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Operational Characteristics Of DC-DC Converters In Maximum Power Point Tracking Operation For Solar PV System

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ABSTRACT:

Green technology has got tremendous attention of researchers, industrialist and governments in the last few decades. It is due to the concerns related to the global energy crisis and climate change threats. Solar energy is considered as the major source of green energy. It is available in abundant and free of cost all across the globe. Solar Photovoltaic (PV) is used to convert the solar energy to unregulated electrical energy. These solar PVs exhibits non-linear characteristic and its efficiency is very low. To overcome these issues a technique known as Maximum Power Point Tracker (MPPT) is used to extract maximum power from solar PV. These MPPT techniques are implemented in the control circuit of power electronics converters. Various types of power electronic converters are used in solar PV application. DC –DC converters are among these topologies used very widely used. The behavior of MPPT varies with change in DC – DC converter topology. This paper is an attempt to analyze the behavior of MPPT with DC – DC converter. It is analyzed that MPPT will fail in certain areas of solar PV characteristic curve. For these analysis three types of DC – DC converter is taken. Incremental Conductance MPPT method is used for this study. The simulation is done using PSIM simulation software.

Keywords: Photovoltaic, Maximum Power Point Tracker, DC –DC converter, Incremental Conductance, PSIM.

I. INTRODUCTION:

Electrical energy has become the basic need of human being. The demand of electrical energy is growing exponentially [1]. These demands are met by generating the electricity using fossil fuels. The extensive use of fossil fuels has led to the concerns of global energy crisis and climate change threats. It is the reason that the governments, researchers and industrialists are paying tremendous attention on alternate sources of energy. Renewable energy sources are considered to be the best alternative sources of energy as it is available free of cost. Among all solar energy is considered to be the most potential renewable sources of energy as it is available in abundant and free of cost.

Solar Photovoltaic (PV) is used to convert solar energy into electrical energy. Solar PV has non-linear characteristics [2] and the efficiency is also very low. To overcome these issues a technique known as Maximum Power Point Tracker (MPPT) scheme is used. Various types of MPPT schemes like Perturb & observe, Incremental conductance, constant voltage, beta are introduced [3-8].

These MPPT techniques are implemented with the control loop of power electronics converters [9]. DC – DC converters of various topologies are widely used in solar PV applications [10]. DC – DC converters behaves differently as per its topology. It is essential for the researcher and engineer to understand this behavior when it is used in solar PV conversion system.

This paper is an attempt to analyze the limitations of DC – DC converter when it works with MPPT scheme in solar PV energy conversion system. Three basic types of DC – DC converter is chosen i.e. Buck, Boost, Buck – Boost converter for this analysis. The Incremental Conductance MPPT scheme is chosen for analysis. PSIM software is used for simulation.

The remaining sections of the digest are arranged as following:

Section II describes the modeling and characteristics of solar PV. In Section III the DC – DC characteristics are analyzed in terms of input, output impedances followed by the simulation results and discussion in the next section.

II. MODELLING AND CHARACTERISTICS OF SOLAR PV:

The characteristic solar PV is non linear. The PV cell output depends on ambient temperature and solar irradiation. Fig. 2 is the equivalent circuit model of PV cell. Equation 1, 2 and 3 are the characteristic equations of solar PV cell [2].

$$I = I_{ph} – I_{os} \{\exp [(q/AKT) (V + I R_s)] – 1\}- (V +I*R_s)/R_p \quad (1)$$

$$I_{os} = I_{or} \exp [q E_{GO}/ Bk ((1/T_r) – (1/T))] [T/T_r]^3 \quad (2)$$

$$I_{ph} = S[I_{sc} + K_I (T- 25)]/100 \quad (3)$$

Where PV output currentis I, PV cell output voltage isV, parallel resistor is R_p, series resistor is R_s . PV module reversal saturation current is I_{os}, ideality factors are A, B , temperature (^oC) is T , boltzmann's constant is k, light-generated current is I_{ph}, electronic charge is q , short-circuit current temperature coefficient at I_{SC} is K_I. Solar irradiation is S in W/m^2, short-circuit current at 25^oC and 1000 W/m^2 is I_{SC} , bandgap energy for silicon is E_{GO}, reference temperature is T_r and saturation current at temperature T_r is I_{or} . The equivalent circuit model of solar cell and the characteristic curve is plotted in Fig. 1 and Fig. 2 respectively. With the change in solar irradiation the power level changes and the maximum power point (MPP) is indicated.

