174. Study of Incremental Conductance Maximum Power Point Technique under Non-Uniform Solar Irradiations Conditions for Solar PV system

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Abstract

To meet the increasing demand of power, there is rapid rise in the development and utilization of renewable energy resources, particularly energy scavenging from solar irradiations. In the recent years energy scavenging from sun has been receiving considerable attention due to versatile advantages. The advantages by the photovoltaic (PV) system when put to use for energy conversion include low maintenance cost, noiseless operation, no limitations, economical friendly and pollution free energy. PV is considered as one of the most important renewable energy sources, since solar energy is inexhaustible, free and clean. In this paper we will be focusing on the maximum output power utilization of PV array, by using incremental conductance (INC) MPPT method, which is commonly used methods to get the optimum efficiency from PV system under non-uniform solar irradiations. MPPT's are used to maximize the output of PV arrays, by tracking MPP. MATLAB software is used for simulation and Microsoft Visio for diagramming and flow charts. In this paper we will investigate output voltage and power variations of INC MPPT technique at different duty cycles (ʎ) under non-uniform solar irradiations. Which will help in selecting the appropriate MPPT technique and its merits and demerits on solar PV array applications for future developments.

Keywords: *"MPPT, Solar PV System Control".*

1. Introduction:

Power crisis are becoming extensive and more severe in today's era. Because depilation of conventional fossil fuels, which unlimitedly used in power and transportation system. From the last few decades considerable efforts have been made to utilize renewable energy sources (RESs) in to conventional power generation system to reduce the rapid diminution of fossil fuels and environmental pollution. Solar energy is one of the abundantly available sources of renewable energy which can be one of the main source of future power generation system in standalone and grid connected for domestic, commercial and industrial applications [1]. Due to its flexibility and adaptability in grid connected or standalone mode, photovoltaic has attracted extensive attention of PV system manufacturers and researcher for its maximum utilization and optimization. Technically there are two ways to improve the effectiveness and optimization of solar PV system, either it could be possible to develop low cost high efficiency solar conversion materials or to control the PV system at maximum power point (MPP) for getting best possible output power. Because of the high cost of solar cells, it is necessary to operate the PV array at the maximum operating point. Therefore maximum power Point tracking (MPPT) is considered as an essential part of PV generation system and is one of the key issue for researchers to reduce the effects of nonlinear characteristics of PV array [2].So far different maximum power point algorithms have been proposed for optimization of PV output power, such as Incremental Conductance (INC) [3, 4], Perturb & Observe (P&O) [5-7], Hill Climbing [8, 9], Fuzzy Logic Control (FLC), Neural Network (NN) and Genetic Algorithm (GA) [10-12].

Among all the aforementioned MPPT algorithms, incremental conductance (INC) and perturb & observe (P&O) are commonly used for small and large scale PV power plants because both the algorithms operates in accordance with power against voltage (P-V) curve of PV module and tune the duty cycle of converter to ensure the next MPP point accordingly. In this paper we will be investigating the INC MPPT method under non-uniform solar irradiance conditions with different duty cycles (λ) to investigate its output voltage stability and power variations. PV array system configuration with MPPT and DC-DC boost converter is depicted in Fig.-1.

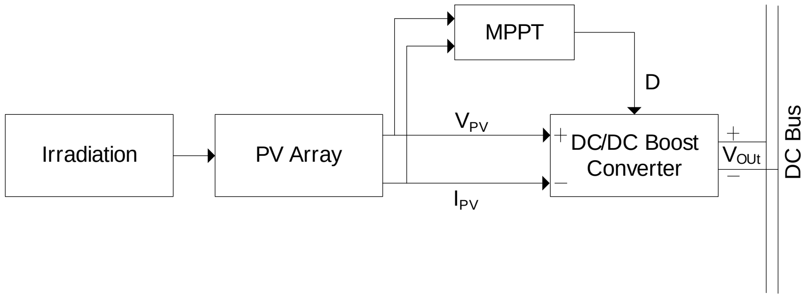

Fig.1. PV System Configuration with MPPT

2. PV Module Modelling

PV generation system are defined as voltage (V) or current (I) source. Practically solar cell is a hybrid behaviour device which can either be V or I source. Because of nonlinearity of environmental conditions PV module has non-linear characteristic. For PV system applications, it is important to model it according to the design requirements of MPPT. In this paper, 36W PV panel is taken as reference, and the required solar cell model is developed in MATLAB/SIMULINK by following the equation-1 to 4. Whereas , PV module electrical data sheet is given in table-1 [13].

