COMPARATIVE ANALYSIS OF SEPIC AND LUO CONVERTER WITH MPPT ALGORITHMS

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ABSTRACT - *Photovoltaic (PV) energy is one of the most important energy resources since it is clean, pollution free and endless.The PV system can supply the maximum power to the load at a particular operating point which is generally called as maximum power point (MPP), at which the entire PV system operates with maximum efficiency and produces its maximum power. These techniques vary in many aspects such as simplicity, digital or analogical implementation, sensors, convergence speed and range of effectiveness, hardware implementation, popularity and cost in other aspects. Maximum Power Point Tracking (MPPT) algorithms is important in PV systems because it reduces the PV array cost by reducing the number of PV panels required to achieve the desired output power. This paper presents a comparative simulation study of two important MPPT algorithms specifically perturb and observe and incremental conductance. These algorithms are widely used because of its low-cost and ease of realization. Some important parameters such as voltage, current and power output for each different combination has been traced for both algorithms. Two dissimilar converters like Sepic and Luo are used proportional in this study. Like buck-boost converters Sepic have a pulsating output current and it requires current handling capability. To overcome these drawbacks the Luo converter is used, it has the ability to reduce ripple voltage and current levels without inverting the polarities. The converters with incremental conductance can track the maximum power with reduced oscillations. The Sepic and Luo converter with MPPT (Perturb and Observe, incremental conductance) algorithms are simulated and the results are compared in PSIM software.*

Keywords— Maximum Power Point Tracking, Sepic and converters, PV module, perturb and observe, incremental conductance*.*

1.INTRODUCTION

Photovoltaic (PV) generation represents currently one of the most promising sources of renewable green energy. Due to the environmental and economic benefits, PV generation is preferred over other renewable energy sources, since they are clean, inexhaustible and require little maintenance. PV cells generate electric power by directly converting solar energy to electrical energy. PV panels and arrays, generate DC power that has to be converted to AC at standard power frequency in order to feed the loads. Therefore PV systems require interfacing power converters between the PV arrays and the grid. Photovoltaic-generated energy can be delivered to power system networks through grid-connected inverters. One significant problem in PV systems is the probable mismatch between the operating characteristics of the load and the PV array. The system's operating point is at the intersection of the I-V curves of the PV array and load, when a PV array is directly connected to a load. The Maximum Power Point (MPP) of PV array is not attained most of the time. This problem is overcome by using an MPPT which maintains the PV array's operating point at the MPP.

A maximum power point tracker is used for obtaining the maximum power from the solar PVmodule and conversion to the load. A non-isolated DC-DC converter (step up/ step down) offersthe purpose of conversion maximum power to the load. A DC-DC converter acts as an interface between the load and the module. By varying the ratio of duty cycle the impedance of load as itappears by the source is varied and matched at the peak power point with the source so as toconversion the maximum power. Therefore maximum power point tracker methods are required to maintain the PV array'sworking at its MPP. Many MPPT methods have been suggested arePerturb and Observe (P&O) methods, Incremental Conductance (IC) methods and constantvoltage methods etc. In this paper the most popular of MPPT technique (Perturb andObserve (P&O) method, Sepic and Luo DC-DC converters will involve inthe comparative study.Some results such as current, voltage and output power for each various combination have beendiscussed. The MPPT technique will be implemented, by using PSIM software.

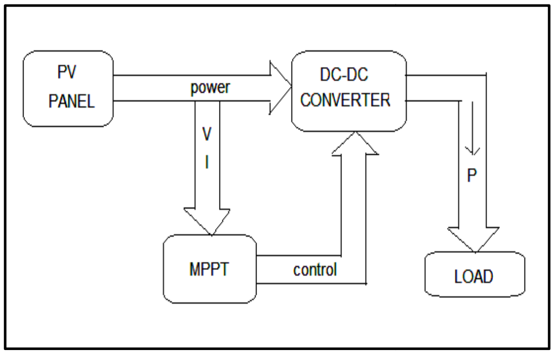

Figure.1 DC-DC converter for operation at the MPP

The most control scheme used is the P&O technique because it is easy to implement. But the oscillation problem is unavoidable. An incremental conductance (INC) MPPT method that is implemented by reducing oscillation problem. These maximum power point technique are faster and also it can minimize the voltage fluctuation after MPP has been recognized. The circuit diagram of photovoltaic system is shown figure.1. The MPPT algorithms are modelled using PSIM input/output ports and conditional blocks. The PV system is modelled using power system block set under PSIM.

