European Journal of Molecular & Clinical Medicine
ISSN 2515-8260 Volume 07, Issue 11, 2020

An Improved high Gain Converter for P&O based MPPT in PV System

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Abstract - This paper presents the fuzzy logic control based single-ended primary-inductor converter (SEPIC) and P&O (perturb & Observe) algorithm based maximum power point tracking (MPPT) operation of a photovoltaic (PV) system. The FLC proposed presents that the symmetrically distributed membership function gives faster response in tracking the peak power point. The fuzzy controller for both the SEPIC converter and inverter scheme shows better precision in current transition and keeps the voltage constant in the variable-load case, represented in small steady-state error and small overshoot. The proposed scheme of PV array proves its efficiency in variable load conditions, unity, and lagging power factor at the inverter output (load) side. The performance of the converter and inverter is tested in both simulation and experiment at different operating conditions. The performance of the proposed FLC-based MPPT operation of SEPIC converter is compared to that of the modified SEPIC converter. The modified sepic converter gives a high stability voltage gain for the PV applications. The results show that the proposed FLC-based MPPT scheme for SEPIC and modified SEPIC converter can accurately track the voltage and current of the PV system.

I. INTRODUCTION

Due to the increase in demand on electricity, and the crisis of conventional sources, the photovoltaic (PV) energy is emerging more now. It also becomes a promising alternative as it is omnipresent, freely available, environment friendly, and has less operational and maintenance costs [1]. The photovoltaic modules are used for both grid-connected power generation and off-grid power generation for remote areas and developing countries. Since the demand of PV generation systems seems to be increased for both standalone and grid-connected modes of PV systems there is a need for an efficient maximum power point tracking (MPPT) technique that is expected to track the peak power point at all environmental conditions and then force the PV system to operate at that MPP point. MPPT is an essential component of PV systems.

The selection of a proper dc–dc converter plays an important role for maximum power point tracking (MPPT) operation. The criteria for photovoltaic (PV) converter selection depend on many factors, such as cost, efficiency, flexibility, and energy flow. In this case, the flexibility represents the ability of the converter to maintain the output with the input varying, while the energy flow is assured by the continuous current of the converter. Among known converters, the SEPIC, conventional buck–boost, and Cuk converters have the ability to step up and step down the input voltage. Hence, this converter can transfer energy for all irradiation levels. Another desirable feature is continuous output current, which allows converter output parallel connection, or conversion to a voltage source with minimal capacitance.

The buck or boost converters are not preferable, due to the lack of output voltage flexibility. For example, for PV system battery charging, both buck and boost converters are unable to charge the battery continuously with MPPT operation because the power–voltage curve changes with irradiation level, and hence, the voltage corresponding to maximum power changes. There are many factors that can be considered for proposing the dc–dc converters, such as input/output energy flow, cost, flexibility, and PV array effect. Unlike a buck–boost converter, the SEPIC has a noninverted output, and it uses a series capacitor to isolate input from output [1]. The buck and buck–boost converters have discontinuous input current, which causes more power loss due to input switching. The boost converter usually has higher efficiency than the SEPIC; however, its output voltage is always larger than the input, which causes inflexibility in maximum power extraction. Both the SEPIC and the Cuk converter provide the choice to have either higher or lower output voltage compared to the input voltage. Furthermore, they have contentious input current and better efficiency compared to buck–boost and fly-back converters [2]. There is no general agreement in the literature on which one of the two converters is better, i.e., the SEPIC or the Cuk [3]–[10]. This paper seeks to use the SEPIC converter because of the Cuk converter's inverted output.

The MPPT algorithm represents optimal load for PV array, producing opportune voltage for the load. The PV panel yields exponential curves for current and voltage, where the maximum power occurs at the curve's mutual knee [11], [12]. The applied MPPT uses a type of control and logic to look for the knee, which in turn allows the SEPIC converter to extract the maximum power from the PV array. The tracking method used, i.e., perturb and observe (P&O) [13], [14], provides a new reference signal for the controller and extracts the maximum power from the PV array.
Among different intelligent controllers, fuzzy logic is the simplest to integrate with the system. Recently, the fuzzy logic controller (FLC) has received an increasing attention to researchers for converter control, motor drives, and other process control because it provides better responses than other conventional controllers [25]–[30]. The imprecision of the weather variations that can be reflected by PV arrays can be addressed accurately using a fuzzy controller. In order to take the advantages of the fuzzy logic algorithm, the MPPT algorithm is integrated with the FLC so that the overall control system can always provide maximum power transfer from the PV array to the inverter side, in spite of the unpredictable weather conditions. This paper presents an FLC-based MPPT operation of the SEPIC converter for PV inverter applications. As the proposed method always transfers maximum power from PV arrays to the inverter side, it optimizes the number of PV modules. The fuzzy controller for the SEPIC MPPT scheme shows high precision in current transition and keeps the voltage without any changes, in the variable-load case, represented in small steady-state error and small overshoot. As the inverter is used in a PV system, FLC is employed for more accurate output sine wave, higher dynamic performance under rapidly varying atmospheric milieu exploiting maximum power effectively, and improved THD, as compared to conventional PI-controlled converters.

