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HIGH GAIN DOUBLE SWITCH PSO BASED CONVERTER FOR PV SYSTEM

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Abstract

In this paper a new high gain converter operating under Particle Swarm Optimisation based MPPT technique is discussed. This converter is double switch double inductor single capacitor-based converter and produces a gain of (1+D)/(1-D). The circuit consists of 2 switches, which are triggered together, thereby aiding the process of feeding MPPT to it with ease. MPPT technique which is prominently used is of conventional type, like PO, InCond, etc. These types of techniques fail with partial shading problems and takes time in tracking back, so optimisation technique stands overpoared among conventional methods. Henceforth, in this paper PSO optimisation technique is utilised. The results of the simulation have been presented along with the comparison between InCond and PSO method. The whole system discussed here stands out to be the initial stage of PV grid system. It finds application in rooftop planted solar grid system and helps the user (household) to earn more by supplying most available power to grid supply.

Keywords:

Double Switch, High gain, PSO MPPT, Rooftop Solar Panel

1. INTRODUCTION

. In the present century our world is demanding a need to change towards renewable sources of energy. Electrical scooters, vehicles and appliances are becoming more common. The new households being built are focused to plant solar panels over their rooftop, and the energy is supplied back to their line supply. So, such a producer or planter will always wish to make huge profit through it. A profit over a product is obtained either by increasing the quality or quantity, here in solar power quality is decided by the line energy supplier, so quantity remains. The parameter relating to quantity here is power, so maximising power means maximising profit. [1]. The only way out of this problem is to shift to renewable energy sector [2]. Different renewable energy sources are available around us, but among them, the most easily available source is solar which is simple, eco-friendly, clean and maintenance free [3].

The PV panel will provide a particular voltage and current for a specific irradiation and temperature [4]. MPPT is used to determine the voltage and current values corresponding to maximum power. MPPT in general consists of offline and online methods. Offline MPPT method requires the panel to be isolated for measuring out the maximum power tracking condition. So, online methods are used in general, for making the system to work in maximum power point condition irrespective of load condition. [5].

There are different online MPPT methods available at present, this includes conventional algorithms like perturb and observe (P and O) technique and incremental conductance method (InCond) [6]. But these conventional methods have the limitations such as oscillations around the region of MPP, and moreover cannot distinguish between local MPP and global MPP [7] [8]. Therefore, these conventional online methods fail during shading, and movement of panel [9]. Hence optimisation methods are brought in to track down MPP even during partial shading. There are different optimisation techniques that are utilised for tracking MPP such as Genetic Algorithm (GA), Ant Colony Optimisation (ANC), Particle Swarm Optimisation (PSO), etc. Among the different optimisation techniques Particle Swarm Optimisation is the simplest and has the capability of faster commutation, so this technique is preferred. [10].

Genetic algorithm is an evolutionary search method, just like the PSO, which means that they can change from one point to another during iteration with better accuracy of result. The GA is discrete in nature whereas PSO is continuous, which gives added advantage for PSO based searching methods over GA. In GA the number of elements increases with increase in complexity, but PSO requires comparatively smaller number of parameters and lower number of iterations. Moreover, GA converges over local minima or at arbitrary points rather than global minima, so PSO stands better with respect to its counterpart [11].

The output of solar panel is of low value, so the voltage needs to be boosted [12]. Boost converter faces problem while working at higher duty ratio for obtaining higher voltage [13]. So various modified converters with different type of boosting techniques are introduced, they include switched capacitor, voltage lift, cascaded, coupled inductor, etc. [14]. Non isolated cascaded boost converter is able to boost the voltage to a higher level but the switch experiences high voltage stress, so high rated switch is required [15]. Voltage lift based on several diodes and capacitor stages reduce voltage stress along with improving the voltage level at output, but the number of components increases [16]. Quadratic boost converter [17] provides higher gain but here current stress experienced is high. Switched inductor discussed in [18] generates a voltage gain of $1+D/1-D$, but experiences a higher voltage at switch. Therefore, here a double switch double inductor single capacitor converter [19] is used (DSDL- SC converter) and DS-DL-SC converter topology with PSO based MPPT is introduced.

