COMPARATIVE PERFORMANCE OF GRID INTEGRATED PV SYSTEM USING VARIOUS MPPT TECHNIQUES

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Abstract

This paper presents the comparison of various MPPT techniques for grid integrated PV system. The PV system is connected to the grid via a DC-DC boost converter and 3-phase 3 level inverter with an intermediate fixed or varying load. The MPPT algorithms are employed in boost converter. The real power, reactive power, voltage and current are observed on PV side, Grid side & Load side under different operating conditions. The fix 350KW load and varying 50KW-350KW load is taken at different power factors of unity, 0.9 lagging and 0.8 lagging. This system is modelled, simulated and analysed in MATLAB/Simulink.

Keywords: *PV system, MPPT algorithm, 3-phase inverter, DC-DC boost converter, grid*

INTRODUCTION

With the leading technology, more and more industries are being set up hence energy demand is increasing. This energy demand is mostly met by fossil fuels. So there is excessive use of fossil fuels, because of which these are on the verge of extinction. Solar energy is the most abundantly available renewable source of energy that can be used to limit the use of fossil fuels. It is the cleanest form of energy available on earth and in case of excess generation of electricity it can be fed back to grid. PV (Photo-Voltaic) panels are used for converting solar energy into electrical energy [3],[4].

Solar cell or photovoltaic (PV) cell is the basic building unit of solar modules or solar panels. A Photovoltaic cell is made up of the semiconductor material, which converts the light falling over the surface of cell i.e. on p-n junction, directly into electricity.To use it efficiently and effectively, cells can be grouped to form panels or modules. There is only one point on the current-voltage (I-V) curve of PV device where maximum power is available as shown in Fig. 1. The I-V curve of PV panel is non linear so to use the output should be maximum [2]. The point of maximum power, called Maximum Power Point (MPP) keeps on fluctuating with atmospheric conditions like temperature and irradiations. With increase in irradiation, the power output of PV panel increases while it decreases with increase in temperature. There are certain techniques which are used for tracking this MPP, called Maximum Power Point Techniques (MPPT).

This paper has presented the three basic MPPT algorithms i.e. FSCC, P&O and INC techniques which control the controlling parameter like duty cycle of the DC-DC boost converter and hence changes the voltage accordingly and tracks the maximum power.

TYPES OF PHOTOVOLTAIC SYSTEMS

A.Standalone PV system

Sometimes it is required to supply power to a critical load when main grid is disconnected. In this mode PV is controlled to supply all the required power by keeping the voltage and frequency within allowed limits. This autonomous mode of might be initiated due to two reasons:

1) Due to planned or intentional islanding for maintenance and economical reasons
2) Due to unplanned or unintentional reasons like failure of main grid due to network fault.

B.Grid connected PV system

In this mode the PV system is connected with the main grid and they together supply the load. PV sources operate in parallel with main power source to feed local loads and possibly feed power in the main grid. Here PV sources act as constant power sources means they are controlled to inject demanded power into the network [8],[9]. The voltage and frequency limits are balanced and controlled by the grid only. The excess generated PV power is fed into the grid so that grid power can be utilized effectively.

MPPT TECHNIQUES

A.Fractional Short Circuit Current (FSCC)

It works on the principle that there is a linear relationship between the current at MPP, Impp and the short circuit current, Isc. Hence Impp is proportional to Isc by a factor k. k is calculated according to PV module datasheet and its value lies between 0.85-0.95.

B.Perturb & Observe (P&O)

Perturb & Observe is one of the most widely used MPPT techniques. It is based on simple logic of regular perturbation of the operating point of PV module by decreasing or increasing the controlling parameter like duty ratio by a small step size and measures output power of PV array before and after the perturbation [3],[5]. The algorithm continues to perturb in the same direction if power is increased. The 3 basic methods used for perturbation are, reference voltage perturbation, reference current perturbation and duty ratio perturbation. Due to this continuous perturbation of P&O algorithm, system output fluctuates about its MPP value [3], [4].