II. PHOTOVOLTAIC SYSTEM

A photovoltaic system converts sunlight into electricity.The basic device of a photovoltaic system is the photovoltaic cell.Cells may be grouped to form panels or modules.Panels can be grouped to form large photovoltaic arrays.The term array is usually employed to describe a photovoltaic arrays.The term array is usually employed to describe a photovoltaic panel or groups of panels.

The electricity available at the terminals of a photovoltaic array may directly feed small loads such as lighting system and DC motors.Some applicaions require electronic converters to process the electricity from the photovoltaic device. These converetrs may be uesd to regulate the voltage and current at the load,tocontrol the power flow in grid connected systems and mainly to track the maximum power point (MPP) of the device.Photovoltaic arrays present a nonlinear I-V characteristic with several parameters that need to be adjusted from experienced data of practical devices.The mathematical model of the photovoltaic array may be useful in the study of the dynamic analysis of converters in the study of MPPT algorithms and mainly to simulate the photovoltaic system and its components using circuit simulators.

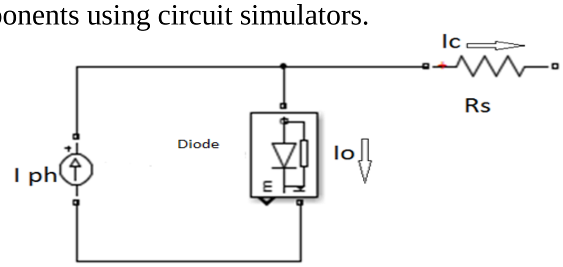

Figure 1. Electrical Model of Photovoltaic Cell.

III. P&O BASED MPPT ALGORITHM

To track the peak power point of the VI curve to utilise the maximum power output of the photovoltaic cell. We have lot of techniques under MPPT. Under these techniques Perturb and observe algorithm is used.

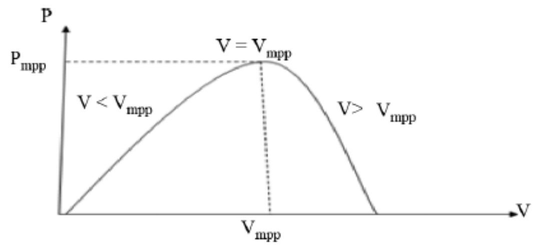

Figure 2. Characteristics of Photovoltaic cell.

The MPPT control technique is applied to achieve a new reference voltage for the fuzzy controller, which changes the duty cycle of the PWM signal for the SEPIC converter. The P&O algorithm has a simple structure and requires few parameters (i.e. power and voltage); that is why it is extensively used in many MPPT systems [21]–[24]. In addition, it can be easily applied to any PV panel, regardless of the PV module's characteristics for the MPPT process.

The P&O method perturbs the duty cycle and compares instantaneous power with past power. Based on this comparison, the PV voltage determines the direction of the next perturbation. P&O shows that, if the power slope increases and the voltage slope increases also, the reference voltage will increase; otherwise, it will decrease. The drawback of most of the fuzzy-based MPPT algorithms is that the tracking point is located away from the maximum power point when the weather conditions change. However, a drawback of P&O technique is that, at steady state, the operating point oscillates around the maximum power point giving rise to the waste of available energy, particularly in cases of constant or slowly varying atmospheric conditions. This can be solved by decreasing the step size of perturbation.

The step size of the P&O method affects two parameters: accuracy and speed. Accuracy increases when the step size decreases. However, accuracy leads to slow response when the environmental conditions change rapidly. Larger step size means higher speed for the MPPT operation, but this will lead to inaccuracy and larger intrinsic oscillations around the maximum power point in steady state. Step sizes should, thus, be chosen well to achieve high speed and accuracy. The step-size rate for the voltage reference signal used is 0.5V/ms.