The contribution of this paper in short is to provide a better stage I topology, as shown in the Fig.1

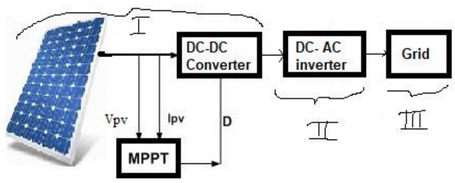

Fig.1. Representation of the proposed topology

2. PRINCIPLE OF WORKING

2.1 CONVERTER OPERATION

The converter topology used in the system is as shown in Fig.2. The circuit consists of 3 diodes, 2 inductors, one capacitor and two switches and provides a gain of '1+*D*/1-*D*'. The circuit is designed to operate in continuous conduction mode. It is designed in such a way that there are 2 modes of operation, and both the switches are turned on together and for making the analysis we assume that switches, diodes, capacitors and inductors are ideal, and there is no stored energy available at the beginning.

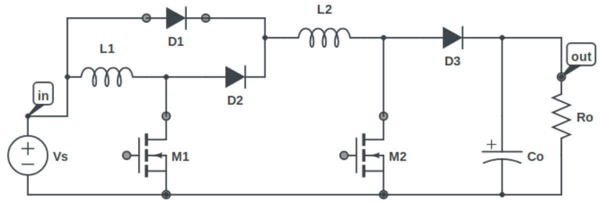

Fig.2. Circuit Diagram of the converter for high gain

2.1.1 Mode-I:

Mode - I or ON mode, both the switches operate at this time. The diode D1 is in forward bias, D2 and D3 are in reverse biased condition. The inductors are magnetized linearly. The circuit functioning is as shown in Fig.3.

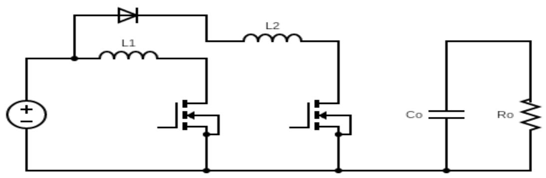

Fig.3. Mode I: On state

$$V_{L1}=V_S \quad (1)$$

$$V_{L2}=V_S \quad (2)$$

2.1.2 Mode-II:

Mode - II or OFF mode, both the switches will be not operated in this mode. Diodes D2 and D3 are forward biased, and D1 is in reverse biased. The circuit functioning is as shown in Fig.4.

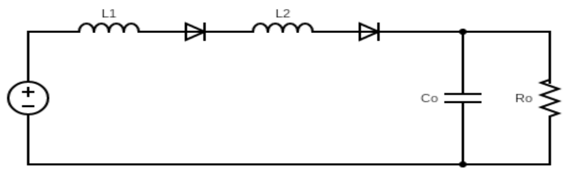

Fig.4. Mode II: Off state

$$V_{L1}=(V_S\text{-}V_O)/2 \quad (3)$$

$$V_{L2}=(V_S\text{-}V_O)/2 \quad (4)$$

The average voltage across each inductor is zero, hence we can state,

$$V_O/V_S = ((1+D))/((1\text{-}D)) \quad (5)$$

2.1.3 Design of Inductor and Capacitor:

The inductor and capacitor can be designed based on the loop equation across each element in both the cycles,

$$L_1=L_2=(V_S D T_S)/(2\Delta I_L) \quad (6)$$

$$C_O=(V_O D T_S)/(2R\Delta V_O) \quad (7)$$

2.2 MPPT COMPARISON - PSO AND INCOND METHOD

To understand the tracking of solar power during partial shading for InCond method as well as PSO, let us consider 2 panels, experiencing different irradiations. One panel is provided with an irradiation of 1000W/sq.km., and the second panel is provided with an irradiation of 1500W/sq.km. The characteristics (PV) for the system are as shown in Fig.5.

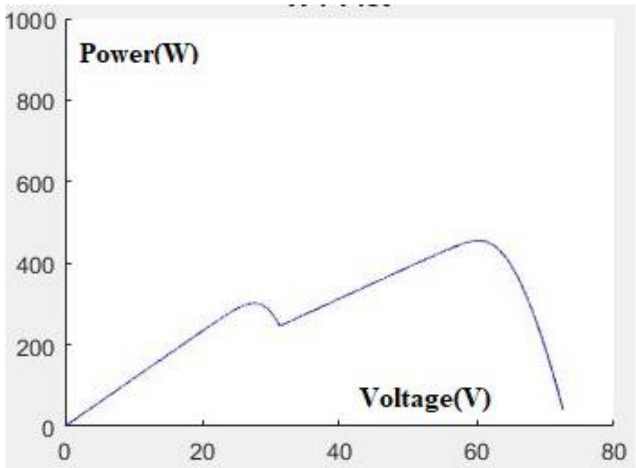

Fig.5. PV Chara under Partial Shading Condition

The observed input power values while working under conventional and optimized MPP tracking technique in the system is shown in Fig.6

From Fig.5, the maximum power that the panel can supply is around 500W. Now our system (converter) is simulated with InCond and PSO MPPT separately. The input power obtained in both the condition is shown in Fig.6.

