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Performance evaluation of Maximum Power Point Tracking algorithm with buck dc-dc converter for Solar PV system

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ABSTRACT
The energy crisis concern leads to look for alternate source of energy. Solar energy is considered as most reliable among the all renewable energy sources. Solar PV (Photovoltaic) is used to convert solar energy into electric energy. The efficiency of solar PV is very low and its characteristic is nonlinear. To overcome these drawbacks a technique known as maximum power point tracking is used. This algorithm is implemented in the control circuit of DC – DC converter. The objective of this paper is to evaluate the MPPT (Maximum Power Point Tracking) with buck DC-DC converter under load varying conditions. The simulation work is done using PSIM simulation software.
Keywords – Power Electronics, Solar PV, MPPT, Buck Converter, Duty Cycle

I. INTRODUCTION

Climate change threats and energy crisis leads to look for alternate sources of energy [1-3]. The world is virtually on the hunt of promising renewable and sustainable sources of energy. In recent years, renewable energy sources like solar, wind, tidal, have attracted the researchers, as it is limitless, non-pollutant and available free of cost. Due to rapid improvement in advancement in power electronics and reduction in the manufacturing cost of PV cell, solar energy is becoming more promising source of energy [4-8]. Solar PV exhibits nonlinear characteristics and its efficiency is also low. It becomes essential to extract maximum power from solar PV under all ambient conditions. MPPT (Maximum Power Point Tracking) algorithm is used to extract maximum power from solar PV [9-10]. The control of MPPT is implemented in the control circuit of Power electronics converters. A converter without MPPT system only regulates the output voltage of PV module, but it does not ensure that PV system is operating at the maximum power point MPP [11]. The operation of MPPT depends on the type of converter used [12-14]. In this paper a buck dc-dc converter is used and the performance of MPPT is evaluated.

II. MPPT TECHNIQUES

Various types of MPPT techniques are proposed by the researcher like Perturb & Observe, Incremental Conductance, open voltage, short circuit etc. In this paper Incremental conductance technique is used.

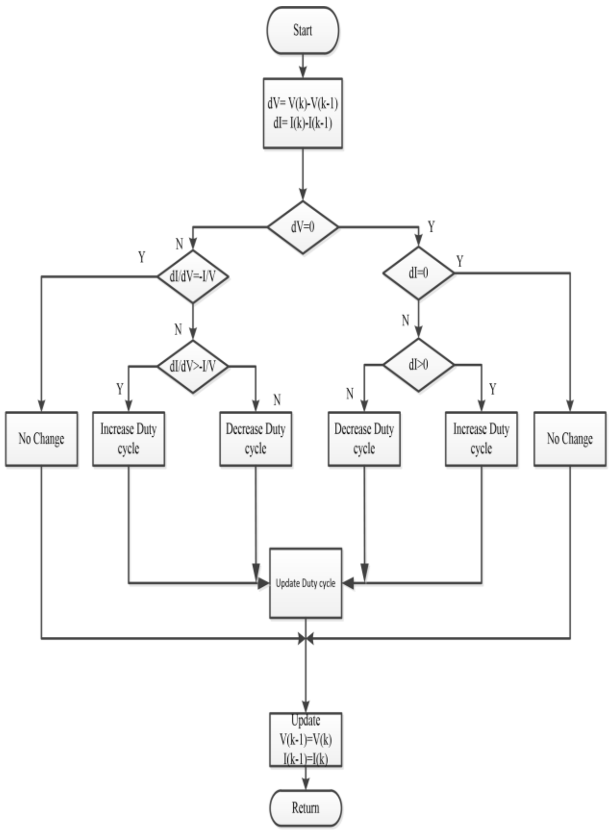

Fig. 1: Flowchart of INC MPPT algorithm

In INC algorithm the slope of the PV curve is measured continuously. In other words, the INC algorithm is based on the fact that the sum of the instantaneous conductance I / V and the incremental conductance ΔI / Δ V is zero at the MPP, positive slope in left hand side of the MPP and negative slope in the opposite side.

$$\frac{dI}{dV} = -\frac{I}{V} \quad \text{At MPP} \qquad (1)$$

The INC MPPT algorithm is the extended form of the Perturb and Observation MPPT algorithm, in which the slope of the curve is zero at the MPP.

$$\frac{dP}{dV} = 0 \qquad (2)$$

Equation 4 can we extended as follows

$$\frac{dP}{dV} = I.\frac{dV}{dV} + V\frac{dI}{dV} \qquad (3)$$

$$\frac{dP}{dV} = I + V\frac{dI}{dV} \qquad (4)$$

And hence

$$I + V\frac{dI}{dV} = 0 \qquad (5)$$

Equation (5) is the basic idea of the INC algorithm. The INC MPPT is written in flowchart form is shown in Fig. 1, which changes the duty cycle on the basis of given input parameter of current and voltage.

