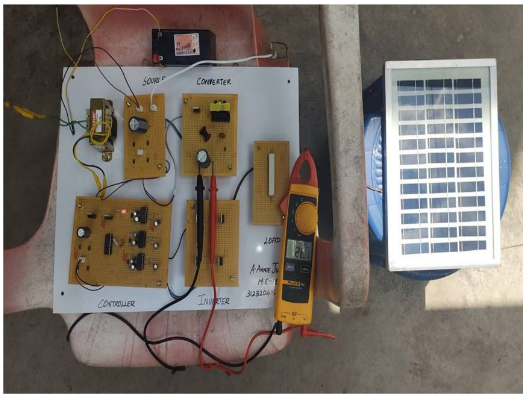

Fig. 10. Hardware setup of proposed open loop system

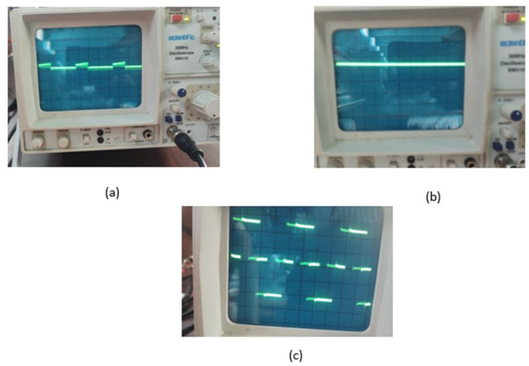

Fig. 11. Hardware output waveform (a) Gate pulse (b) Converter output (c) Inverter output

VI. CONCLUSION

The working of dual input voltage source-based non-isolated Single-Ended Primary-Inductor Converter (SEPIC) was successfully implemented in MATLAB simulation and hardware setup with PV module, and 12V Battery. The output of the converter was given to the inverter for converting dc voltage to ac voltage for AC loads. The performance of the proposed work was analysed with open loop and closed loop control with PI and FOPID controller. And FOPID controller provides improved performance and reaches steady state faster when compared to PI controller. The proposed converter is able to maintain its maximum output voltage of 24V for varying irradiation. The proposed work can be implemented in various applications where the output voltage needed to be constant irrespective of input voltage.

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