$$I_{ph} = \left[I_{SCr} + K_i(T - 298) * \frac{\lambda}{1000}\right] \quad (1)$$

In equation-1 solar cell photocurrent I_{ph} is obtained, where the short-circuit current I_{SCr}=2.55A with (STC) standard test condition at 25°C and solar irradiation of$1000W/m^2$. Further, the I_{SC} temperature co-efficient($K_i = 0.0017\, {}^{A}/_{°C}$), operating temperature of module is T in Kelvin.

$$I_{rs} = {}^{I_{SCr}}\Big/\left[\exp\left(\frac{qVoc}{N_s kAT}\right) - 1\right] \quad (2)$$

In equation-2, $q = 1.6 \times 10^{-19}C$, V_{OC} is 21.24 as given in manufacturer voltage of PV panel data sheet, Boltzmann constant $k = 1.3805 \times 10^{-23}\, {}^{J}/_{K}$ and ideality factor is (A=1.6).

$$I_o = I_{rs}[\frac{T}{Tr}]^3 \exp[q * \frac{Eg_0}{BK}\left\{\frac{1}{T_r} - \frac{1}{T}\right\}] \quad (3)$$

In equation-3, the band gap *Ego* of silicon solar cell = 1.1eV

$$I_{PV} = N_p * I_{ph} - N_p * I_0[\exp\left\{q * \frac{[\{q*(V_{PV}+I_{PV}R_S\}]}{N_s AKT}\right] - 1 \quad (4)$$

According to the data sheet specification of solar panel as given in table-1. 3 KW PV system is simulated where, in one PV panel number of parallel solar cell (Np=1), numbers of solar cell in series

(Ns=36) and PV output voltage V_{PV} are equal to open circuit voltage V_{OC} of PV panel.

Table-1: Solar 36W PV Module Electrical Data Characteristic

Description	Rating
Maximum Power (MP)	37.08 W
Voltage at (MP)	16.56 V
Current at (MP)	2.25 A
Open Circuit Voltage (V_{OC})	21.24 V
Short Circuit Current (I_{SC})	2.55 A
Total Number of Cell in Series (N_S)	36
Total Number of Cell in Parallel (N_P)	1

3. Incremental Conductance MPPT Method.

The conventional incremental conductance method is driven by following the equation (6) to find the slope of P-V curve. In equation 6 it determines that the operating point of PV module is at its MPP level as can seen in Fig 2. Whereas, reference to equations (7) & (8) are operating at left and right side of P-V curve to achieve the MPP accordingly by increasing and decreasing duty cycle of INC controller algorithm methodology as shown in table-2 and in Fig. 3 its flow chart is given [14, 15] .

$$\frac{dI}{dV} = -\frac{I}{V} \tag{6}$$

$$\frac{dI}{dV} > -\frac{I}{V} \tag{7}$$

$$\frac{dI}{dV} < -\frac{I}{V} \tag{8}$$

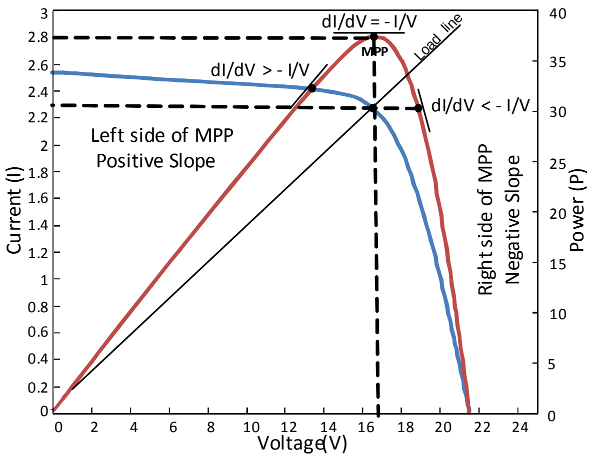

Fig. 2. Incremental Conductance MPP Curve

Table-2. Incremental Conductance Algorithm Methodology[16]