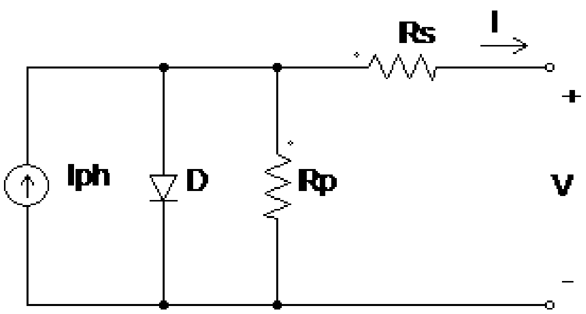


Fig. 1: Equivalent model of PV Cell different Solar Irradiation level.

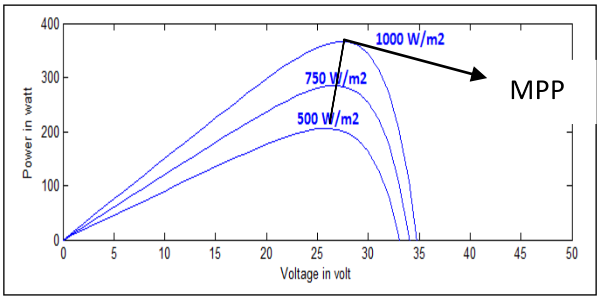
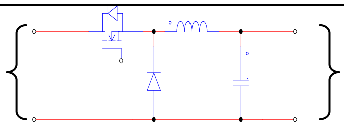
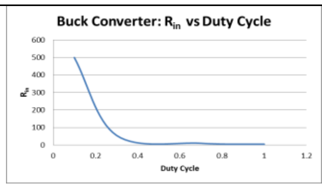


Fig.2: Solar PV Power Characteristics with

III. DC – DC CONVERTER & ITS CHARACTERISTICS:

In almost all types of MPPT schemes the duty cycle of DC – DC converter is varied to achieve the maximum power point. It can be understood in terms of maximum power transfer theorem i.e. the duty cycle of the converter's switch is varied to match the input impedance of the DC – DC converter with its output impedance. It is important to understand the relationship between input and output impedance in terms of duty cycle. From this relationship the limitations of MPPT scheme with DC –DC converter can be analysed. The relationships are given in Table 1.

TABLE I : CHARACTERISTIC EQUATIONS OF DC –DC CONVERTERS

S.No.	DC – DC Converter Topology	Input Output Relationship	Plot
1	Rin  Ro Buck Converter	Rin = Ro/D^2	
2		Rin = Ro(1-D)^2	

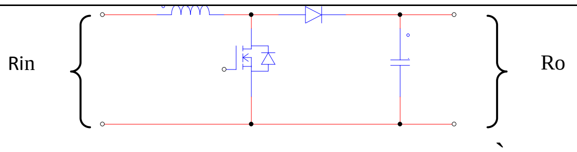
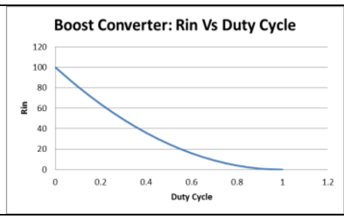
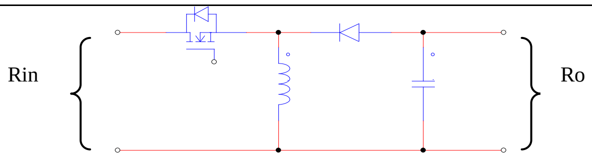
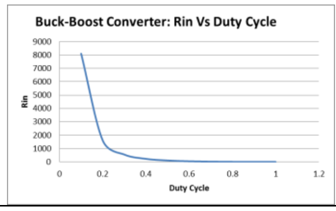
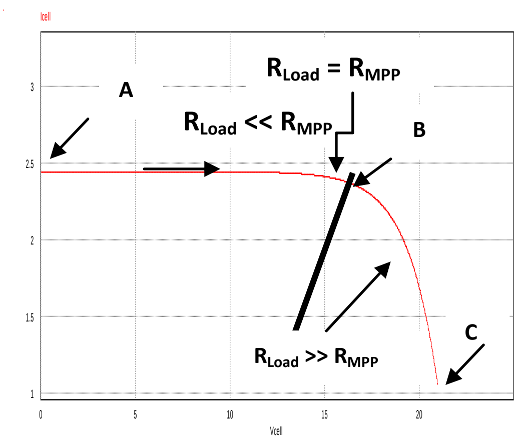
	 Boost Converter		
3	 Buck-Boost Converter	Rin = $(1\text{-}D)^2 * Ro/D^2$	