With the received data, we can analyse that InCond failed to identify the maximum power point, whereas PSO based MPPT converged to provide input power around 500W, which shows it matched with the MPP determined in Fig.5.

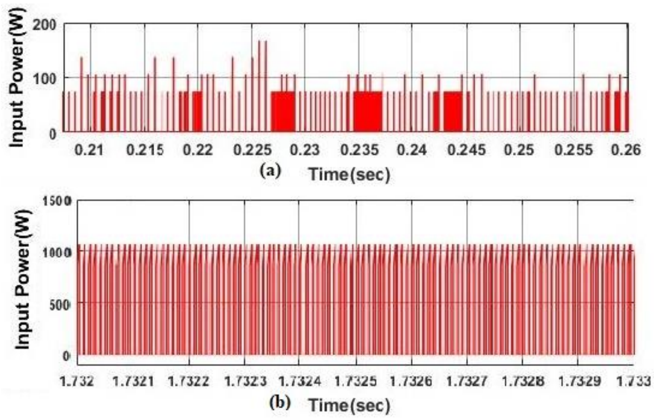

Fig.6 (a) Input power for the converter with InCond MPPT technique (b) Input power for the converter with PSO based MPPT technique

2.3 MODELLING OF PARTICLE SWARM OPTIMISATION

Maximum power point technique (MPPT) is applied to derive the maximum power that is available, from the installed solar PV array. The MPPT implementation starts with sensing the PV panel voltage Vspv and PV current Ispv. Then their product is determined, and the value is compared at each iteration for maximum power inside the controller. The duty ratio is thus decided based on the maximum product value. The procedure followed for the PSO based MPP tracking is as given below:

Initialisation of an array of population having particles with different positions and velocities on a single plane dimension.

Fitness function for each particle is evaluated.

The P_{best} and P_{best} locations are updated.

Similarly looking into all P_{best} values the G_{best} and its location is found out and are updated.

Now the velocity and position of the particle will be updated based on the Eq.(8) and Eq.(9)

$$X_i^{(k+1)} = X_i^k + V_i^{k+1} \quad (8)$$

$$V_i^{k+1} = \omega^k V_i^k + C_1 r\left[Pbest_i^k - X_i^k\right] \quad (9)$$

3. SIMULATION RESULTS

3.1 SIMULATION RESULT OF CONVERTER

The converter is designed to operate for an input voltage of 100V at 0.5 duty ratio which supplies an output voltage of 500 V with an output current of 1.5A, making a dc power of 450W. The simulation diagram is shown in Fig.7 and the obtained waveform of, input and output, voltages and currents characteristics are shown in Fig.8.

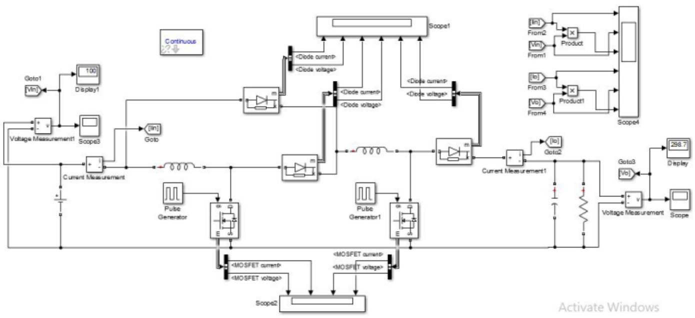

Fig.7. Simulation of converter in MATLAB/Simulink platform

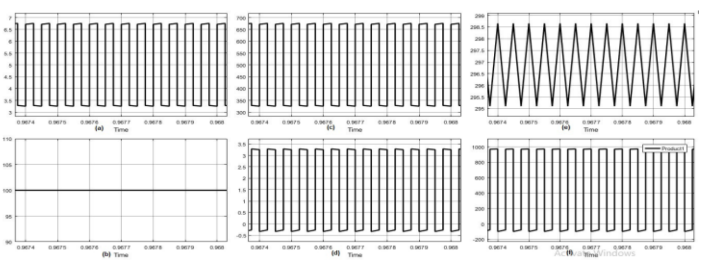

Fig.8. Simulated waveforms of the converter (a)Input current (b)Input voltage (c)Input power (d)Output current (e)Output voltage (f)Output power