B.Incremental Conductance (INC)

This algorithm follows the slope of PV curve of solar PV array. It is based on the principle that PV curve of a PV array of a PV array at constant solar irradiance and temperature level has only one MPP. At this MPP, derivative of power with respect voltage (dP/dV) equals zero i.e. incremental conductance $dIpv/dVpv$ equals negative of instantaneous conductance Ipv/Vpv. At the left of MPP, slope is positive and at the right of MPP, slope is negative. The incremental conductance algorithm compares $dIpv/dVpv$ and Ipv/Vpv and decides whether to increase or decrease the control parameter [3], [6].

MODELLING AND SIMULATION

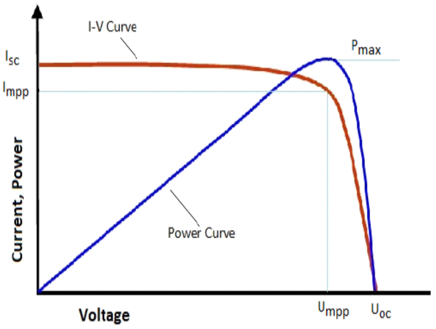
The brief description of the grid integrated PV system is presented below:

- A Solar panel of SunPower SPR-305 series generating 100KW at 1000W/m^2 and 25ºC is used for PV generation. The array consists of 66 strings of 5 series-connected modules connected in parallel (66*5*305.2 W= 100.7 kW).

- Dc-Dc boost converter employing MPPT techniques and boosting voltage from 273.5 V to 500V is used.
- This 500 V DC voltage is converted into 500 V AC by a 3 phase 3 level inverter which is further stepped up to 11KV.
- The grid is supplying 500KVA, 11KV.
- Load : Fixed load of 350KW at 0.8 lagging pf & varying load of 50KW to 350KW at UPF, 0.8 lagging pf & 0.9 lagging pf.

The PV system is connected to the grid via a DC-DC boost converter, 3-phase inverter and and the load[10].

A PV array of SunPower SPR-305 module is used whose parameters are given in Table 1. IGBT is used as switchimg device which recieves duty cycle from the control block. The P&O and INC techniques algorithms are coded in MPPT controller whose output is given to PWM generator which generates the duty cycle.



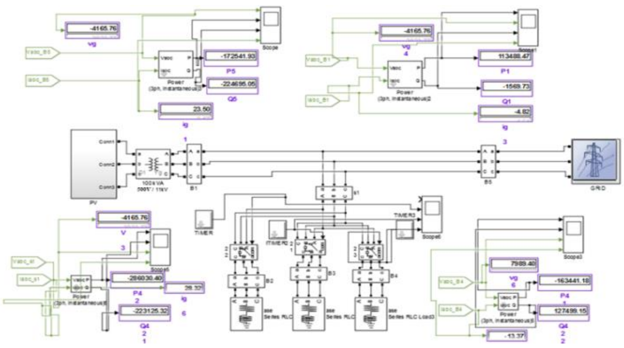


Fig. 1: I-V and P-V curve of solar PV cell *Fig. 2: Internal structure of the grid connected PV system*

SIMULATION RESULTS

The grid integrated PV system is analysed for fixed load of 350KW and a varying load of 50KW to 350KW. The comparison of FSCC, PO & INC techniques for fixed load at 1000W/m^2 and 25°C is shown in Fig.4 to Fig.6. Also for varying load the similar results are shown in Fig. 7 to Fig.9. For varying load, the change in real power, reactive power, voltage & current at different irradiations of 1000W/m^2, 800W/m^2 & 1200W/m^2 and at different power factors of UPF, 0.9 lagging & 0.8 lagging is given in Table II to Table IV. It can be observed from the tables that as the irradiation is increased from 800W/m^2 to 1200W/m^2, the power output of the PV panel increases and the load demand is met by both PV and grid. Similarly the reactive power demand of the load is also met by the grid. The Fig.3 indicates various colours of different algorithms.

