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Research paper

Maximum power point tracking of a solar PV array using single stage three phase inverter

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Abstract

Solar power is widely available around the globe but efficient transfer of solar power to the load becomes a challenging task. There are various methods in which the power transfer can be done, the following work proposes a method for efficient tracking of solar power. MPPT [maximum power point tracking] algorithm applied on three phase voltage source inverter connected to solar PV array with a three phase load. MPPT is applied on inverter rather than conventionally applying MPPT on DC-DC converter. Perturb and Observe method is applied in the MPPT algorithm to find the optimal modulation index for the inverter to transfer maximum power from the panel. Sine pulse width modulation technique is employed for controlling the switching pattern of the inverter. The algorithm is programmed for changing irradiation and temperature condition. The system does not oscillate about the MPP point as the algorithm set the system at MPP and does not vary till a variation in irradiation is sensed. The proposed system can be installed at all places and will reduce the cost, size and losses compared to conventional system.

Keywords: *solar panel, MPPT, inverter, solar irradiation.*

1. Introduction

The future of power generation is focusing much on renewable energies as they are more reliable and eco-friendly. The mark of solar energy in this phase in very eminent because it is available throughout the year with less maintenance compared to other renewable sources. The efficiency of the solar panels is not in the desirable range but that does not come as a set back as the availability of sun light is very high. Solar energy has seen a steep development in recent years and used in large plants like airport without the support of other types of energy. The output power of the solar panel keeps on varying because of the change in sunlight by environmental factors. For changing environmental factors, the system should be able to draw the maximum electrical power from the panel and the system should be fast and precise in attaining the MPP. Conventionally the MPPT algorithm is applied on the DC-DC converter [1-6]. In this paper, MPPT is applied in the single stage inverter there by reducing the size and cost of the system. In conventional system, MPPT algorithm keeps oscillating at steady state and response to fast changing irradiance is slow.These drawbacks are overcome in the proposed single stage inverter as the response of the system is fast to changing irradiance.Also,MPP does not oscillate in steady state and efficiency of the system is high.The objective of the proposed work is to develop an MPPT algorithm for solar panel which gives a fast response for changing irradiation that can be implemented in single stage three phase inverter.

2. System under study

Fig. 1 shows the schematic diagram of the system under study.

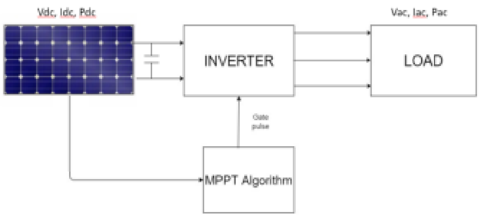

Fig. 1: Schematic diagram of single stage solar plant

Solar panel is connected to the input DC terminals of the inverter through a DC link capacitor, which stores the power from the solar panel and helps to have a constant output voltage from the solar panel. The voltage and current of the solar panel are sensed by voltage and current sensors and fed into the controller. The MPPT algorithm is implemented in the controller which takes these inputs and increments the modulation index of the inverter to an optimal value. For each increment in the modulation index, the impedance seen by the source varies and the power flow is altered. The MPPT algorithm makes the panel to move towards MPP and it sets the panel at MPP when it reaches there by giving maximum power from the panel to the load. For decreasing irradiation, the load is not operated at rated value and so the voltage at the load varies [10]. To regulate the voltage at the load, load shedding technique is employed. The load shedding is done in such a way that the load connected in the system is equal to the maximum power of the solar panel for the corresponding irradiation.

Specifications of solar panel are given in Table 1.To obtain a voltage of 415V at the load end, 42 solar panels of the above specified rating is connected in series. DC link voltage is 680V and value of DC link capacitor is 0.00119F. The simulated results of I-V and P-V characteristics of solar panel are shown in

Fig.2 and Fig.3.To implement load shedding 4 load are taken, whose details are given in Table 2.

