



DESIGN, ANALYSIS, OF EFFICIENT SOLAR POWER OPTIMIZER FOR DC MICRO GRID SYSTEM

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ABSTRACT

This paper presents a high step-up gain Solar Power Optimizer (SPO) to harvests maximum energy from a photovoltaic (PV) panel and feed this energy to a DC micro-grid. The arrangement consists of coupled inductor and switched capacitor to increase voltage gain. The leakage inductance energy of the coupled inductor can be recycled to reduce voltage stress and power losses across the power device. Low voltages rating and low-conduction resistance power switch improves system efficiency by employing the incremental conductance algorithm method for the maximum power point tracking (MPPT). Because of its high tracking accuracy, the method is used in the energy harvest from PV systems. The planned SPO that have an input voltage range of 20 to 40 V and a maximum PV output power of 400 V/300 W are considered. The highest PV power conversion efficiency is 97%. The maximum MPPT accuracy is 99%. The above efficiency obtained is verified by using MATLAB Simulink.

Keywords—*High step-up voltage gain, Incremental conductance algorithm (ICA), Maximum power point tracking (MPPT), Solar power optimizer (SPO).*

I. INTRODUCTION:

Fossil fuels continue to be depleted, and their use has been instrumental to climate change, a problem that grows more severe each year. A photovoltaic (PV) power generation system, which uses a renewable resource, has been extensively used in emergency facilities and in generating electricity for mass use. A conventional PV generation system is either a single- or a multi string PV array that is connected to one or several central PV inverters. Numerous series-connected PV modules are connected in the PV array to achieve the DC link voltage that is high enough to be connected to electricity through the DC-AC converter. However, the power reduction that is caused by the shadow effect is an inevitable problem in a centralized PV system. The use of a micro inverter or ac module has recently been proposed for individual PV panels. Although this discrete PV power generation solution may partially eliminate the shadow problem, a micro inverter structure constrains the system energy's harvesting efficiency and entails high costs. A solar power optimizer (SPO) was developed as an alternative to maximize energy harvest from each individual PV module. An SPO is used as a DC-DC converter with maximum power point tracking (MPPT), which increases PV panel voltage to optimum voltage levels for a

dc micro grid connection or through a dc-ac inverter for electricity. This passes through an SPO to a DC micro grid system. A 400 V DC- micro grid system was proposed as an energy-efficient distribution option for data center systems and telecommunication facilities. The SPO attempts to improve the use of distributed renewable resources and lower system cost. It may also potentially improve the efficiency of PV systems, has an anti-shadow effect, and can monitor the status of PV modules. Moreover, the dc-grid voltage is regulated by bidirectional inverter and battery tank. In case of low-loading condition, the redundant energy will store into battery or through bidirectional inverter to ac grid. A high step-up solar power optimizer (SPO) that efficiently harvests maximum energy from a photovoltaic (PV) panel then outputs energy to a dc-micro-grid. An SPO is used as a DC-DC converter with Maximum Power Point Tracking (MPPT), which increases PV panel voltage to optimum voltage levels for a dc micro-grid connection or through a DC-DC converter for electricity Fig.1 below shows a single PV panel's energy. PV solar electricity together with solar thermal has the highest potential of all the renewable energies since solar energy is a practically unlimited resource, available everywhere. [1-4]

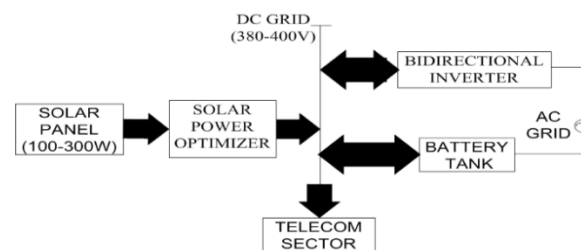


Fig: 1 Configuration of multiple parallel SPO for a DC-micro grid system.

