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Performance Analysis of SEPIC converter Fed PV System

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Abstract- *Photovoltaic (PV) systems are a choice of conventional energy sources that contribute significantly to the resolution of energy problems. The adverse effects of fossil fuel on the environment are even mitigated by combining fossil-fuel plants with renewable energies (e.g. photovoltaic system). The basic problem of the present PV system is the effect of climate, the dc-dc converter. Here in this paper discuss the new type of dc-dc converter SEPIC for implementation of the PV system with the MPPT. The whole work is simulated in MATLAB software for checking the validation of the proposed converter in PV system.*

Keywords:- PV System, SEPIC, MPPT, BCC, SPTLE, SOFLC.

Introduction

Over the decades, the development, investigation, and application of renewable energies such as wind, solar, Hydro and tidal power have strengthened global environmental concerns regarding the amount of CO_2 emitted into the atmosphere by human activities. In addition to this, the hybrid system combined with renewable sources is being increasingly used for the use of renewable energy.

Photovoltaic solar systems are a choice of conventional energy sources that contribute significantly to the resolution of energy problems. The adverse effects of fossil fuel on the environment are even mitigated by combining fossil-fuel plants with renewable energies (e.g. photovoltaic system). The need to reduce carbon emissions has affected the price of photovoltaic systems and in particular of solar modules, thus increasing the profitability of photovoltaic. Solar is an energy source driven by climate, it varies considerably over time and the area. Planning and implementation of any SPV system are quite demanding multi-stage processes including site solar potential assessment, photovoltaic source assessment, overall feasibility, design, simulation, system output optimization and long-term performance. Various tools and databases for the design, sizing, modeling and simulation and performance assessment of PV systems are now available. The current problem is that due to the great complexity of the process, only one tool by itself cannot perform a complete analysis of a PV system. Thus, input data and results are commonly combined with various modeling size and design tools together with measurements on the site in order to achieve the most reliable results.

In this paper here discuss the performance analysis for the application of new type of converter single ended primary inductor converter (SEPIC) in the PV system for DC microgrid. In the next section firstly discuss the background of the the MPPT system and dc-dc converter topology which is used in current scenarios. After that discuss the SEPIC converter working and application, and then discuss the implementation and performance of the proposed PV system.

II. Background of MPPT in PV System

The solar irradiance is dynamic in nature with temperature. Therefore an online algorithm is necessary which calculates dynamically the solar panel operating point. With the Maximum Power

Point Tracks (MPPT) algorithm, efficient solar energy conversion is possible. This chapter deals with the different algorithms in MPPT and its topology.

Trishan Esram et al [1] talk about numerous methodologies in their paper for tracking maximum power points (MPPs) for PV arrays. Hung-I Hsieh et al [2] proposed a PV-PC for lead-acid battery guiding a high-frequency photovoltaic pulse charge for the purpose of maximum power point tracking, to eliminate sulfate crystallization on the LAB electric plate and extend the battery life by a PV-PC implemented by a Boost Current Converter (BCC).

K.H. Hussein et al [3] developed the algorithm of incremental and instantaneous conductance of a PV-Array for tracking Maximal Power Point (MPP). Zheng Shicheng et al [4] suggested new MPPT method for PV array feature and theory of operation called the CVT (Constant Voltage Tracking) analysis. Noppadol Khaehintung et al [5] present an adaptable self-organizing Fuzzy Logic Controller (SOFLC) with an integrated MPPT system with a low-cost microcontroller for Solar powered Traffic Light Equipment (SPTLE), which consists of an HPC converter. C. S. Chin et al [6] presented a Fuzzy-based solar panel MPPT with Perturb and observation (P&O) algorithm. \

Panom Petchjatuporn et al [7] implemented maximum power point tracking algorithm using the solar energy systems with artificial neural network. S. Yuvarajan et al [8] proposed for a photovoltaic panel that uses open circuit voltage and short circuit current to have a quick and accurate Maximum Power Point Tracking (MPPT) algorithm. Prof. Dr. Ilhami Colak, et al [9] modeled three separate solar farms with a capacity of 15kW, using real-time analysis software from MATLAB/Simulink.