TABLE II : MPP ZONE WITH DC –DC CONVERTER TOPOLOGY

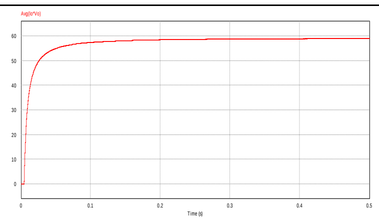
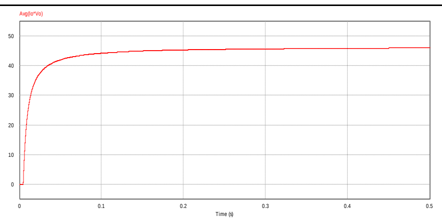
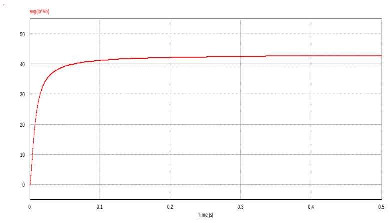
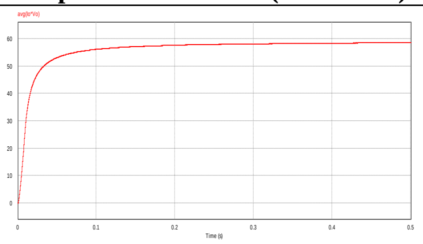
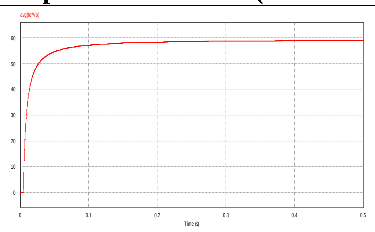
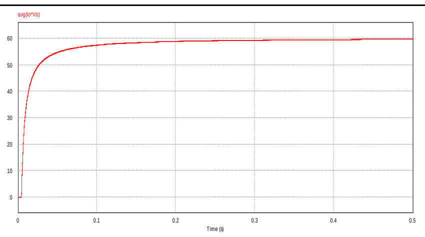
	DC – DC Converter	MPP Zone	
		Working Zone	No-Working Zone
	Buck	A-B	B-C
	Boost	B-C	A-B
	Buck- Boost	A-B. B-C	None

Based on the relationship shown in Table I, the MPP operating zone and non-operating zone is defined in Table II for different converters. As it can be seen that MPP is functional only in a portion of PV characteristic curve for Buck and Boost DC – DC converters but it is functional for the entire region for Buck – Boost Converter. It is verified in the next section by simulation results.

IV. SIMULATION AND RESULTS:

The simulation of DC –DC Converter along with solar PV and Incremental conductance MPPT scheme is done using PSIM simulation software. The results are given below in Table III. The solar PV taken for this study has the **Maximum Power of 60 Watts** at solar irradiation of 1000 w/m^2 and ambient temperature of 25 degree celcius. The V_{MPP} is 17.1 V and I_{MPP} is 3.5 A. The **R_{MPP} is 4.89 Ω.**

TABLE III : RESULTS OF MPP ZONE WITH DC –DC CONVERTER TOPOLOGY

S.No.	**Converter Topology**	**When R_{load} << R_{MPP}**	**When Rload >> R_{MPP}**
1	Buck	 **Output Power ~ 60W**	 **Output Power ~ 46 W (MPP Fails)**
2	Boost	 **Output Power ~ 42 W (MPP Fails)**	 **Output Power ~ 60 W**
3	Buck - Boost	 **Output Power ~ 60 W**	 **Output Power ~ 60 W**

The simulation results shown in Table III are the verification of the discussion in previous section. It can be seen that MPPT works in limited portion of its characteristic curve with Buck and Boost converters. MPPT works in the entire zone with Buck boost converters.

V. CONCLUSION

The analysis done in this paper may be useful for the researchers and designers to choose a proper DC – DC converter in solar PV applications. The MPPT operating zone is the major criteria for selecting the type of converter to be used in solar PV energy conversion system. However, these MPPT zones will remain same irrespective of the type of MPPT scheme used.

VI. REFERENCES

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