Simulation of Incremental Conductance MPPT Algorithm for PV Systems using LabVIEW

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Abstract: Among all types of renewable energies, solar energy has the widespread utilization. This popularity is achieved for its sustainability, cleanliness, ease of maintenance and absolute zero noise characteristics. The global economic convenience of a PV system depends on the cost and the energy conversion efficiency. It is necessary to reduce the cost and increase the efficiency to make solar energy effectively. Thus, MPPT algorithm is necessary in order to track the optimum operating point or maximum power that can be extracted from the PV array. In this paper, Incremental Conductance MPPT algorithm is implemented using LabVIEW (Laboratory Virtual Instrument Engineering Workbench) and its performance is observed.

Keywords: PV system, Incremental conductance, MPPT algorithm, LabVIEW.

I. INTRODUCTION

Energy is absolutely essential for our life. Recently, with the industrial development, the conventional fossil energy sources are rapidly declining and the cost of energy is rising, and a looming energy is more & more becoming an obstacle to social development. Among all types of renewable energy sources, solar energy regarded as the green energy of the new energy and becomes a promising alternative source due to its availability and low noise characteristics. The solar energy is popularly used to provide heat, light and electricity. One of the most important technologies is photovoltaic (PV) which converts the radiation directly to electricity by the photovoltaic effect. This generated voltage is used for charging batteries which is further given to AC or DC loads depending on the load used. The PV module converts the incident solar radiation into electrical power. For the better utilisation of the power generated Maximum Power Point Tracking technique is preferred. The maximum power point tracking mechanism makes use of an *algorithm* and an electronic circuitry. The mechanism is based on the principle of impedance matching between load and PV module, which is necessary for maximum power transfer. This impedance matching is done by using a DC to DC converter. It step ups or step downs the source voltage at MPP depending on the output of controller.

The algorithm used in the controller is to track the maximum power point. Different Algorithms are existing and are being developed. Among the various conventional methods for MPPT, the most commonly used are Perturb & Observe Method, Incremental conductance Method, Fractional Short Circuit Current Method, Fractional Open Circuit Voltage Method, Fuzzy Logic Control Method, etc., The primary algorithm implemented in the MPPTs is the P&O method which involves perturbing the point of operation and observing the power delivered by the PV array. Such a course of action leads to climbing of the hill-like P-V curve to ultimately reach the MPP & oscillate around it until the P-V curve changes due to the next change in atmospheric conditions. The major benefits of this technique include relatively simple and easy understand. In some papers, P&O is also referred as Hill climbing method because it uses the same concept in perturbing Maximum power point. In fact the only difference between them is the output control variable in which P&O produces the change from the reference voltage to the converter while Hill climbing produces the change from the duty cycle [1].

The two critical weaknesses of voltage P&O is that, the system oscillates around the MPP which will cause loss of energy. Secondly, it will not be able track the maximum power point during fast changing of weather condition. A major challenge faced by this algorithm is the tendency of tracking in the wrong direction which is known as drift. These limitations are overcome in Incremental conductance MPPT algorithm. Incremental conductance method utilizes the fundamental concept of hill climbing, in which the slope of the PV array power curve is zero at the MPPT, positive at the left side and negative at the right side of the PV curve [1][2].

II. PV SYSTEM

The solar energy is popularly used to provide heat, light and electricity. One of the most important technologies is photovoltaic (PV) which converts the radiation directly to electricity by the photovoltaic effect [3]. The solar cells are mostly made of silicon (14-17% of cell efficiency) or Gallium Indium Phosphide (30-35% of cell efficiency) and are available in the form of arrays or panels [4]. This generated voltage is used for charging batteries which is further given to AC or DC loads depending on the load used as shown in Fig.1.