S. G. Tesfahunegn et al [10] designed a new solar-battery charging controller has which is the combination of MPPT and over-voltage control systems as a single function. Yuncong Jiang et.al [11] presents a photovoltaic (PV) solar system addition with Maximal Power Point Tracking (MPP) controller using a load current to maximize solar output power.

Arash Shafie et al [12] proposed a new algorithm of MPPT, mainly for applications considering constant voltage loads for battery charge. This has mainly been achieved with the maximization of output current. Ali F Murtaza et al [13] addresses this problem of P&O technology and therefore presents a new hybrid MPPT technique that combined two basic technologies i.e. P&O and FOCV techniques to overcome the legacy shortcomings found in P&O technology.

Weidong Xiao et al [14] introduce a performance analysis of photovoltaic modules in non-ideal and topological conditions to minimize the performance degradation resulting from these conditions. Jun Pan et al [15] present a design of photovoltaic loading system with maximum power point tracking (MPPT) according to output characteristics of photovoltaic (PV) array and battery charge characteristics. Sandeep Anand et al [16] proposed controlled battery life limitation. The dc-dc converter was used in this paper as an autonomous dc system to connect solar photovoltaic with batteries.

Mohamed Azab [17] submitted a new photovoltaic arrays maximum power point tracking algorithm. The PV's maximum power point is determined by this algorithm. A reference value (set point) of the control system was used as the calculated maximum power. Ashish Pandey et al [18] describe the limitation of Perturb & Observe (P&O) method which changes constantly with changing of environmental conditions. A variable step-length algorithm was proposed, which reduced the drift by evaluating the whole trend in a voltage / power curve.

Ahmed k et al.[19] propose a high-performance P & O-based MPPT adaptive system. This paper presents an amended P&O MPPT technique for PV systems. The technique proposed achieves:

firstly, adaptive tracking; thirdly, no stable state oscillations of MPP; and lastly, a generic design core, which is not required for predefined system-dependent constants. Y.Jiang et. al [20] present adaptable step-size Digital MPPT Single Photovoltaic Sensor Controller with adaptive-perturbation frequency.

Venkata Reddy et al [21] present the PV Modules Using a 2-dimensional Lookup table as the Simple and Efficient MPPT Scheme. Venketa Reddy Kota et al [22] present a new MPPT P&O scheme based on linear tangents. This document provides an overview of traditional MPPT algorithms for maximum power points.

Ahmad Ghamrawi et.al [23] presents a new algorithms based on a Perturb and Observe (P&O) modified algorithm for maximum strength tracking. Ke Yan et.al [24] proposes a new solution in order to balance the performance of the MPPT method with the cost. The disturbance step dimension is determined offline based on local irradiance data for a particular location.

III. Working & Application of SEPIC Converter

Many converters only have to buck or boost the voltage tendency and so it can be use as the related converters easily. The desired output voltage is however sometimes within the input voltage range. If this is the case, a converter which can reduce or increase the voltage should usually be used best. Buck-boost converters can be less expensive as only one inductor and a condenser are required. These converters however are affected by a large amount of current input ripples. This ripple can produce harmonics, which involve the use of a large condenser or a LC filter in many applications. This makes it often costly or ineffectual to boost buck. The fact that they invert voltage is also an issue that can make the use of a buck booster converter difficult. Converters overcome these two problems by using an extra condenser and inductor. The operation of both the Cúk and the Buck-Boost converter, however, causes high electronic pressure of the components, which can lead to failure or overheating. Both of these problems are resolved by SEPIC converters. Circuit diagram shown in Fig. I is SEPIC DC / DC converter. It consists of one Power switch, one diode (D), two inductor (L1 and L2) and two condensers (C and C1).