2.CIRCUIT CONFIGURATION

The DC-DC converter transfers voltage from the source to load. At first, energy is transferred to switches and it is stored. Then it is supplied to load. The DC-DC converter, which is used for performance analysis for this paper are Sepic and Luo converters.

2.1 SEPIC 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.12V) from an unregulated input power supply. One converter that provides the needed input-to-output gain is the SEPIC (single-ended primary inductor converter) converter. A SEPIC converter is shown in figure 2. It has become popular in recent years in battery-powered systems that must step up or step down depending upon the charge level of the battery. SEPIC is a type of DC-DC converter, that allows the voltage at its output to be more than, less than, or equal to that at its input. The output voltage of the SEPIC is controlled bythe duty cycle of the MOSFET. A SEPIC is similar to a traditional buck-boost converter, but has advantages of having non-inverted output, by means of coupling energy from the input to the output is via a series capacitor. When the switch is turned off output voltage drops to 0 V. SEPIC is useful in applications like battery chargingwhere voltage can be above and below that of the regulator output.

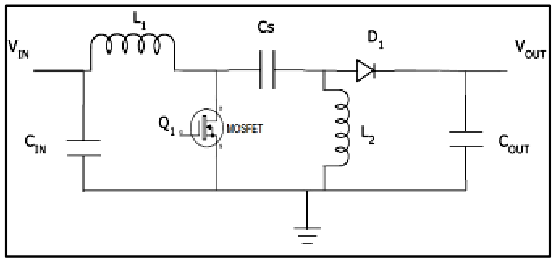

Figure.2 Circuit diagram of SEPIC converter

2.1.1 MODE I

A SEPIC is said to be in continuous conduction mode if the current through the inductor L_1 never go down to zero. During a SEPIC's steady-state operation, the average voltage across capacitor Cs (VCs) is equal to the input voltage (V_{IN}). Because capacitor Cs blocks direct current. The average current across it (ICs) is zero, making inductor L_2 the only source of load current. Hence the average current through inductor L_2 is the same as the average load current and hence independent of the input voltage.

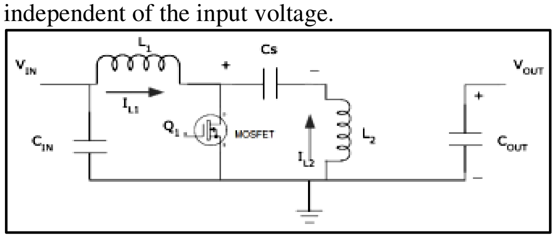

Figure.3 SEPIC on state (continuous conduction mode)

When switch Q_1 is turned on, current IL_1 increases and the current IL_2 increases in the negative direction. The energy to increase the current IL_1 comes from the input source. Since Q_1 is a short while closed, and the instantaneous voltage VCs is approximately V_{IN}, the voltage VL_2 is approximately $–V_{IN}$. Therefore, the capacitor Cs supplies the energy to increase the magnitude of the current in IL_2 and thus increase the energy stored in L_2.

2.1.2 MODE II

When switch Q_1 is turned off, the current ICs becomes the same as the current IL_1, as the inductors will not allow instantaneous changes in current. Current IL_2 will continue in the negative direction, in fact it never reverse direction. It can be seen from the figure.4 that a negative IL_2 will add to the current IL_1 to increase the current delivered to the load.