Table 1: Specifications of solar panel

Maximum Voltage at MPP	16.5V
Maximum Current at MPP	4.13A
Open circuit Voltage (Voc)	23.2V
Short circuit Current (Isc)	5.11A
Cells Per module	11
Temperature Coefficient of Voc	-0.38 (%/deg C)
Temperature Coefficient of Isc	0.1 (%/deg C)

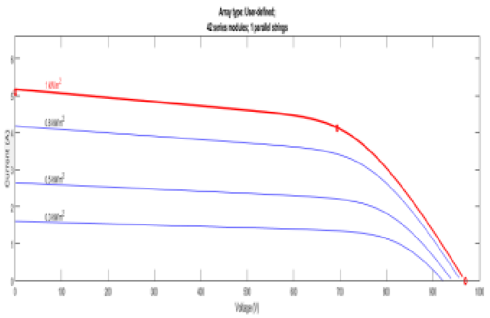

Fig. 2: I-V Characteristic of solar panel

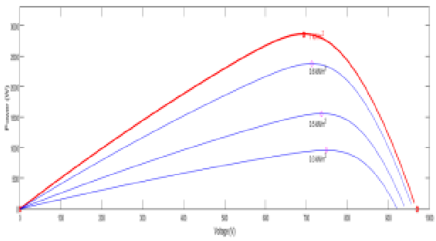

Fig. 3: P-V Characteristic of solar panel

3. MPPT Algorithm

Maximum power transfer happens when the load and source impedances are equal. MPPT algorithm is used in the system to vary the modulation index of the sinusoidal PWM signal there by altering the impedance of the load seen by the source (solar panel). When the impedance of load and source matches, MPPT algorithm settles at that modulation index. There are three possible cases of operation for the system. In each case, the algorithm should move towards the MPP. dI_{dc} is change in solar panel current and dP_{dc} is change in solar panel power.

Table 2: Specifications of Load

Load 1 (L1)	415V, 950W
Load 2 (L2)	415V, 600W
Load 3 (L3)	415V, 850W
Load 4 (L4)	415V, 450W

Case (i) :dI_{dc}= -ve (change is less than 0.05A)
dP_{dc}= +ve (change greater than 5W)
Left side of the MPP, Then decrement modulation index by 0.02
Case (ii):dI_{dc}= -ve (change is less than 0.05A)
dP_{dc}= +ve (change less than 5W)
At MPP, modulation index to be constant till any change in irradiation
Case (iii) :dI_{dc}= -ve (change is greater than 0.05A)
dP_{dc}= -ve (change greater than 5W)
Right side of the MPP, Then increment modulation index by 0.02.

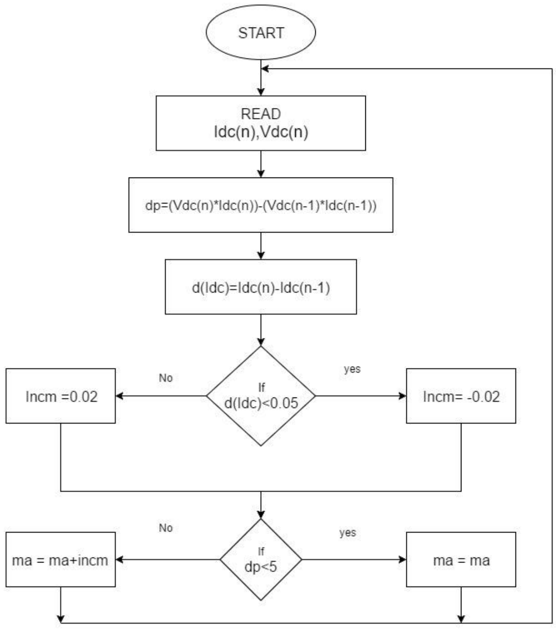

Fig. 4: Flow chart of MPPT algorithm implemented in three phase inverter

Fig. 4 shows the flowchart of the MPPT algorithm implemented in three phase inverter. The algorithm takes V_{dc} and I_d as inputs. Subscript n corresponds to present iteration and n-1 corresponds to previous iteration. Change in power dP and change in current dI are calculated. If dI is less than 0.05A , incm(increment) = -0.02(left of MPP). If dI is greater than 0.05A, incm = 0.02 (right of MPP). If dP is less than 5W modulation index is not incremented (MPP reached). If dP is greater than 5W modulation index in incremented by in cm(MPP not reached).
The voltage at the load keeps on varying for different irradiations as there is a mismatch between the load and solar power. So load shedding is employed to match the solar panel output and the load power.