Mode	Mode	MPP Level	Status
Mode-1	$dP/dV = 0$	At MPP	Hold V_{PV}=V_{MPP}
Mode-2	$dP/dV > 0$	Left side of MPP	Increase Voltage till V_{PV}=V_{MPP}
Mode-3	$dP/dV < 0$	Right side of MPP	Decrease Voltage till V_{PV}=V_{MPP}

The scheme of (6), (7) & (8) is that the slope of P-V curve at MPP is equal to zero as described in (9).

$$\frac{dP}{dV} = 0 \quad (9)$$

Therefore, (9) can be rewritten as

$$\frac{dP}{dV} = \frac{d(I*V)}{dV} = V * \frac{dI}{dV} + I * \frac{dV}{dV} \quad (10)$$

$$\frac{dP}{dV} V * \frac{dI}{dV} + I \quad (11)$$

Which implies that

$$\frac{dI}{dV} + \frac{I}{V} = 0 \quad (12)$$

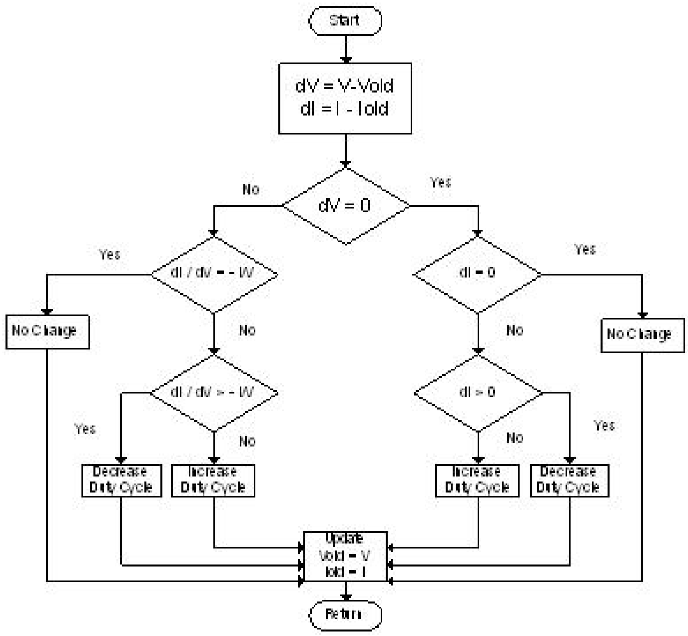

Fig. 3. Incremental Conductance MPPT Algorithm Flow Chart

However, in INC the slope of PV curve determines by varying the converter duty cycle in fixed or variable step size until the MPP is achieved. The larger step size helps to reduce the MPP tracking time but not get rid of the oscillation around MPP [17], the smaller step size reduces the oscillation under rapidly changing solar irradiance conditions with greater efficiency but due to smaller step size and complicated algorithm speed is slow [4, 18].

4. Simulation Results and Discussions.

To investigate the performance of incremental conductance MPPT method under non-uniform solar irradiance at different duty cycles. A MATLAB Simulink model was developed as shown in Fig. 4, which consist of the PV array, a DC-DC boost converter and incremental conductance MPPT controller technique.