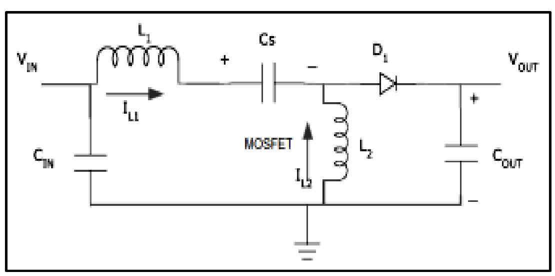

Figure.4 SEPIC off state (discontinuous conduction mode)

2.2. LUO CONVERTER

The Luo converters perform DC-DC voltage increasing conversion with high power density, high efficiency, and cheap topology in simple structure. They are different from any other DC-DC step up converters and possess many advantages including a high output voltage with reduced ripples. Therefore, these converters are widely used in computer peripheral equipment and industrial applications, especially for high output voltage projects. These rapidly efficient DC-DC converters must be used to provide appropriate voltage levels and the power management between different energy level sources and storage elements. The proposed developed DC-DC converter is Luo converter it overcomes the parasitic problems present in the classical dc-dc converter.

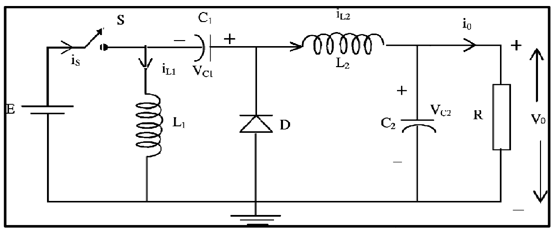

Figure.5 Circuit diagram of Luo converter

2.2.1. MODE I

When the switch is ON, the inductor L_1 is charged by the supply voltage E. At the same time, the inductor L_2 absorbs the energy from source and the capacitor C_1 shown in figure 3.2. The load is supplied by the capacitor C_2. The equivalent circuit of Luo converter in mode 1 operation is shown in figure.6.

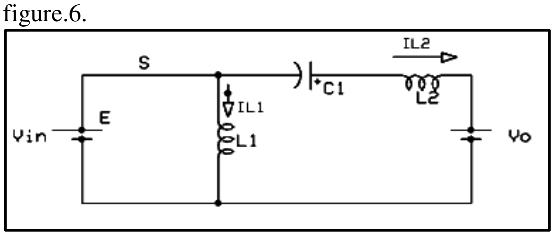

Figure.6 ON state (continuous mode)

2.2.2 MODE II

When switch is in OFF state, and hence, the current is drawn from the source becomes zero, as shown in figure.7. Current IL_1 flows through the freewheeling diode to charge the capacitor C_1. Current IL_2 flows through C_2-R circuit and the freewheeling diode D to keep itself continuous.

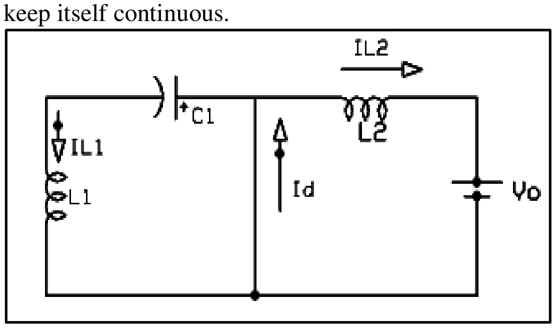

Figure.7 OFF state (discontinuous mode)

3. MAXIMUM POWER POINT TRACKING

MPPT algorithms are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array. The MPPT is done by matching source impedance with the load impedance. So impedance matching should be clearly done to get maximum power point.

$Z_S = Z_L^*$

3.1 PERTURB AND OBSERVE

Perturb & Observe (P&O) is the simplest method. In this we use sensors to sense the PV array voltage and so the cost of implementation is less. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of thealgorithm. The change of power which defines the strategy of the P&O technique is described in the following equation.