The proposed SPO is shown in fig.1. Its configuration is based on a high step-up DC-DC converter with an MPPT control circuit. The converter includes a floating active switch S and a coupled inductor $T1$ with primary winding $N1$, which is similar to the input inductor of a conventional boost converter capacitor $C1$, and diode $D1$ recycle leakage inductance energy from $N1$. Secondary winding $N2$ is connected to another pair of capacitors, $C2$ and $C3$, and to diodes $D2$ and $D3$. Rectifier diode $D4$ connects to output capacitor $C0$ and load R . The duty ratio is modulated by the MPPT algorithm, which uses the hill climb/ perturb & observe method method that is employed in the proposed SPO. It detects PV module voltage V_{pv} and current I_{pv} to determine the increase and decrease in the duty cycle of the dc converter. Therefore, the MPP can be obtained by comparing instantaneous conductance I/V and incremental conductance dI/dV . The algorithm is programmed into TMS320LF2407A, a digital signal microprocessor.

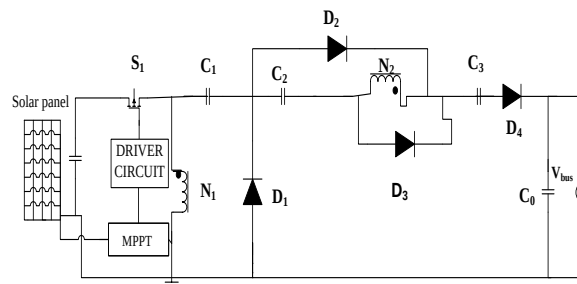


Fig.2: Configuration of the proposed SPO.**1.1 The Proposed Converter Features**

- 1) Its voltage conversion ratio is efficiently increased by using the switched capacitor and coupled inductor techniques.
- 2) The leakage inductance energy of the coupled inductor can be recycled to increase efficiency, and the voltage spike on the active switch is restrained.
- 3) The floating active switch isolates the PV panel's energy during non-operating conditions, thereby preventing any potential electric hazard to humans or facilities. The MPPT control algorithm exhibits high-tracking efficiency; hence, it is widely used in the energy harvesting of PV systems.

II. OPERATING PRINCIPLES

The operating principles for continuous conduction mode (CCM) and discontinuous conduction mode (DCM) are given below.

Fig illustrates a typical waveform of several major components in CCM operation during one switching period. To simplify the circuit analysis of the proposed converter, the following assumptions are made:

- 1) All components are ideal, except for the leakage inductance of coupled inductor T1, which is taken into account. On-state resistance $R_{DS(ON)}$ and all the parasitic capacitances of main switch S are disregarded, as are the forward voltage drops of diodes D1 to D4.
- 2) Capacitors C1 to C3 and C_o are sufficiently large that the voltages across them are considered constant. 3) The equivalent series resistance (ESR) of capacitors C1 to C3 and C_o , as well as the parasitic resistance of coupled inductor T1, is neglected;
- 4) Turns ratio n of coupled inductor T1 windings is equal to N_2 / N_1 . The CCM operating modes are described as follows.

III. SOLAR POWER OPTIMIZATION

The converter used here is a high step up and high voltage gain DC-DC converter shown in fig.2. Mostly the DC-DC converter mentioned in this work is a no inverted Sepic converter. It shows the similarity to the modified buck boost topology, the converter has both coupled inductor and switched capacitors. By using a diode and a capacitor, the leakage inductance energy from the coupled inductor is recycled to minimize the switching loss. Similarly, the switched capacitors helped to increase the voltage gain up to 20 times with 96.7% of system efficiency. The configuration is based on a high step-up voltage gain DC-DC converter with an MPPT control circuit. The suggested fig.2 converter includes a floating active switch S and a coupled inductor T1 with primary winding N_1 , which is similar to the input inductor of a conventional boost converter capacitor C1, and diode D1 recycle leakage inductance energy from N_1 . Secondary winding N_2 is connected to another pair of capacitors, C2 and C3, and to diodes D2 and D3. Rectifier diode D4 connects to output capacitor C_o and load R. The duty ratio is modulated by the MPPT algorithm, which uses the hill climb/ perturbs or Incremental conductance observe method that is employed in the planned SPO. It detects PV module voltage V_{pv} and current

I_{pv} to determine the increase and decrease in the duty cycle of the dc converter. Therefore, the MPP can be obtained by comparing instantaneous conductance I/V and incremental conductance dI/dV . [5-7]