Table 1: *Datasheet of SunPower SPR-305 module*

Imp – Current at maximum power	5.58 A
Vmp –Voltage at maximum power	54.7 V
Pmax, Maximum power	100 KW
Isc-Short circuit current	5.96 A
Voc-Open circuit voltage	64.2 V
Kv-Voltage co-efficient	-0.1230 V/K
KI- Short circuit temperature co-efficient	0.0032 A/K
Ns-Number of series connected cell	96
a=Ideality factor	1.3

Fig. 3: Colours indicating various algorithms

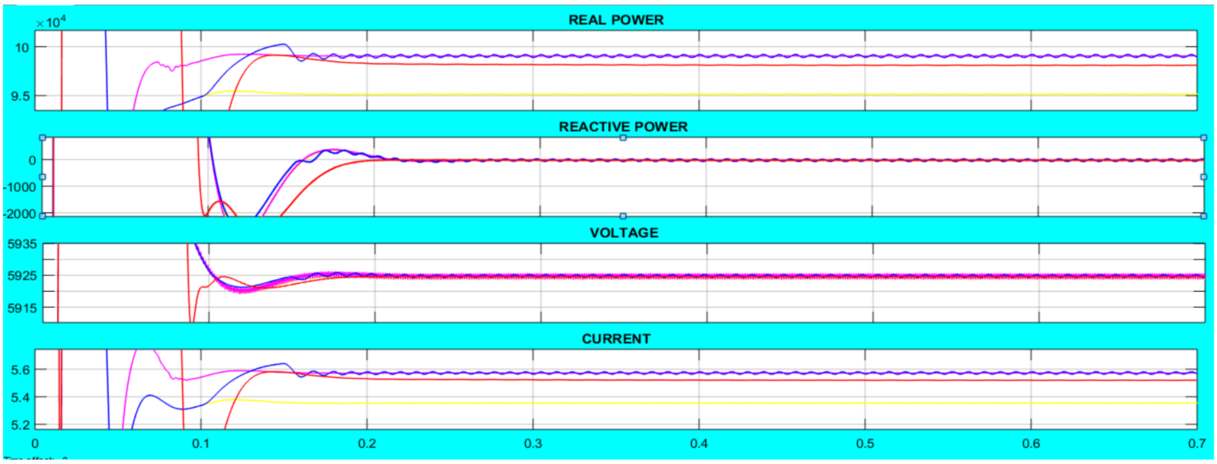


Fig.4: Comparison of algorithms for fixed 350KW load on PV side

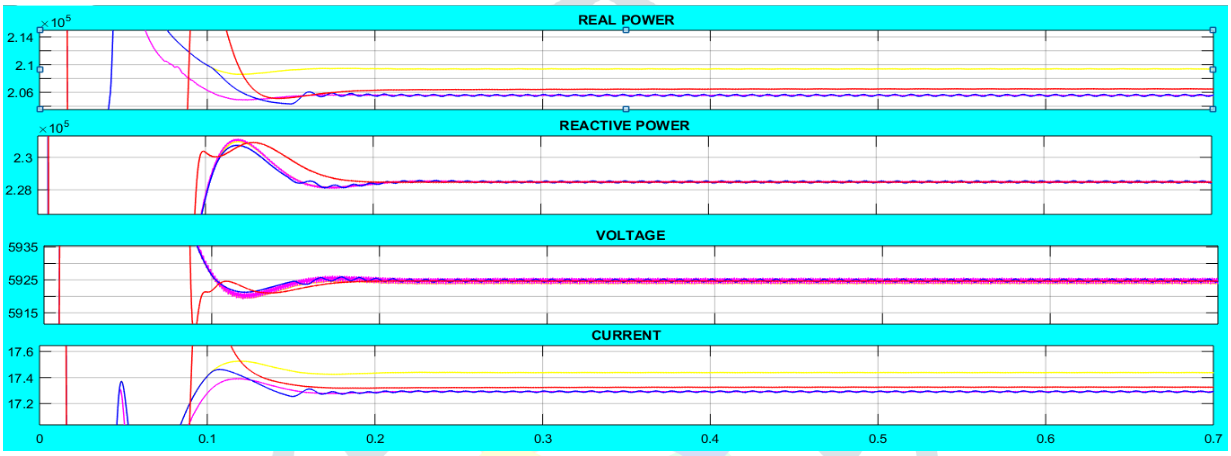


Fig. 5: Comparison of algorithms for fixed 350KW load on Grid side

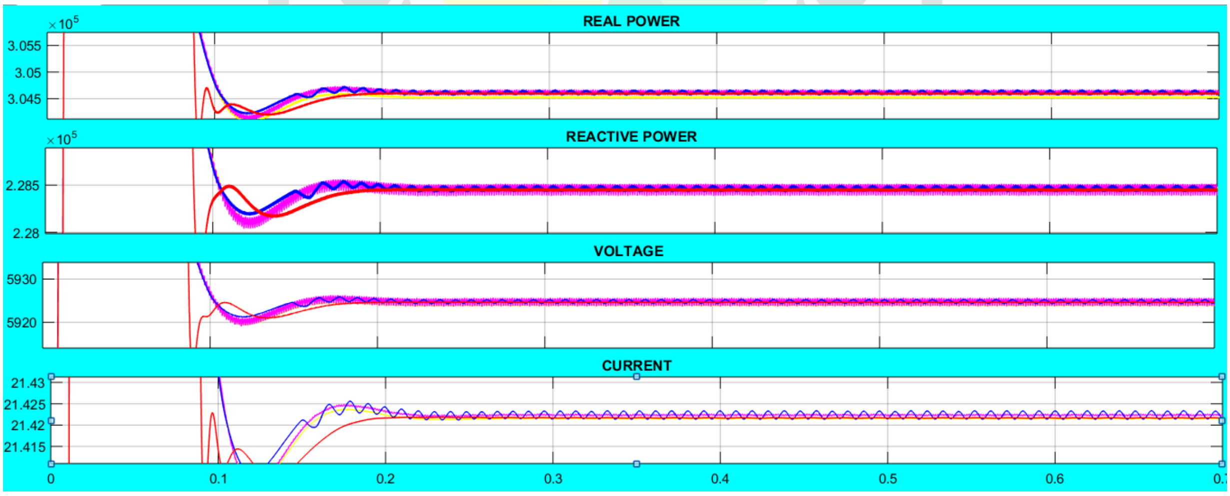


Fig. 6: Comparison of algorithms for fixed 350KW load on Load side

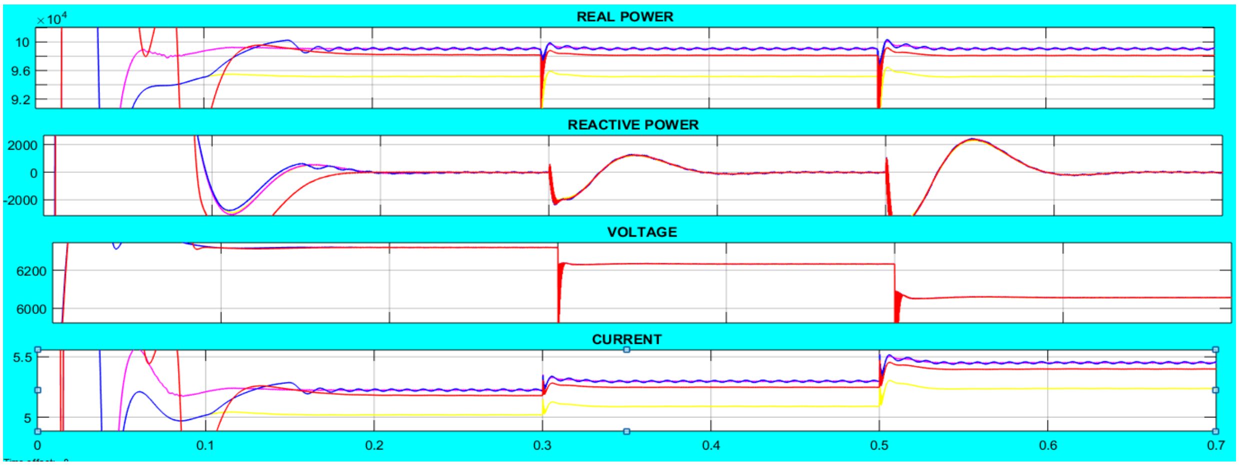