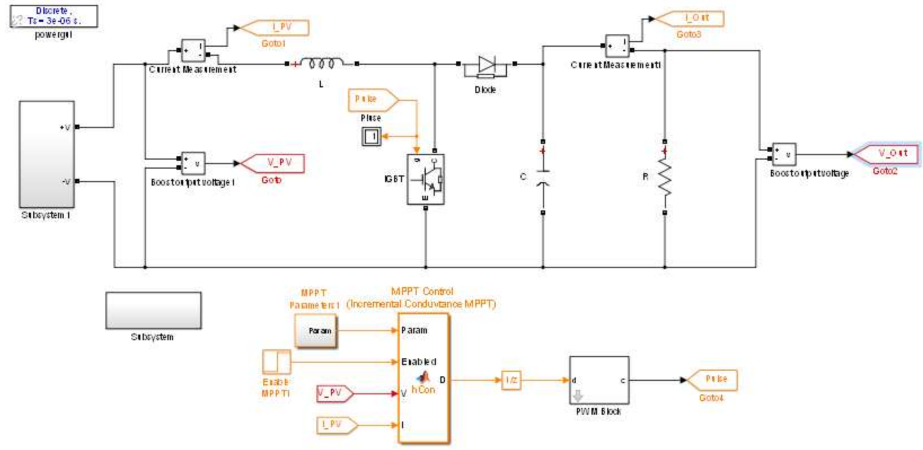

Fig. 4. MATLAB/Simulink Model of INC MPPT

Furthermore, to investigate the effectiveness of the incremental conductance MPPT method at different duty cycles at Δd= 0.001, 0.005 and 0.01. The output voltage results in Fig-5 (A, B and C) in magenta colour and output power in Fig -6 (A, B and C) in green colour clearly illustrates that performance of the INC MPPT.

Fig.5. Output Voltage of MPPT Control at Δd= 0.001, 0.005 and 0.01

It can be observe in Figs. 5 (A, B & C) as Δd is increases from 0.001 to 0.01, INC's output voltage decreases from the range of (385-407) volts to (374-397) where the upper limit decreases to 10 volts and the lower limit went down to 11 volts.

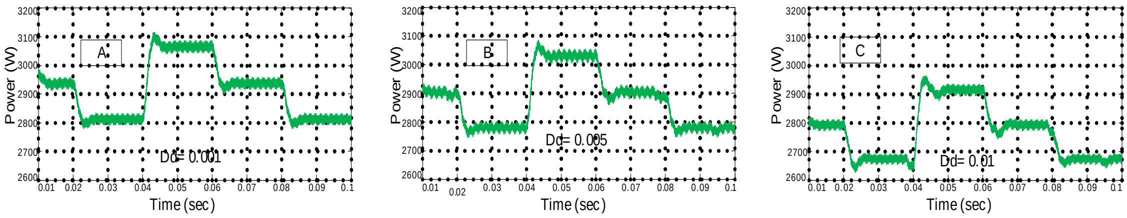

Fig.-6. Output Power of MPPT Control at Δd= 0.001, 0.005 and 0.01

In the same way, in Fig. 6 (A, B & C) output power of INC at Δd = 0.001, INC's output power is between (2775-3100) watts, and at Δd=0.01 INC's output power is (2625-2955).

Furthermore, table-3 surmises the measurement output voltage and power of INC at duty cycle Δd= 0.001, 0.005 and 0.01 in order to verify the repeatability of the results, It can be seen that smaller Δd reduces the steady-state losses caused by the oscillation of the PV operating point around the MPP, but it makes the algorithm slower and less efficient in the case of rapidly change in solar irradiations and larger step size contributes to faster dynamics but excessive steady state oscillations, resulting in a comparatively low efficiency as it can easily be seen in Figs. 5 & 6.

Table-3. INC Output Voltage and Power Comparisons at Different Δd

	Δd					
	Voltage			Power		
Irradiation (W/m^2)	0.001	0.005	0.01	0.001	0.005	0.01
600	388.4	383.1	378.5	2827	2751	2687
800	396.8	391.5	386.7	2953	2874	2804
1000	404.9	399.4	395.7	3081	2992	2931

5. Conclusion

This paper presents a study analysis of incremental conductance method with different duty cycles (Δd) under non-uniform solar irradiations in MATLAB/Simulink. Simulation results reveals smaller Δd decreases the steady-state losses caused by the oscillation around the MPP and the larger the step size tends to faster dynamics but produces unnecessary steady state oscillations. Resulting in a comparatively low efficiency. Considering the best possible rapport of incremental conductance simulation at 0.001 step change response of Δd obtained maximum power from PV system.

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