A. Block Diagram of Battery Charging System Using Solar Energy

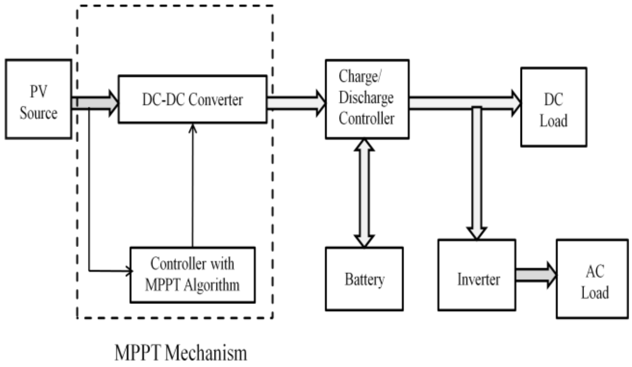

Fig. 1. Block diagram of Battery charging system

A detailed block diagram of the battery charging system is shown in Fig.1 which consists of

- Photovoltaic (PV) source
- DC-DC converter
- Controller with MPPT algorithm
- Charge or discharge controller
- Battery with DC Load
- Inverter with AC load

Description: The PV module converts the incident solar radiation into electrical power. For the better utilisation of the power generated Maximum Power Point Tracking is preferred [5]. The main block of this is the MPPT Mechanism. The maximum power point tracking mechanism makes use of an *algorithm* and an electronic circuitry [6]. The mechanism is based on the principle of impedance matching between load and PV module, which is necessary for maximum power transfer [7]. This impedance matching is done by using a DC to DC converter. It step ups or step downs the source voltage at MPP depending on the output of controller. The algorithm used in the controller is to track the maximum power point [8]. Different Algorithms are existing and are being developed.

B. Incremental Conductance (Inc) Method

Incremental conductance method utilizes the fundamental concept of hill climbing, in which the slope of the PV array power curve is zero at the MPPT[9], positive at the left side and negative at the right side of the curve as shown in the Fig. 2 [1][2].

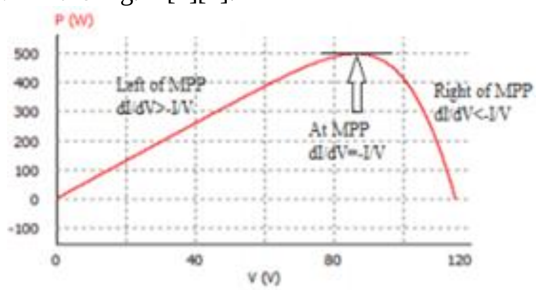

Fig. 2. Operating principle of InC

At MPP, $V = V_{amp}$, $\frac{dp}{dv} = 0$ => $\frac{dI}{dV} = -\frac{I}{V}$ (1)

Left of MPP, $V < V_{mp}$, $\frac{dP}{dV} > 0$ => $\frac{dI}{dV} > -\frac{I}{V}$ (2)

Right of MPP, $V > V_{mp}$, $\frac{dP}{dV} < 0$ => $\frac{dI}{dV} < -\frac{I}{V}$ (3)

Operation: It is based on the fact that the derivative of out power "P" for the voltage of the solar module becomes "0" at the maximum power point (MPP) [10]. The following equation using P=VI relationship is calculated,

$$\frac{dP}{dV} = \frac{d(VI)}{dV} = I.\frac{dV}{dV} + v.\frac{dI}{dV} \quad (4)$$

$$=> \frac{dP}{dV} = I + V.\frac{dI}{dV}$$

(5) When MPP is reached, the slope $\frac{dP}{dV} = 0$,

then, $\frac{dI}{dV} = -\frac{I}{V}$

(6) *i.e,* Incremental conductance = instantaneous conductance.