$\Delta P = P_K - P_K - 1$

The flow chart of the P&O method is shown in figure.8. The voltage and the current value of each instant is sensed in the algorithm and the power value is calculated. For the power value at each instant, the duty ratio is updated based on the algorithm.

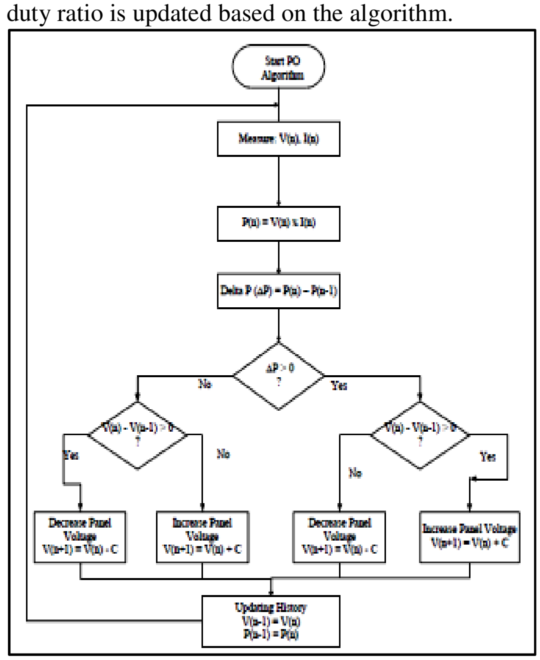

Figure.8 Flow chart of P&O algorithm

3.2 INCREMENTAL CONDUCTANCE

In this method, the array terminal voltage is always adjusted according to the MPP voltage. It is based on the incremental and instantaneous conductance of the PV module, that the slope of the PV array power curve is zero at the MPP, increasing on the left of the MPP and decreasing on the right-hand side of the

MPPT. The basic equations of the incremental conductance method is,

dI/dV = - I/V, at MPP

This method inherently has a good efficiency, the aforementioned amendments increase the complexity and cost of the system and there was no remarkable change in system efficiency. When compared to perturb and observe MPPT method, these algorithm used to track the maximum power output with reduced oscillations. First we measure the PV voltage and current, then we calculate the change in voltage and change in current. Again we check the conditions given in flowchart until we can track the maximum power. Flow chart for the incremental conductance is given below in figure.9.

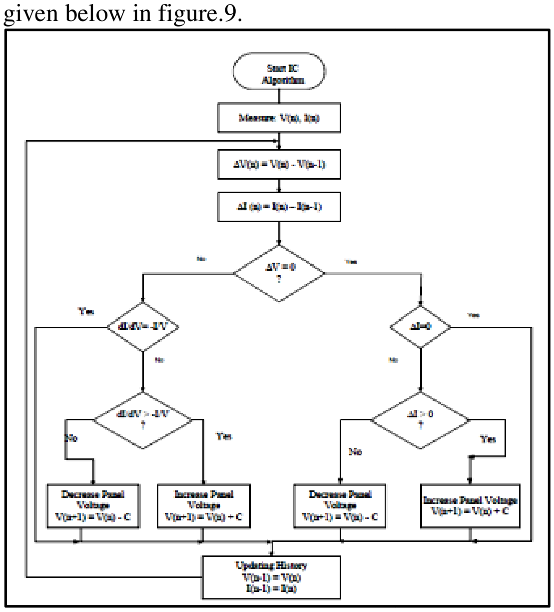

Figure.9 Flow chart of IC algorithm

4. SIMULATION RESULTS

4.1SIMULATION MODEL OF SEPIC CONVERTER

Figure shows the simulation model of the sepic converter in PSIM software. The output power is measured and track the maximum power by using the MPPT algorithms.