4. Simulation results

At constant irradiation

Fig. 5 shows the MATLAB simulation diagram of the whole system. Table 3 shows the theoretical values of maximum power points of solar voltage and power obtained from I-V and P-V graphs.Table 4 shows the tabulated results of voltage, current and power on DC side and AC side of three phase inverter corresponding to different modulation index values of ma of the simulated system for various constant solar irradiations. The power output of the solar panelP_{dc} matches with the theoretical values of $P_{dc[}$. There is a difference in power between $P_{dc}$and P_{ac} because of the losses in the inverter.The losses are proportional to the current flowing through the inverter andlosses decrease for decreasing irradiation.Table 5 shows the details of load connected depending on the availability of solar irradiation [11].

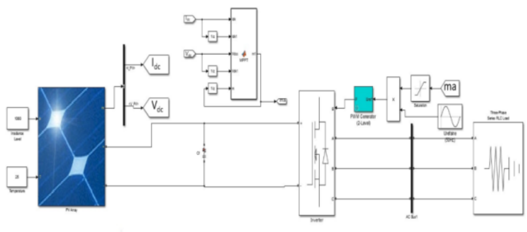

Fig.5: MATLAB simulation diagram of the system under study

Table 3: Theoretical values of MPP solar voltage and solar power obtained from I-V and P-V characteristics

Ir(W/m^2)	V_{dc} (V)	P_{dc} (W)
1000	693	2862
800	715	2379
500	736.1	1516
300	750.4	958

Table 4: Tabulated results from simulation of the system under study

Ir(W/m^2)	m_a	Vdc(V)	Idc (A)	Vac(V)	Iac(A)	Pdc(W)	Pac(W)
1000	0.68	680	4.20	415	3.97	2861	2849
800	0.62	708	3.36	412.5	3.32	2379	2368
500	0.52	781.5	1.93	409.3	2.12	1510	1505
300	0.50	784.5	1.19	411.5	1.13	935	933

Table 5: Load shedding for different solar irradiations

Ir(W/m^2)	**Pdc (W)(MPP)**	**Load connected**	**Full load (W)**
Greater than 1000	2862	L1, L2, L3, L4,	2850
Greater than 800	2379	L1, L2, L3	2400
Greater than 500	1516	L1,L2	1550
Greater than 300	958	L1	950