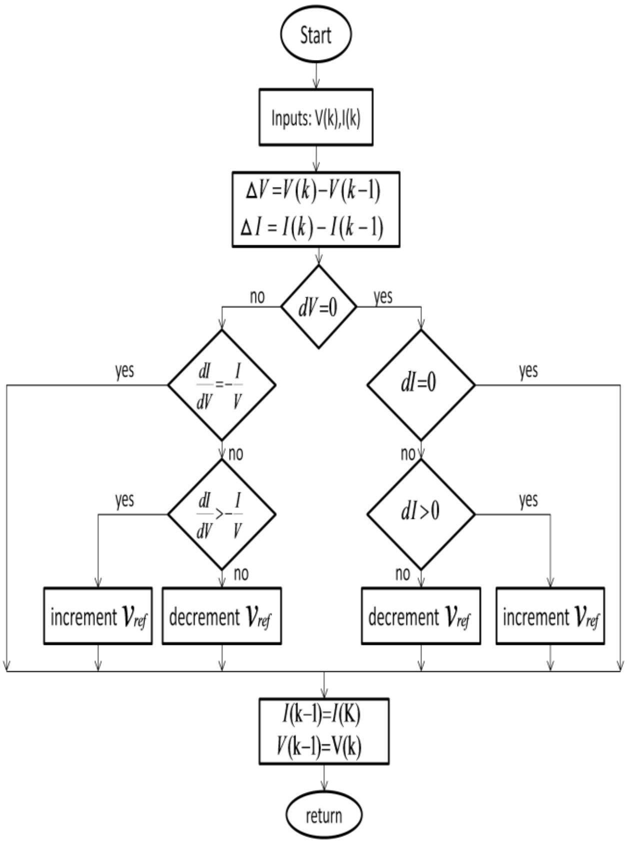

Fig. 3. Flow chart of InC

The MPP can be determined by comparing both the conductance & is attained when both the conductance are equal according to equation (6) [11]. The flowchart depicts the procedure to track the MPP by using reference voltage, & in theory, the MPP will maintain constant without oscillations until the current changes [12]. The change in current indicates the change in irradiation level. This method is therefore capable to capable to track the MPP during rapid variation of sun irradiation [13].

The main advantage is that it can be used to determine the maximum power point without oscillating around this value and also eliminates the steady state error and drift

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[14]. The main drawback of this algorithm is that it is Expensive and complex system. This complex computation leads to slow convergence speed.

III. SIMULATION

Simulation is the process of using modern computer software and hardware to analyse the potential outcome of a given situation, based on known factors and introduction of one or more variables that have the ability to influence the outcome of any given situation. The power of simulation is that even for easily solvable linear systems a uniform model execution technique can be used to solve a large variety of systems without resorting to a "bag of tricks" where one must choose special-purpose and sometimes arcane solution methods to avoid simulation.

A. *Simulation of PV Cell*

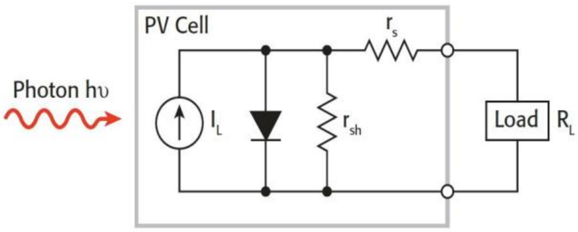

Fig. 4. Equivalent circuit of PV cell

The equations representing the operation of equivalent circuit of PV cell in Fig. 4 are given below:

$$I=\left[N_pI_{sc}-N_pI_0\left(e^{\left(\frac{V}{N_s}+IR_sT\right)}-1\right)-\frac{V/N_s}{R_{sh}T}\right] \quad (9)$$

$$R_sT=\frac{N_s}{N_p}R_s \quad (10)$$

$$R_{sh}T=\frac{N_p}{N_s}R_{sh} \quad (11)$$

$$I_{sc}=\frac{G}{1000}\left[I_{scr}+K_i\left(T_c-T_r\right)\right] \quad (12)$$

$$V_{oc}=N_s\ln\left(\frac{I_{sc}}{I_o}+1\right)\left(\frac{AKT_c}{q}\right) \quad (13)$$

TABLE I : SPECIFICATIONS DATA OF PV PANEL XH250P (72) SOLAR PANEL [15]