The Fig.9 indicates the voltage and current ratings across each switch. The voltage rating of switch 2 is equal to the output during off time and switch rating of switch 1 is of less value.

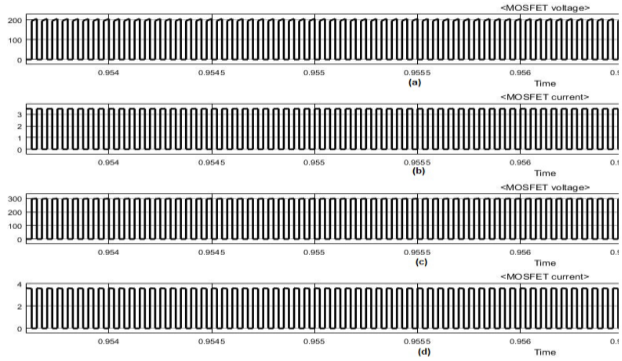

Fig.7 Switch stress (a) Current across switch 1 (b) Voltage across switch1 (c) Current across switch 2 (d) Voltage across switch 2

The output voltage obtained for different input voltages and with different duty ratios are simulated and the details are tabulated in Table.1. The converter is initially designed for 100V input and duty ratio of 0.5, with a power rating of 450W.

Table.1. Tabulation of Converter Output Values

Duty ratio	V_S	Expected V_O	Obtained V_O	Efficiency
0.5	100V	300V	298.7V	99.57
0.5	200V	600V	599.7V	99.95
0.8	100V	900V	883.6V	98.17
0.8	200V	1800V	1772V	98.44

The simulation was performed by considering following details:

1. Diodes
   - Forward voltage = 0.8V
   - Snubber resistance = 500Ω
   - Snubber capacitance = 250nF
   - Resistance on time = 0.001Ω
   - Inductance = 83.33mH
   - Capacitance = 12.5μF
   - Load resistance = 200Ω
2. MOSFET
   - FET resistance on = 0.1Ω
   - Internal diode resistance = 0.01Ω
   - Snubber resistance = 10μF

3.2 CIRCUIT WORKING WITH PSO BASED MPPT

The converter simulation for PV application with PSO MPPT was performed in MATLAB/Simulink software, and is shown in Fig.10. The input was taken from solar PV array, having 2 series modules (in that 1.5 is considered, assuming shading condition) and 2 parallel strings. Each having a V_m=29V and I_m=7.35A. Input irradiation was provided using signal builder, varying between 500W/sq.km and 1000W/sq.km which provided varying input voltages. To optimize the efficiency of photo voltaic modules maximum power point tracking algorithm (MPPT) is required.

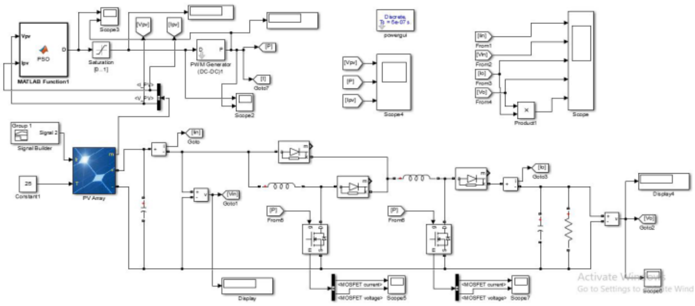

Fig.10. MATLAB/Simulink modelled Circuit with PSO based MPPT

For the simulation, solar PV with the characteristics shown in Fig.11, was selected as source. Power characteristics are then compared with circuit output power and input voltage, which gave nearly equal result.