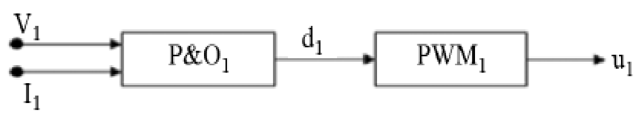

Figure 3. Traditional P & O technique

IV. SELECTION OF DC – DC CONVERTER

The single-ended primary-inductance converter (SEPIC) is a DC/DC-converter topology that provides a positive regulated output voltage from an input voltage that varies from above to below the output voltage. This type of conversion is handy when the designer uses voltages (e.g., 12 V) from an unregulated input power supply such as a low-cost wall wart. Unfortunately, the SEPIC topology is difficult to understand and requires two inductors, making the power-supply footprint quite large. Recently, several inductor manufacturers began selling off-the-shelf coupled inductors in a single package at a cost only slightly higher than that of the comparable single inductor. The coupled inductor not only provides a smaller footprint but also, to get the same inductor ripple current, requires only half the inductance required for a SEPIC with two separate inductors.

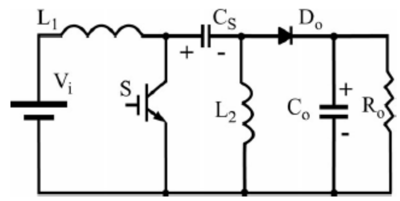

Figure 4. Classical Sepic Converter Circuit.

In Figure 3.5, the SEPIC converter can use single switch. However, for PV applications, the dc–dc converter can be used to supply the inverter, as well as to charge the batteries in standalone systems, hence using bidirectional switch.

Then the performance of sepic is compared with the modified sepic converter which presents a static gain close to twice of the classical boost converter and the switch voltage is close to half of the value obtained with the classical boost converter in the operation with high values of the duty cycle.

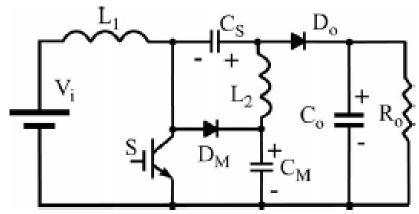

Figure 5. Modified Sepic Converter Circuit.

V. FUZZY LOGIC CONTROLLER

Recently fuzzy logic controllers have been introduced in the tracking of the MPP in PV systems [12-14]. They have the advantage to be robust and relatively simple to design as they do not require the knowledge of the exact model. They do require in the other hand the complete knowledge of the operation of the PV system by the designer.

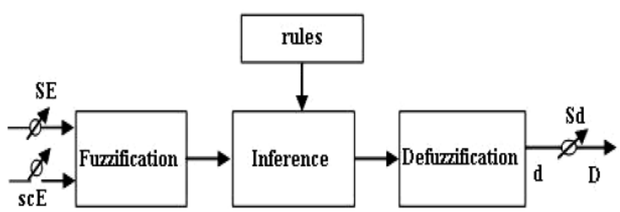

Figure 6. General diagram of a fuzzy controller

The proposed FL MPPT Controller, shown in Fig 5, has two inputs and one output. The two FLC input variables are the error E and change of error CE at sampled times k defined by:

$$E(k) = \frac{P_{ph}(k) - P_{ph}(k-1)}{V_{ph}(k) - V_{ph}(k-1)}$$

$$CE(k) = E(k) - E(k-1)$$

Where Pph(k) is the instant power of the photovoltaic generator.

The input E(k) shows if the load operation point at the instant k is located on the left or on the right of the maximum power point on the PV characteristic, while the input CE(k) expresses the moving direction of this point. The fuzzy inference is carried out by using Mamdani's method, and the defuzzification uses the centre of gravity to compute the output of this FLC which is the duty cycle:

$$D = \frac{\sum_{j=1}^{n} \mu(D_j) - D_j}{\sum_{j=1}^{n} \mu(D_j)}$$

The control rules are indicated with E and CE as inputs and D as the output. These two variables and the control action D are used for the tracking of the maximum power point.

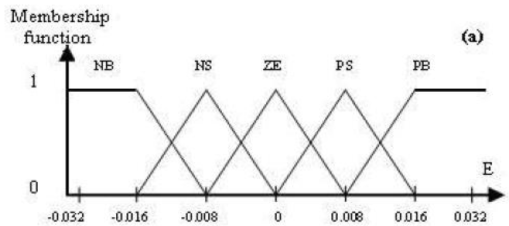

Figure 7. Membership Function for Error e(n)

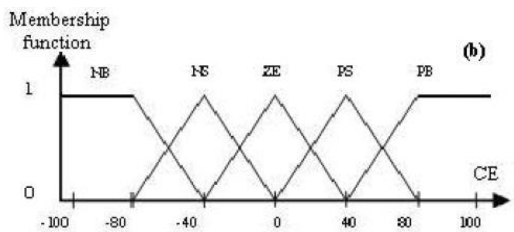

Figure 8. Membership Function for Change in Error E(n).