IV. MPPT OPTIMIZATION

MPPT control is a control algorithm by which the Duty ratio is kept in a specific value and hence, the power extracted from the PV panel will be maximum. Power from the PV panel varies in accordance with solar irradiation, ambient condition and temperature. Similarly the electrical characteristics vary from the each solar cell. Incremental Conductance algorithm, P&O method, Hill climbing algorithm etc. are the important MPPT technique. During fast changing irradiance conditions and partial shading the incremental conductance algorithm is optimized MPPT in the suggested system. A portion of solar panel is shaded by any factors such as tree, building, and clouds etc. cause partial shading. As a result, a portion of PV panel is separated by shadow and more current will flows through the un-shaded portion. Therefore electrical characteristics of PV panel will be altered and causes damage to the PV panel. In order to avoid the shadow effect up to a limit, Incremental Conductance algorithm with D-sweep fig.3 (Duty ratio-sweep) is introduced [8]. Incremental conductance locates maximum power when the incremental conductance equal to the negative of instantaneous conductance. [9-13]

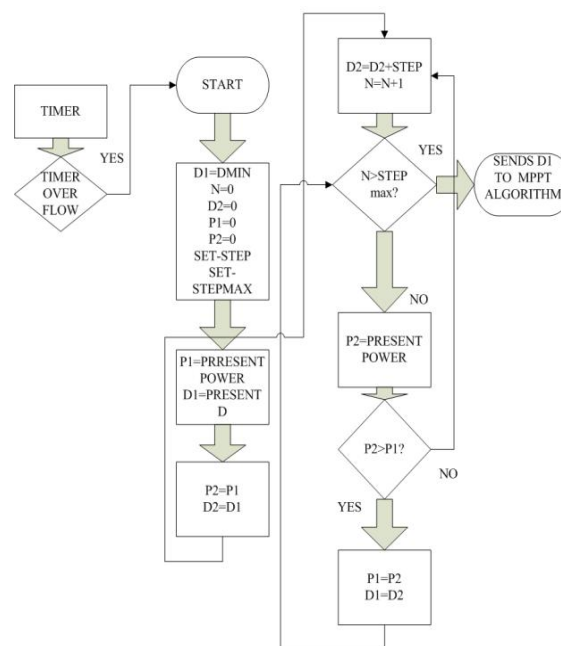


Fig. 3: D- sweep technique Flowchart

V. RESULTS

A 400V/300 W, solar PV system is used to verify the feasibility of multi-Solar power optimizer with MPPT results.

The output waveform of the solar power converter obtained is shown in the fig. below. The fig.4 input voltage is varies from 20V to 40V .The output of the Solar power converter is fed to DC grid. DC grid

voltage is maintained to 400V.

The above Simulink results are obtained as shown in below fig (4) which shows the pulsating square input wave form of DC source. Fig (5), also inductor leakage current waveform shown in fig (6) and for (remaining) devices for capacitor current & diode current is shown in fig (7). These results are obtained for the continuous current conduction mode of operation for high step up boost converter.

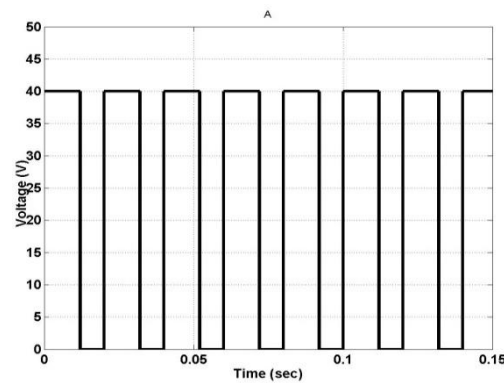


Fig. 4: Input voltage (v_{gs}) vs. time (t)

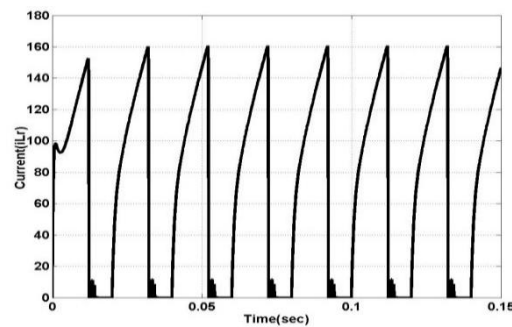


Fig. 5: Inductor leakage current (I_{lk}) v time

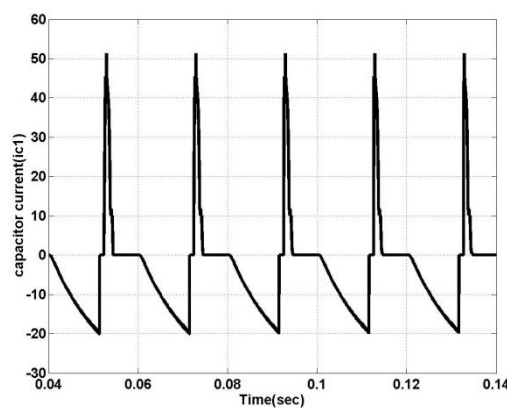


Fig. 6 : For capacitor current (i_{c1}) vs. time (t)