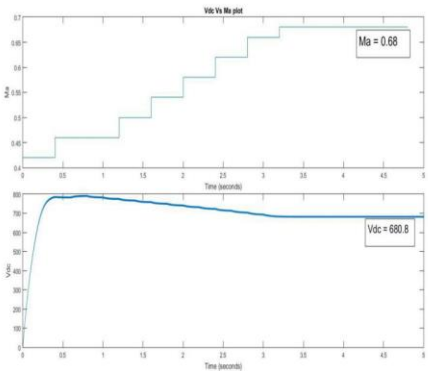

Fig. 6: Panel voltage with corresponding modulation index

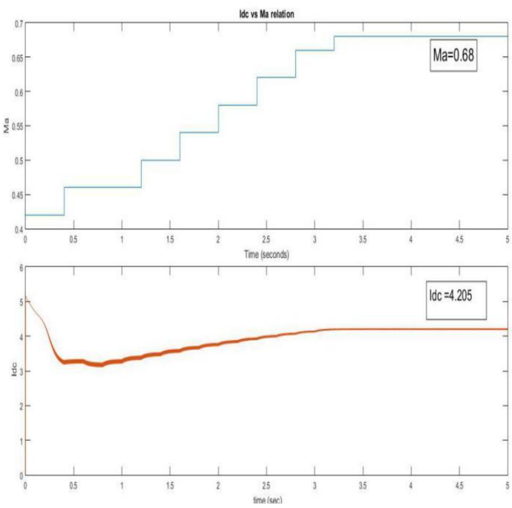

Fig. 7: Panel current with corresponding modulation index

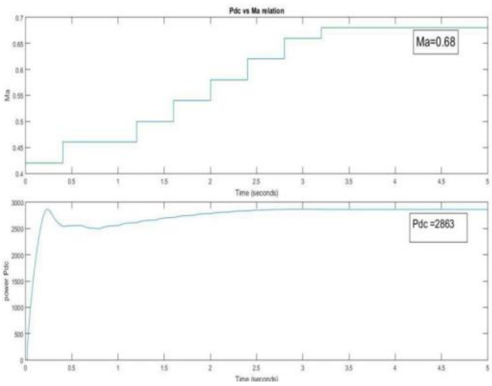

Fig. 8: Panel power with corresponding modulation index

Fig.6, Fig.7 and Fig.8 show the variation of modulation index with solar panel voltage, solar panel current and solar panel power respectively for achieving maximum power from solar panel at constant irradiation of 1000W/m^2. Solar panel voltage decreases and solar panel current increases with increase in modulation index. When there is a change in the modulation index, the impedance seen by the source varies and the power output of the panel varies. When both the source and the load impedance matches, maximum power flows.

At varying irradiation

A change in irradiation of 1000W/m^2 to 800 W/m^2 is simulated at time t= 3sec.The system operates at MPP of 1000 W/m^2 irradiation from time t=2 sec. The system responds to the change in irradiation at t=3 sec and settles at MPP of 800 W/m^2 at 4.4 sec. Fig.9,Fig.10 and Fig.11 show the change in solar panel voltage, solar panel current and solar panel power with corresponding change in modulation index.

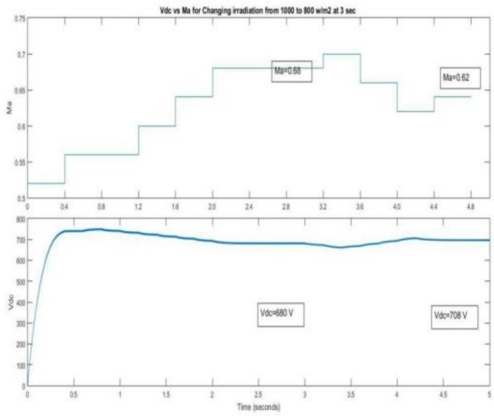

Fig. 9: Panel voltage for changing irradiation from 1000 to 800 W/m^2

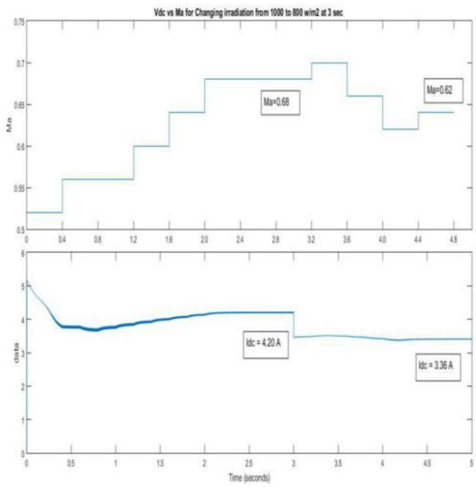

Fig. 10: Panel current for changing irradiation from 1000 to 800 W/m^2

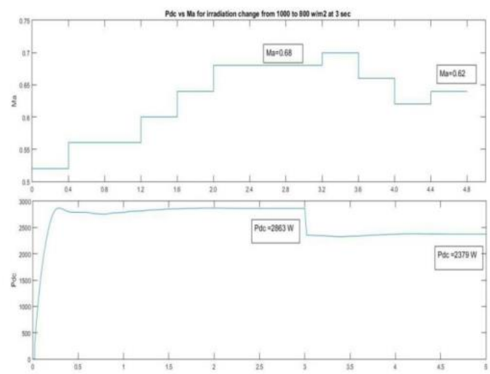

Fig. 11: Panel power for changing irradiation from 1000 to 800 W/m^2

5. Conclusion

In this paper, solar PV system with three phase inverter is simulated in MATLAB simulink and results are presented. MPPT algorithm is implemented in inverter, which is working efficiently for different solar irradiations. The power extracted from the panel is almost same as the theoretical maximum power valuesof the system. The system does not oscillate about the maximum power point tracking, which makes the system more efficient. When there is a change in solar irradiation, the system responds fast and smooth. Voltage regulation is also achieved at the load end by load shedding.

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