The desired duty cycle is calculated according to MPPT algorithm, and PV system must operate on the calculated duty cycle to reach at the MPP. The new duty cycle in the system is updated according to the sampling time of the controller. If large step sizes are used to reach the MPP quickly, the tracking accuracy will degrade and steady state power oscillation will occur around the MPP. However, smaller step size increases the tracking accuracy but at the cost of increase in dynamic time response.

III. BUCK DC-DC CONVERTER

The DC – DC buck converter is used to implement the MPPT scheme. The schematic of DC – DC buck

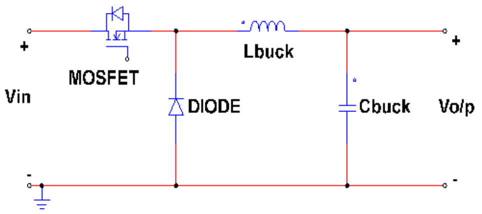

Fig. 2: Flowchart of INC MPPT algorithm

converter is shown in Fig (2). The input voltage of DC – DC buck converter is the output voltage of solar PV. Equation (4) gives the relationship between input and output voltage of buck converter [10].

$$Vo = d * Vin \qquad (6)$$

Where *Vo* is the output voltage, d is the duty cycle and *Vin* is the input voltage of buck converter.

The parameters of buck converter calculated for the design work of this paper is listed in Table I.

TABLE I: PARAMETERS OF DC-DC BUCK CONVERTER

S.No.	Name of the Parameter	Values
1	Vin	V_{MPP} : when MPP is working $V_{MPP} < Vin \leq Voc$: In NO MPP Zone
2	MOSFET	20A, 600V
3	DIODE	12A, 1000V
4	L_{buck}	1mH, 15A Saturation
5	C_{buck}	1000 uF
6	Vo	$d * V_{MPP}$: when MPP is working $V_{MPP} < d * Vin \leq Voc$: In NO MPP Zone
7	R_{LOAD}	Variable
8	Frequency	20 kHz
9	Power Output	40W

IV. BUCK CONVERTER WITH MPPT

The block diagram of Buck DC-DC converter is shown in Fig. 3. The Input resistance is shown as Rin and output resistance as Rload.

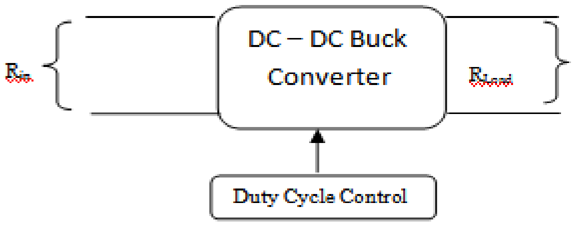

Fig. 3: Block Diagram: DC-DC Buck Converter

The MPPT is implemented by controlling the duty cycle. The maximum power can be transferred with source to load when impedance at source side matches with load impedance. The resistance of solar PV is the input resistance R_{in} for DC-DC converter. Since the MPPT is implemented and the operating point is MPP so the corresponding resistance at input is R_{MPP}. The resistance connected at the output of DC – DC converter is R_{LOAD}.

$$R_{in} = R_{Load} / d^2 \qquad (7)$$

The relationship between the input resistance, output resistance and duty cycle is shown by equation (7). Its variation is plotted in Fig (4).

At the maximum power point (MPP) on the PV curve of solar PV the input resistance (i.e. the resistance of solar PV) is matched with R_{Load} by adjusting the duty cycle with the above empirical relation. Once the R_{Load} is changed the duty cycle is adjusted to make MPP as operating point. The detailed results are given in later section.