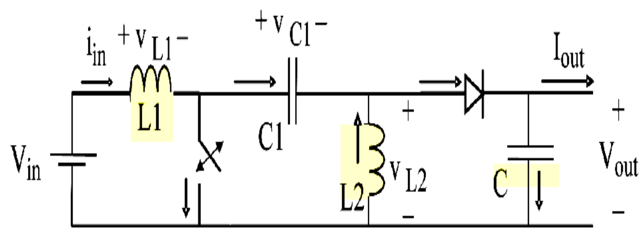

Fig I: Schematic Diagram of SEPIC Converter.

The working of the SEPIC converter is divided in two basic modes as shown in Fig II. & Fig III

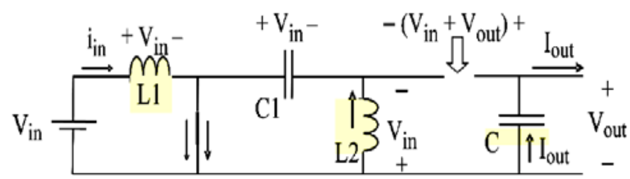

Fig II: ON State Mode of Operation.

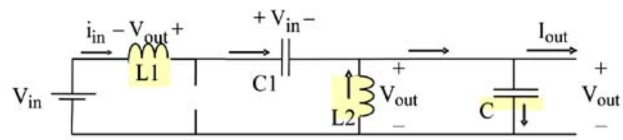

Fig III: OFF State Mode of Operation.

When the switch is shut down by the diode in reverse, the cathode is more positive than the anode, and the voltage supply power to the inductive system (L1), condenser (C1). Output voltage V_{out} also discharges the condenser (C) in the time condenser (C). By the KVL

$$V_{C1} = V_{L1} = V_{in} \qquad [1]$$

If the switch is opened, the diode is biased and leads because the anode is more positive than the cathode, and the condenser supplies V_{out} with heat, and the inductor (L1) current flows across the condenser (C1) and the diode. An inductive discharge that is reverses the polarity of its voltage. Condenser (C1 and C) are charges in this mode. By the KVL

$$V_{L1} = V_{out} \quad [2]$$

$$(V_{L1}, SW\ Closed)(DT) + (V_{L1}, SW\ \text{Open})(1-D)T = 0$$
[3]

$$V_{in}(DT) - V_{out}(1-D)T = 0 \quad [4]$$

$$V_{out} = V_{in}\left(\frac{D}{1-D}\right) \quad [5]$$

$$\text{D = Duty Cycle} = \frac{T_{on}}{T} = \frac{V_{out}}{V_{out} + V_{in}} \quad [6]$$

The formula shows that the output voltage is achieved by multiplying the input voltage by the duty cycle. i.e The SEPIC converter's output voltage is always less, greater and equal to the input voltage.

The operation of the SEPIC converter is also in two different modes:

1. Continuous Conduction Mode of operation (CCM): In this mode the inductor current always remains low as shown in Fig. IV. In most of the applications of the SEPIC converter, once fully loaded, the inductor current never drops to zero and the output produced is usually better.

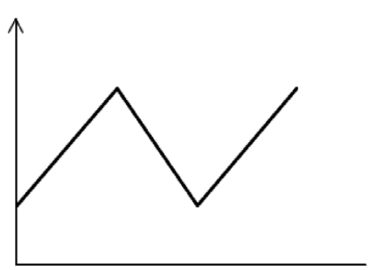

Fig IV: Continuous Conduction Mode of Operation.

2. Discontinuous Conduction Mode of Operation (DCM): In this mode, the inductor current falls to zero and remains at zero during the specified switching cycle period shown in Fig V. It starts at zero and reaches a high value. It is used in applications that have a relatively low maximum load current that can reduce the total converter size.