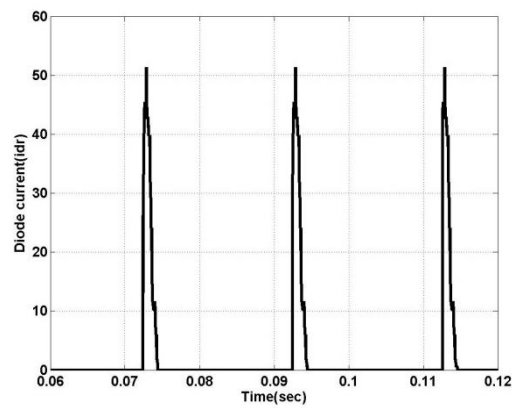


Fig. 7: For diode current (d1) vs. time (t)

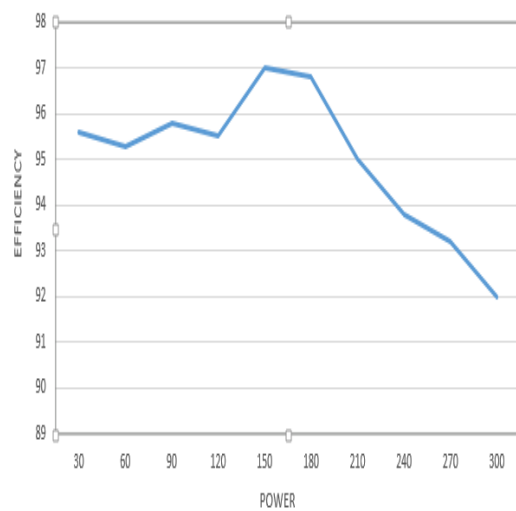


Fig. 8: Efficiency of SPO

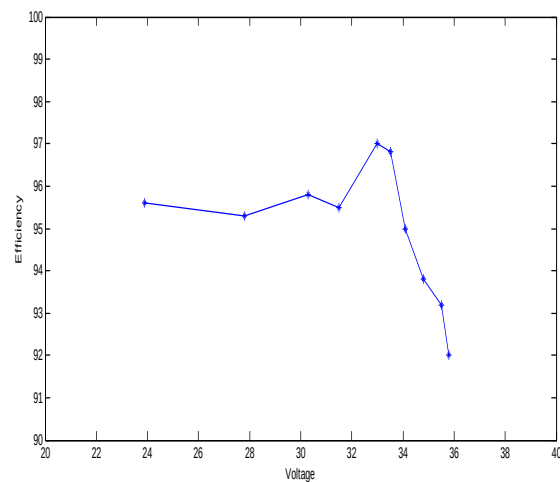


Fig. 9: Efficiency with MPPT

Efficiency=output of PV panel/ input voltage=38.7/40=97% is shown in fig.8-9.



The fig. 4-7 shows waveform of major components in CCM operation during one switching period. And the fig.8-9 shows the efficiency obtained by SPO &MPPT.

Efficiency = OUTPUT/INPUT=38.6/40=97%.

VI. CONCLUSION

The high step-up SPO uses the coupled inductor with an appropriate turn's ratio design and switched-capacitor technology to achieve a high-voltage gain that is 12.5 times higher than the input voltage. Because the leakage inductance energy of a coupled inductor is recycled and the voltage stress across the active switch S is constrained, the low RDS (ON) of active switch can be selected to improve maximum efficiency up to 96.7%. As a result, full load efficiency reaches 92.8%. The highest MPPT accuracy is 99.9% and the highest average accuracy is 97.9% at P_{PV} = 150 W. A 300W SPO with a high step-up voltage gain and MPPT functions are implemented and verified.

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