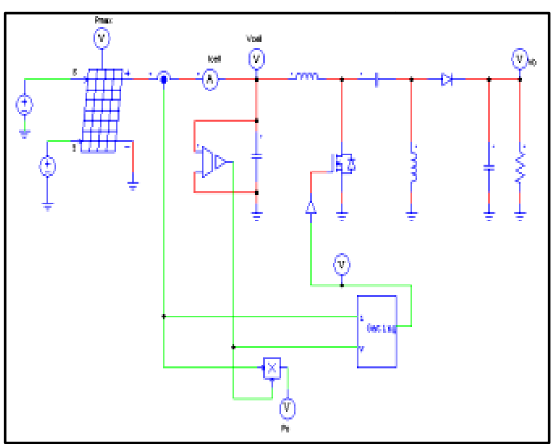

Figure.10 Simulation model of SEPIC converter

The main circuit parameters are chosen as follows:

(1) Panel size : 60W
(2) Panel voltage : 17.1V
(3) Short circuit current : 3.8amps
(4) Irradiance : 1000
(5) Temperature : 25*C
(6) Number of cells : 36
(7) Capacitance : 36u
(8) Resistance : 50

4.2 SIMULATION MODEL OF LUO CONVERTER

Figure shows the simulation model of luo converter operated at the maximum power. Luo converter helps to reduce the oscillations as well as it has the better current handling capability.

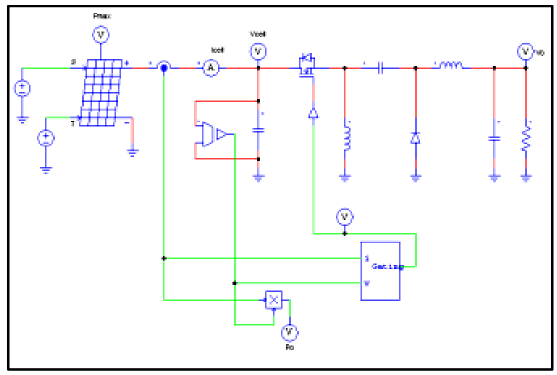

Figure.11 Simulation model of LUO converter

4.3 SUBCIRCUIT OF P&O

The sub circuit used here is for tracking the maximum power which is given to the converter gate pulse and it generate the triggering pulse for the operation of converter. This tracking method is very simple but does not produce the better output. The power output of this algorithm with converter have oscillations. The simulation diagram of the P&O algorithm is developed using the input/output ports and the conditional blocks. The circuit modelling is shown in figure.