Type	**Unit**	
Model		**XH250P(72)**
Irradiance(G)	W/m^2	1000
No. of series cells (Ns)	Number	72
No. of parallel cells(Np)	Number	1
Max-Power (Pmax)	Watts	250
Max-Voltage(Vm)	Volts	34.4
Max-Current(Im)	Amp	7.27
Open circuit Voltage (Voc)	Volts	42.6
Short circuit Current (Isc)	Amp	7.82
Cell temperature (Tc)	Kelvin	298
Reference temperature (Tr)	Kelvin	273
Series resistance (Rs)	Ohms	5E-7
Shunt resistance (Rsh)	Ohms	5*10^(-7)
Reverse saturation current at standard condition(Io)	Amp	1.6234*10^(-7)

The PV cell with above specifications is simulated in LabVIEW. The simulated PV cell is shown in Fig 5:

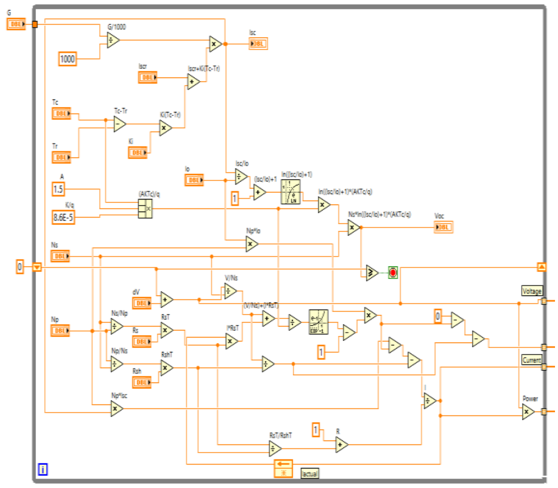

Fig. 5. PV panel simulation

B. *Simulation of Incremental Conductance Algorithm*

The simulation of MPP tracking of PV panel using Incremental Conductance Algorithm is shown in the Figure 6. This InC Algorithm is simulated by using the flow chart mentioned in the above. Case structure is used for implementing the conditional operations in the flow chart.

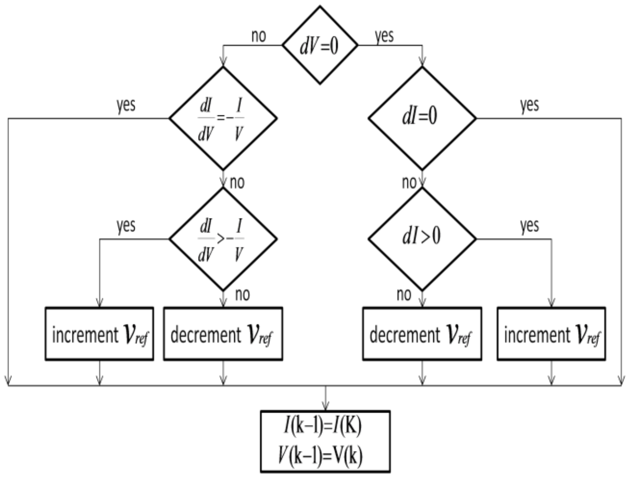

FIG. 5 FLOWCHART OF INC ALGORITHM

The flowchart of above algorithm is performed in LabVIEW as shown in Figures 6 (a-f).

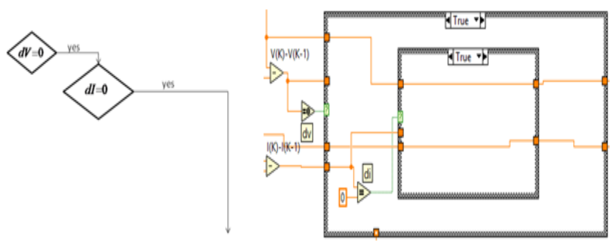

Fig. 6(a)

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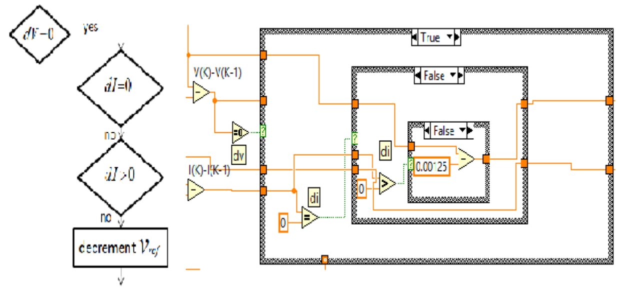