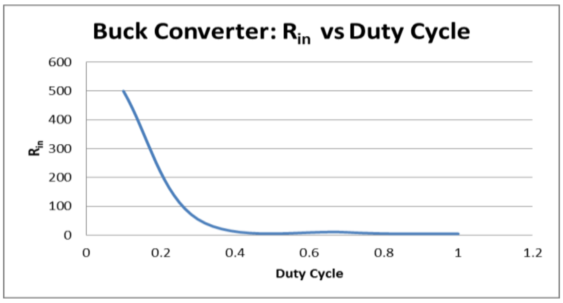

Fig. 4: Input Resistance versus duty cycle

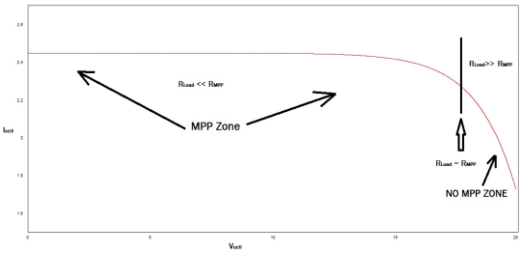

Fig. 5: MPP Zones of Solar PV (I – V) Curve.

Figure 5 shows the MPP zones in which MPPT will work and No MPP zone in which MPPT will not work.

V. Results

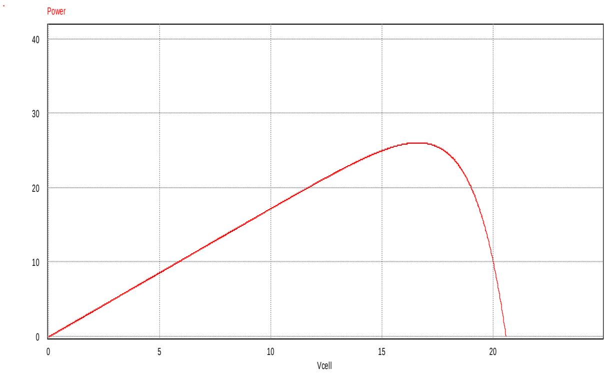

Fig. 6: Simulation Result: Solar PV: P-V Curve (Solar irradiation: 700 W/m^2, Ambient Temp: 35 deg cel)

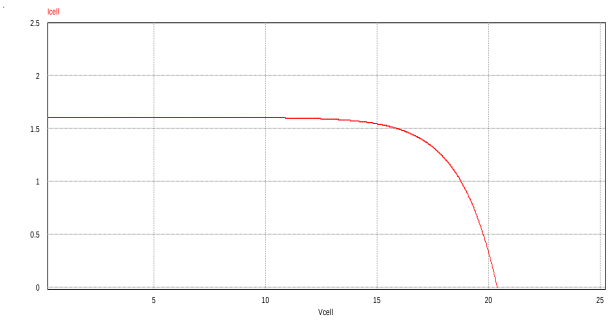

Fig. 7: Simulation Result: Solar PV: I-V Curve (Solar irradiation: 700 W/m^2, Ambient Temp: 35 deg cel)

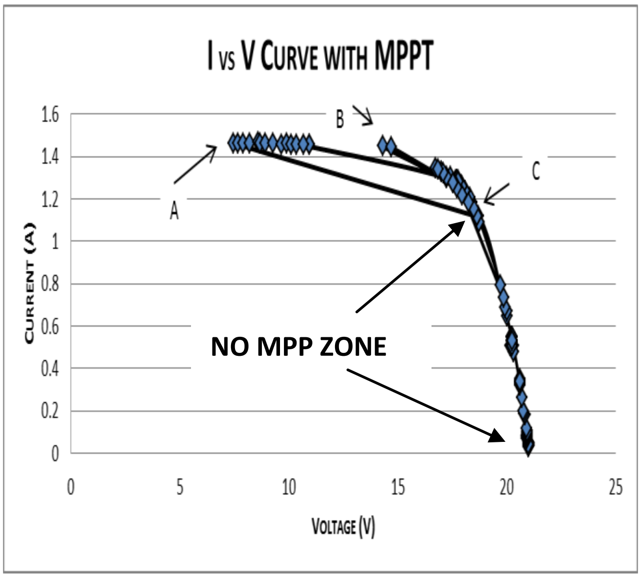

Fig. 8: Experimental Result: Solar PV: P-V Curve with MPPT (Solar irradiation: 700 W/m^2, Ambient Temp: 35 deg cel)

Figure 7 and 8 shows the simulation results of PV characteristic. Fig 8 is the experimental result of I-V curve of solar PV with variation in load. It shows that whole curve is divided in two parts i.e. MPP zone and no MPP zone. Within MPP zone if load is varied then MPP is restored.

VI. Conclusion

The main objective of the work of this paper is to evaluate the performance of MPPT with buck DC-DC converter. It is evident from the results that there is a zone on characteristic curve in which MPP works and outside this zone the MPP will fail.

VII. Acknowledgements

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