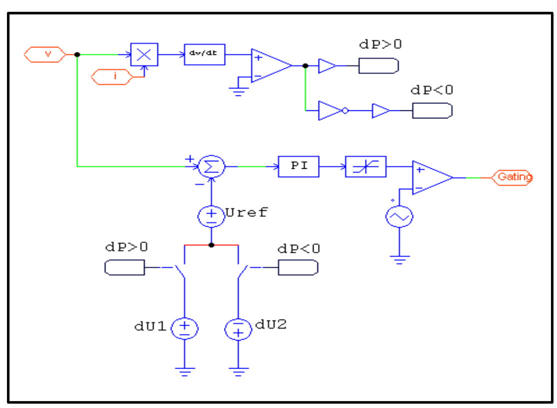

Figure.12 Sub circuit of P&O

4.4 SUB CIRCUIT OF INCREMENTAL CONDUCTANCE

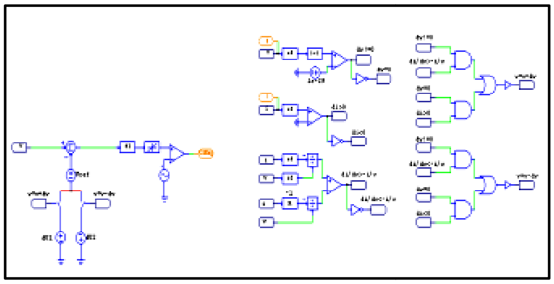

Figure.13 Sub circuit of IC

4.5 OUTPUT POWER OF SEPIC WITH P&O

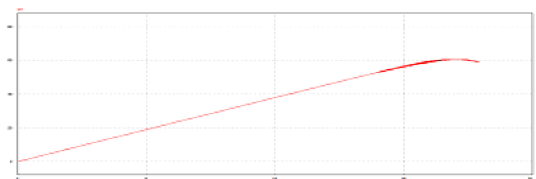

Figure.14 Output power of SEPIC with P&O

4.6 OUTPUT POWER OF LUO WITH P&O

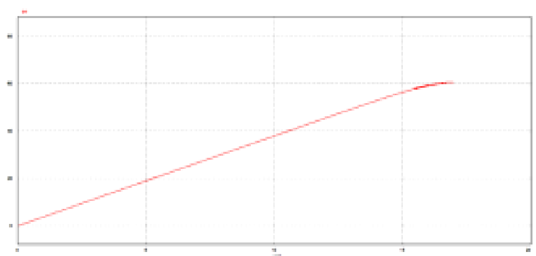

Figure.15 Output power of LUO with P&O

When using perturb and observe method along with converters produce the power output with oscillations shown in figure 5.5 and figure 5.6. These drawback can be avoided by using the incremental conductance algorithm.

4.7 OUTPUT POWER OF SEPIC WITH IC

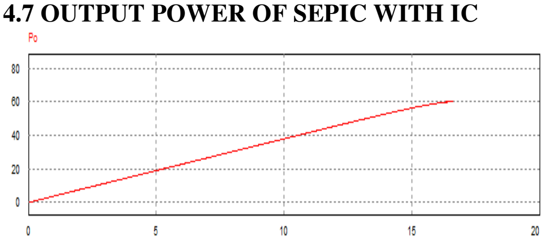

Figure.16 Output power of SEPIC with IC

4.8 OUTPUT POWER OF LUO WITH IC

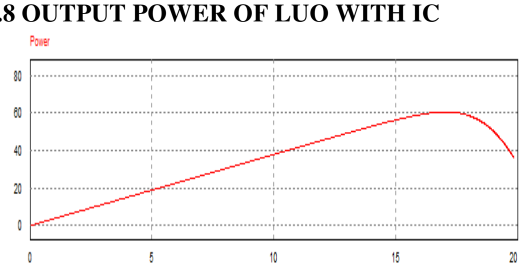

Figure.17 Output power of LUO with IC

The converter with incremental conductance produce the power with reduced oscillations. The figure 5.7 and figure 5.8 shows the power outputs of incremental conductance with reduced oscillations.

4.9 I-V CHARACTERISTICS OF PV PANEL

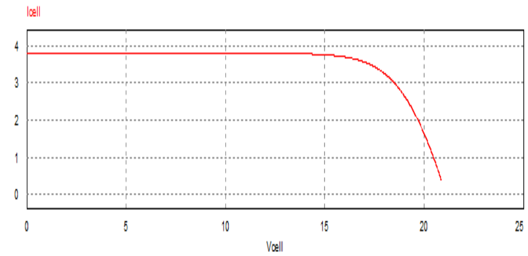

Figure.18 I-V characteristics of panel

5.CONCLUSION

. The maximum power point varies with insolation and temperature, so to achieve maximum power it is necessary to match the provided load impedance to the internal impedance characteristics of PV panel such that the equilibrium operating point coincides with maximum power point. This study compares the performance of SEPIC and LUO converters used in MPPT design using perturb and observe as well as incremental conductance technique. When comparing the power graph of two converters it can be concluded that the MPPT techniques of perturb and observe method converges slowly when compared to the incremental conductance method. Incremental conductance based MPPT technique is used to track the maximum power point exactly and the converters with incremental conductance can track the maximum power with reduced oscillations. LUO converter based PV power generation along with the incremental conductance is more efficient with reduced voltage ripple. The SEPIC and LUO converter with MPPT (Perturb and Observe, incremental conductance) algorithms are simulated and the results are compared in PSIM software.

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