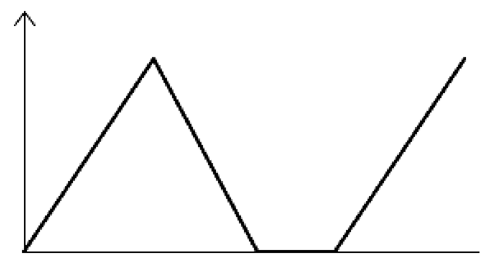

Fig V: Discontinuous Conduction Mode of Operation.

IV. Design Calculation of L and C for SEPIC

The first step is needed to calculate the values of an inductor and a condenser based upon the equations for the design of a SEPIC converter [1]. The inductor value is measured by,

$$L1 = \frac{V_{in} * D}{i_{ripple} * f} \quad [7]$$

$$L2 = \frac{V_{out} * (1-D)}{i_{ripple} * f} \quad [8]$$

Where, i_{ripple} is the ripple current through the inductor.

A true ripple current value must be chosen in determining the inductor value (L1 and L2). If the value for ripple current is chosen at an extremely low value, then it must have a relatively high value and a very large and very expensive inductor would be required. If the value for the Ripple current is chosen at a very high value, the MOSFET switching loss is increased. Between these impacts, there would be optimum option. The value of the rib current is usually assumed to be 10% to 30% of the average output current in order to achieve a good converter efficiency.

$$i_{ripple} \approx 0.10 \times I_{Load} \quad [9]$$

Capacitor value is determined as:

$$C1 = \frac{i_{out} * D}{\Delta V_{C1} * f} \quad [10]$$

$$C2 = \frac{i_{out} * D}{\Delta V_{C2} * f} \quad [11]$$

Where, ΔV_{C1} and ΔV_{C2} = output voltage ripple

The value of the output voltage ripple is usually assumed between 1% and 2% of the output voltage to achieve good converter efficiency.

V. Simulation & Results

The aim of this paper is to develop the new type of cost effective DC microgrid for the different type of DC loads. So for this here in this paper a SEPIC converter fed solar based DC Micro grid is developed. Figure VI shows that the SIMULINK model of the proposed work. The whole work is modeled in the MATLAB software for checking the performance of the proposed system.

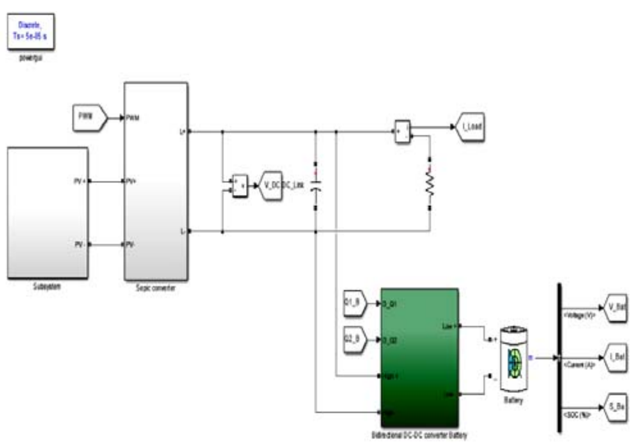

Fig VI: Proposed SIMULINK model of DC Microgrid.

The whole work is simulated in MATLAB 8.2 to validate the result. The whole model is run in the solver using 23tb ODE. The total run time of the simulation in this project is 3 sec. The various results are obtained which is discussed in this section. Table I shows the parameter which is used in this simulation of the PV module. Here in this thesis we used SEPIC converter as DC-DC converter.

Table I: Parameter used in SIMULATION

Parameter	Value
Parameter Used in PV System Modelling	
No of Series Cell	96
Open Circuit Voltage of PV Module (V_{oc})	64.2 V
Short Circuit Current (I_{sc})	5.96 A
Series Resistance (R_{se})	0.118 Ω
Shunt Resistance (R_{sh})	360
No of Series and Parallel Module	2
Parameter Used in SEPIC Converter	
SEPIC Inductor (L_2 & L_3)	L_2=L_3=56.667 µH
SEPIC Capacitor	20.9 µF
DC link Capacitor	10 µF
DC Link Capacitor Load Side	4700 µF
Parameter Used in Battery	
Type of Battery	Ni-Metal-Hydride
Nominal Voltage	12 V
Rated Capacity	65 Ah
Nominal Discharge Current	13 A
Fully Charged Voltage	14.14 V

Figure VII shows the output DC voltage generated by the PV array in this proposed system.