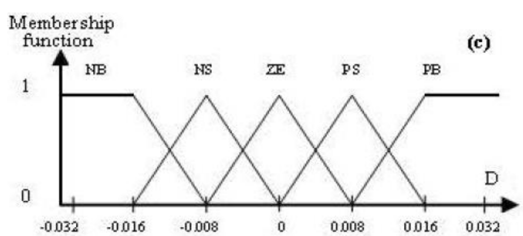

Figure 9. Membership Function for Duty Cycle D(n).

VI. SINGLE PHASE INVERTER

Single phase dc–ac inverter, also known as boost inverter it consists of two individual dc-dc boost converters, as shown in Figure 4.1. In this inverter topology, both individual converters are driven by two 180º phase-shifted dc-biased sinusoidal references whose differential output is an ac output voltage. The idea of controlling [8] the phase shift between two boost dc-dc converters to achieve a dc-ac inverter is also provided by the theory of phase modulated inverters.

ISSN 2515-8260 Volume 07, Issue 11, 2020

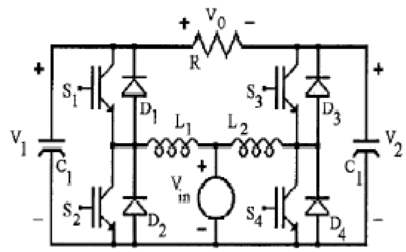

Figure 10. Single phase inverter circuit.

These converters produce a dc biased sine-wave output, although each source produces only a unipolar voltage. The modulation of each converter is 180º out of phase with the other, which maximizes the voltage excursion across the load. The load is connected differentially across the converters. Thus, whereas a dc bias appears at each end of the load, with respect to ground, the differential dc voltage across the load is zero. Thus a bipolar voltage at output is obtained by a simple push pull arrangement. One important requirement is that the dc–dc converters need to have bidirectional current carry capability.

The principle of boost inversion with two dc–dc converters can be explained through the current bidirectional boost dc–dc converter. For a dc–dc boost converter, by using the averaging concept, the input–output voltage relationship for continuous conduction mode is given by where D is the duty cycle. The voltage gain, for the boost inverter, can be derived as follows: assuming that the two converters are operated 180º out of phase. The boost dc-ac inverter exhibits several advantages, the most important of which is that it can naturally generate an ac output voltage from a lower dc input voltage in a single power stage. This boost inverter achieves dc-ac conversion by connecting the load differentially across two dc-dc converters and modulating the dc-dc converter output voltage sinusoidal without using transformer. The proposed boost inverter circuit has several desirable features such as low cost and compact size as number of switches used.

VIII. RESULTS AND DISCUSSION

The PV panel is designed in MATLAB/SIM POWER SYSYEMS with the temperature value as 40+273.15 and irradiance value as 700.The output voltage coming from PV is the initial dc voltage coming from PV panel which is boosted with the converter subsystem.

From this panel subsystem, the voltage Vpv and the current Ipv is taken and tracked for obtaining maximum peak point in the MPPT curve. Ppv = Vpv * ipv is determined and given to the feedback loop to next subsystem of inverter circuit.

A basic electrical model is represented with voltage controlled current source to get the short circuit current Ish and Im. A diode is used since PV panel is made of semiconductor material which intakes the material properties.

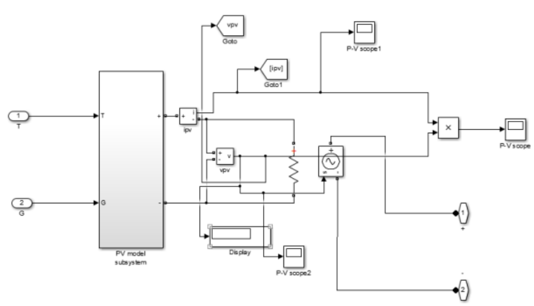

Figure 11. Simulink Model for PV System

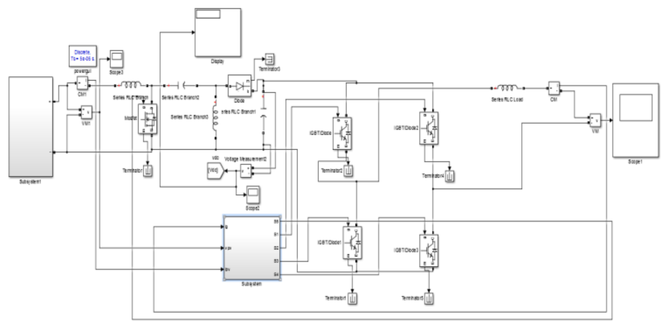

Figure 12. Simulink Model of FLC based Sepic Converter and Inverter.