Fig. 7: Comparison of algorithms for varying load on PV side

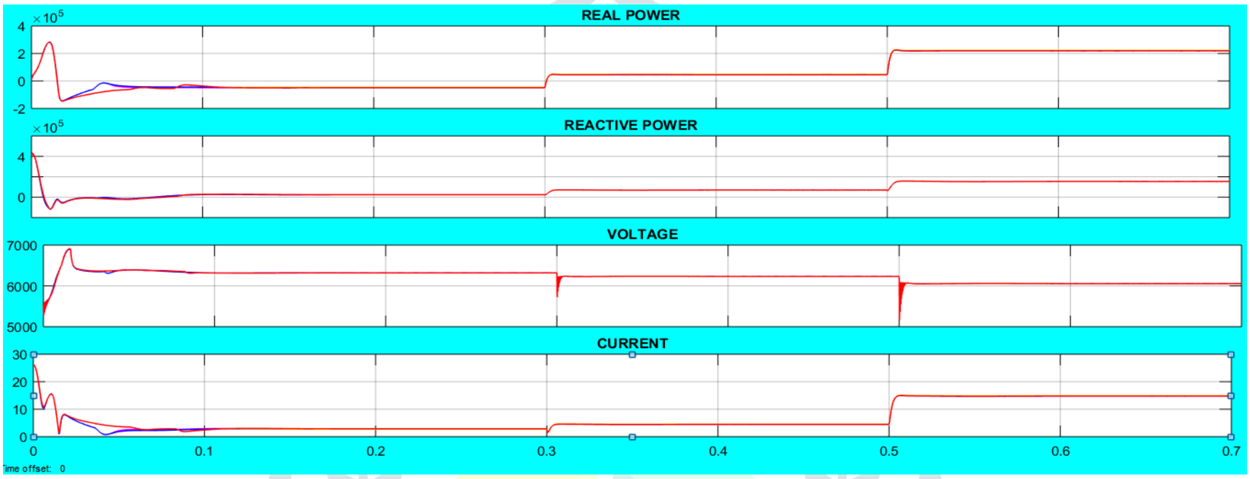


Fig. 8: Comparison of algorithms for varying load on Grid side

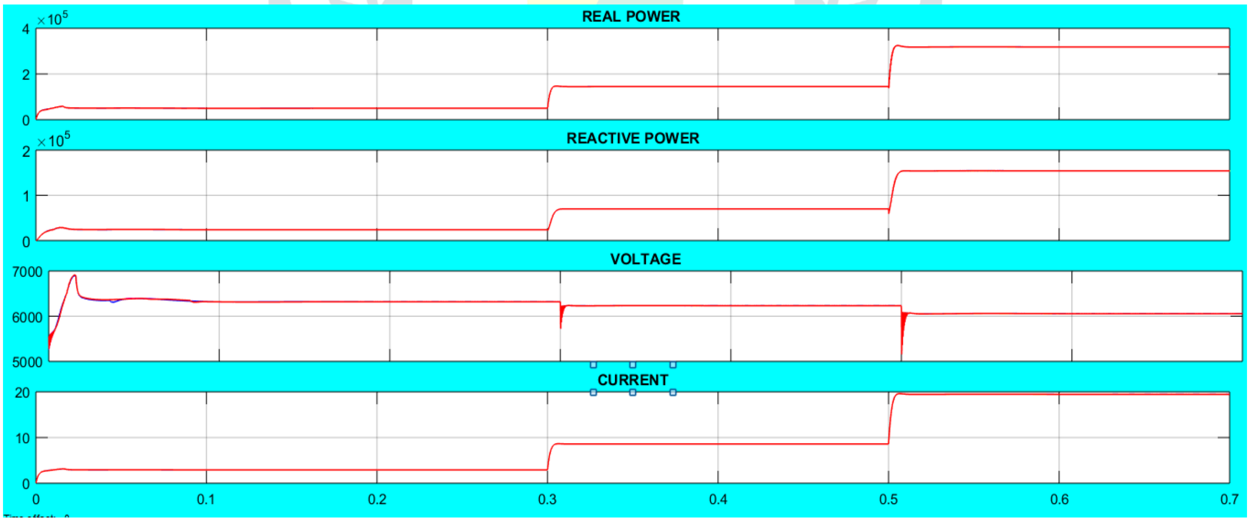


Fig. 9: Comparison of algorithms for varying load on load side

Table 2: *Power Flow for different loads at 1000W/m²* ***Table 3:*** *Power Flow at 800 W/ m²*