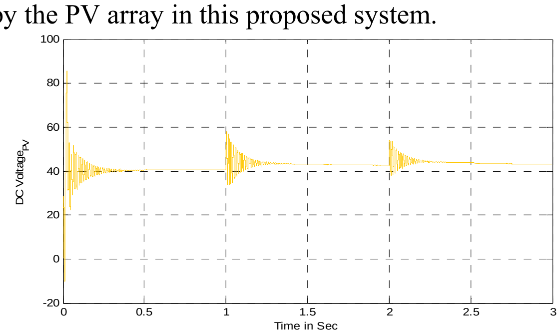

Fig VII: Output Voltage of PV Array.

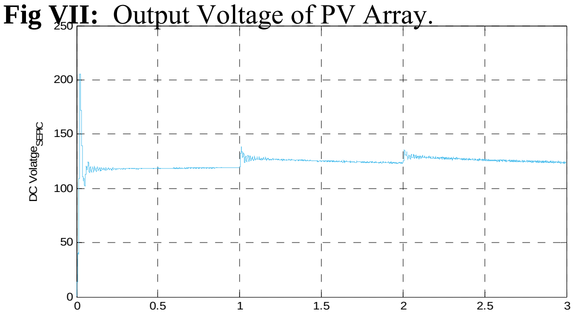

Fig VIII: Output Voltage of SEPIC Converter of Proposed System.

The variation of the voltage is due to Irradiation pattern of the solar system. The main converter here used for controlling the output voltage is SEPIC converter. Figure VIII shows the output voltage of the proposed converter. It converter the output voltage of the PV system from 40 V to 120 V.

Battery system is the other part of the proposed system. It is used for the work as a secondary source when the solar system is not working. Figure IX shows the battery voltage behavior of the proposed system.

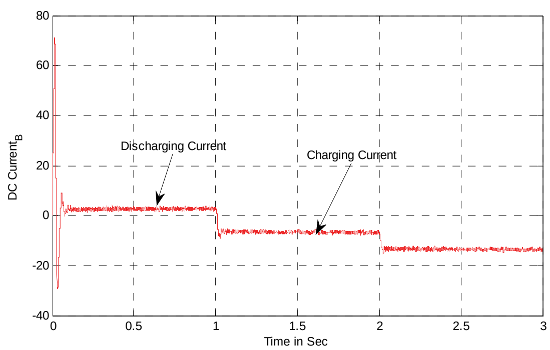

Fig IX: Battery Performance of the Proposed System.

The working of Solar system is based on the irradiation pattern of the solar system. So when it changes the output voltage get changed. When at low irradiation time the battery system provide energy to the system so the power is uninterrupted. Here it is clearly seen that from t= 0 to t=1s the battery is operated and it gives power to the load till the minimum irradiation is achieved in the PV array. After that it goes to charge with access amount of energy which is supplied by the PV array.

VI. Conclusion

This paper is based on the implementation of new converter topology for boosting the voltage outcomes from PV module. Here in this paper SEPIC converter is implemented in the PV module. SEPIC converter is a special type of converter which is used for boosting the voltage. The main advantage of SEPIC converter is its robust nature and also produces low stress in the power switch. Due to low stress the fault tolerances limit is also increase in this type of converter. Also due to low loss in the circuit it gives higher output rather than other converter like Boost and Cuk Converters. The whole converter is based on the coupling of inductors so it produce low ripple in the circuit hence the performance of the system get increase.

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