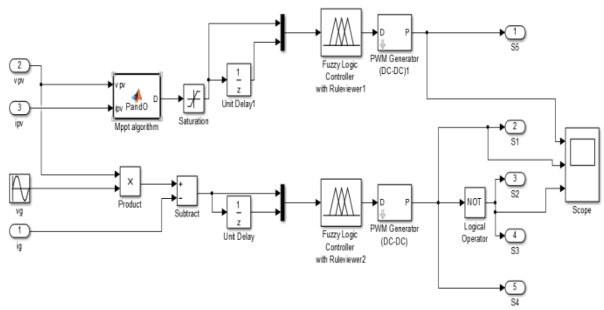

Figure 13. Simulink Model of Fuzzy Control Block.

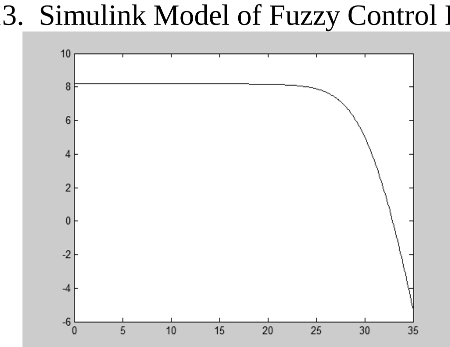

Figure 13. Voltage and Current Characteristics of PV.

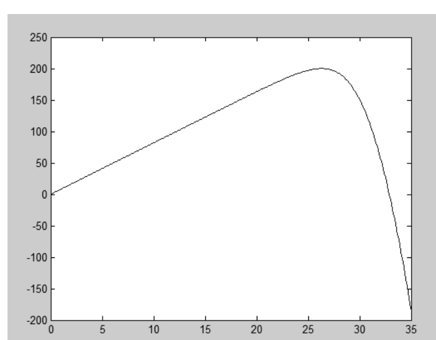

Figure 14. Voltage and Power Characteristics of PV.

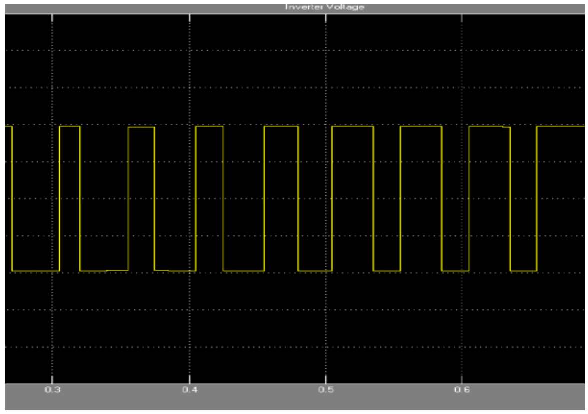

Figure 15. Inverter output Voltage.

The total harmonic Distortion of sepic and modified sepic converter is compared and the inverter gives continuous output current.

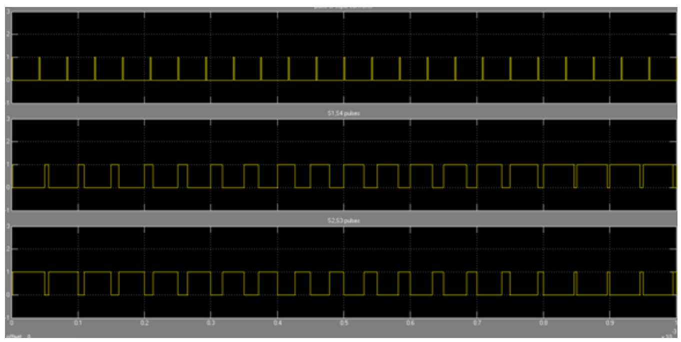

Fig 16 Pulses for Converter and Inverter.

VII. CONCLUSION

An FLC-based MPPT scheme for the SEPIC converter and inverter system for PV power applications has been modeled and simulated in MATLAB. The performance of the proposed sepic converter is compared with the modified sepic converter and found that modified sepic converter gives better output .The experimental results indicated that the proposed FLC scheme can provide a better THD level at the inverter output. Thus, it reduces the cost of the inverter and the associated complexity in control algorithms. Therefore, the proposed FLC-based MPPT scheme for the modified SEPIC converter is for real-time PV inverter applications under variable load conditions.

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