LOAD (KW)		LOAD				SOLAR				GRID			
		PL (KW)	QL (KVAR)	VL (KV)	IS (A)	PS (KW)	QS (KVAR)	VS (KV)	IS (A)	PG (KW)	QG (KVAR)	VG (KV)	IG (A)
UPF	50	-50	-2×10-8	9.3	4	110	0	9.4	8.8	62	0	9.3	2.5
	150	-150	-2×10-8	9.1	11.5	120	0	9.2	9.2	-30	0	9.1	5
	350	-350	-2×10-8	9	26	120	0	9	9.3	-225	0	9	17
0.8 Lag	50	-50	-37	9.4	4.6	110	0	9.5	9	65	-37	9.5	5.5
	150	-149	-115	9.2	13.5	120	0	9.4	9.5	-26	-110	9.2	8.3
	350	-330	-240	8.8	30	120	0	9	10	-200	-236	8.8	24
0.9 Lag	50	-50	-25	9.6	4	110	0	9.5	9	68	-25	9.6	5.3
	150	-150	-72	9.5	12.2	120	0	9.4	9.5	-25	-74	9.3	6
	350	-330	-160	9	27	120	0	9.1	9.9	-220	-160	9	19.8

Table 3: *Power Flow for different loads at 1200W/m^2*

CONCLUSION

The comparative results of GRID connected PV system using all the MPPT here tested for the following disturbances:

1. CHANGE IN IRRADIATIONS

- As the irradiation is changed from 800W/m2 to 1000W/m^2 & 1200W/m^2, the power output is maximum in case of FSCC and minimum with PO.
- The fluctuations are more in PO technique

2. CHANGE IN LOAD

- As the load is increased from 50KW to 350KW, maximum power output is obtained in INC and PO technique.
- But the fluctuations are very high in case of PO as compared with FSCC & INC

LOAD (KW)		LOAD				SOLAR				GRID			
		PL (KW)	QL (KVAR)	VL (KV)	IS (A)	PS (KW)	QS (KVAR)	VS (KV)	IS (A)	PG (KW)	QG (KVAR)	VG (KV)	IG (A)
UPF	50	-50	-2×10-8	9.3	3.9	98	0	9.3	7.4	50	0	9.3	3.5
	150	-150	-2×10-8	9.1	11.5	100	0	9.15	7.6	-50	0	9.1	4
	350	-350	-2×10-8	9	26	100	0	9	7.8	-240	0	8.9	18.5
0.8 Lag	50	-50	-37	9.5	4.6	97.5	0	9.5	7.6	52	39	9.5	4.5
	150	-150	-109	9.4	13.5	99	0	9.3	8	-50	-110	9.2	9
	350	-325	-235	8.9	30	99.5	0	8.7	8.4	-230	-240	8.8	25
0.9 Lag	50	-50	-24	9.6	4	98	0	7.5	7.5	50	-25	9.6	4
	150	-150	-73	9.3	12	99.5	0	8	8	-50	-75	9.4	6.5
	350	-330	-160	9	27	100	0	8.3	8.3	-230	-162	9	21

LOAD (KW)		LOAD				SOLAR				GRID			
		PL (KW)	QL (KVAR)	VL (KV)	IS (A)	PS (KW)	QS (KVAR)	VS (KV)	IS (A)	PG (KW)	QG (KVAR)	VG (KV)	IG (A)
UPF	50	-50	-2×10-8	9.3	4	75	0	9.3	6	25	0	9.25	2.1
	150	-150	-2×10-8	9.1	11.5	80	0	9.1	6.2	-75	0	9.15	5
	350	-350	-2×10-8	9	26	80	0	9	6.3	-270	0	9	20
0.8 Lag	50	-50	-37	9.5	4.8	78	0	9.5	6.2	28	-40	9.4	4
	150	-149	-115	9.2	13.8	80	0	9.3	6.5	-70	-110	9.2	10
	350	-330	-240	8.8	30	80	0	8.7	6.7	-240	-240	8.6	25.5
0.9 Lag	50	-50	-24	9.5	4.1	80	0	9.5	6.1	27	-24	9.5	3
	150	-150	-70	9.2	12	82	0	9.3	6.5	-70	-70	9.3	7.5
	350	-330	-165	8.95	27.5	82	0	8.9	6.8	-240	-160	8.9	22.5

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