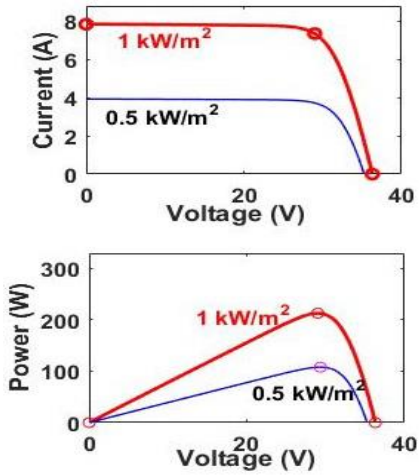

Fig.11. V-I and P-V characteristics for 1000W/km^2 and 500W/km2

The Fig.12 and Fig.13 shows the waveform obtained corresponding to1000W/sq km and 500W/sq km irradiation respectively. When irradiation was set to 1000W/sq.km, the input voltage was 58V, and the output obtained was 120V by operating at a duty ratio of 0.33 producing current of 3.65A output current. Hence output is greater than that of conventional Boost, SEPIC and CUK converters [20][21]. The output waveform for the irradiation for 1000W/sq.km is given in Fig.12. Here for a voltage of 58V, the output is around 120V, with a power of 1kW.

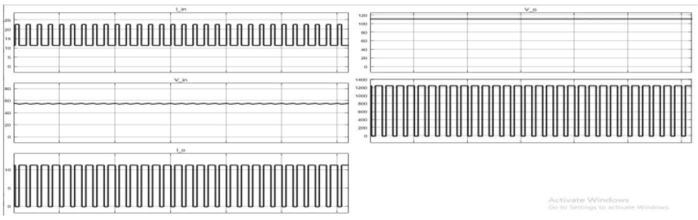

Fig.12. Simulated waveforms for 1000W/km2 insolation level (a) Input current (b) Input voltage (c) Output current (d) Output voltage (e) Output power

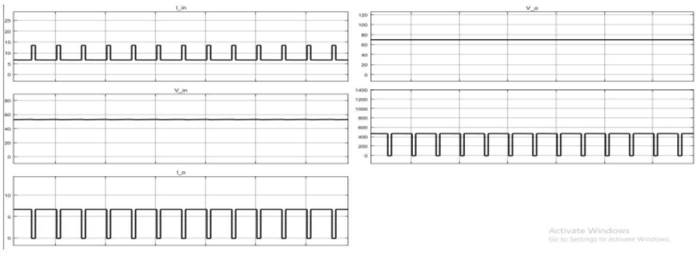

Fig.13. Simulated waveforms for 500W/km2 insolation level (a) Input current (b) Input voltage (c) Output current (d) Output voltage (e) Output power

It is necessary to understand how the response of the system changes, when the irradiation changes, which is highlighted in Fig.14. The switch voltage stress is measured across each switch, and the value are found out in Fig.9, though the voltage across first switch is low, the second switch is having higher voltage across it. The output obtained across output was nearly 1+*D*/1-*D* times the input voltage and the duty ratio changes accordingly suiting for the condition of maximum power derivation.

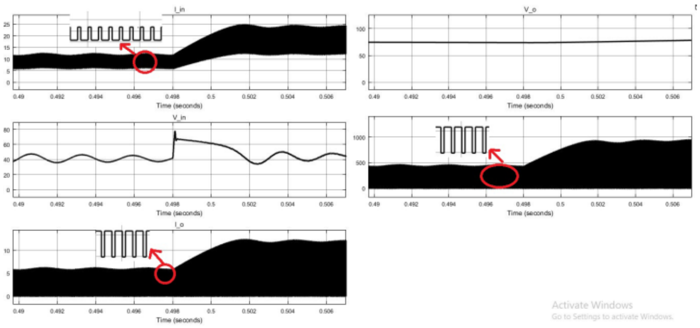

Fig.14 Simulated waveforms for the condition when irradiation changes from 500W/km^2 to 1000W/km^2

4. CONCLUSION

A high gain DS-DL-SC dc-dc converter topology with Particle Swarm Optimisation based MPPT is introduced, which can be used for boosting PV voltage. The converter is integrated with solar PV system where solar energy is the most reliable and efficient renewable source for Electrical Power Generation. The converter is introduced with PSO based MPPT technique to ensure maximum power absorption even under partial shading condition. This system is useful for rooftop solar plants, supplying power to grid. The converter and the system was designed and simulated in MATLAB/Simulink platform. It is verified that the the converter can provide (1+D) times more gain than ordinary boost converter and works well with PSO based MPPT.

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