Fig. 6(b)

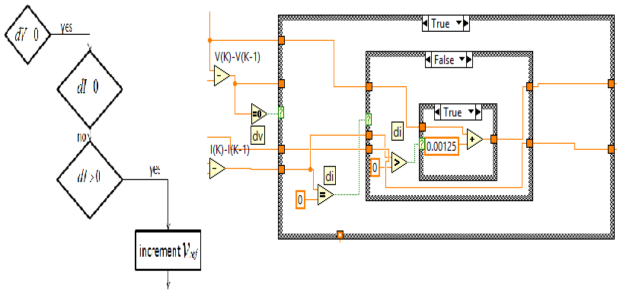

Fig. 6(c)

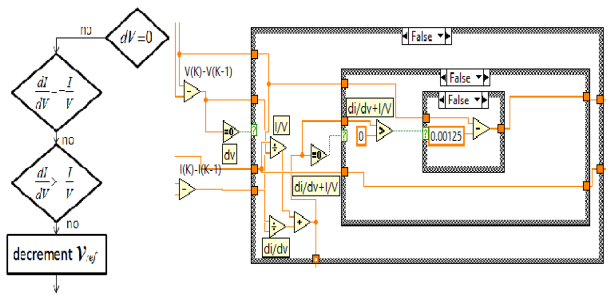

Fig. 6(d)

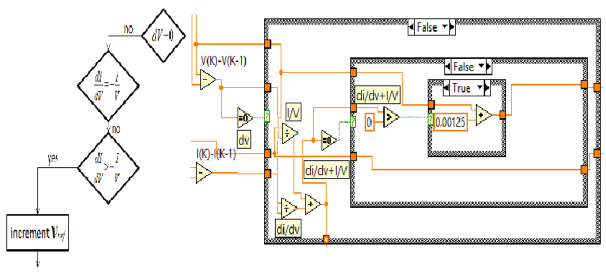

Fig. 6(e)

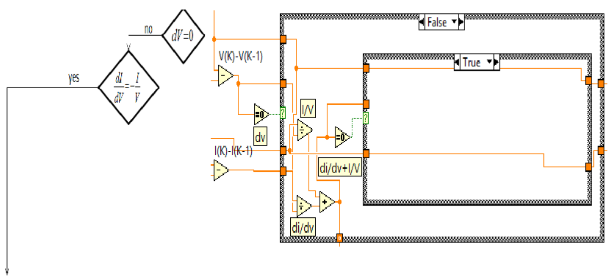

Fig. 6(f)

C. *Simulation Results*

The MPP tracking of PV Panel Characteristics by InC algorithm at an irradiance value (G=1000w/m^2) is shown in Fig. 7.

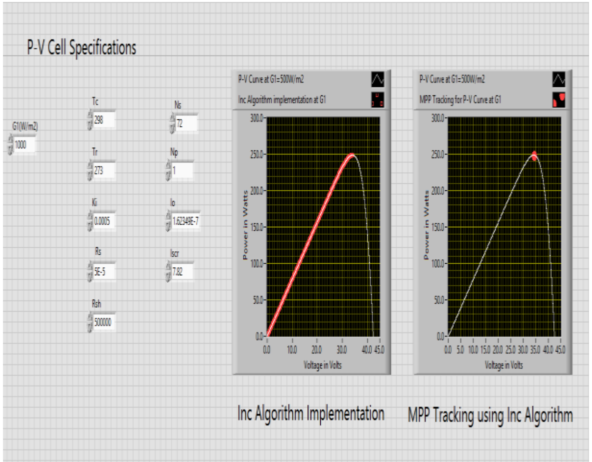

Fig. 7. PV characteristics of InC algorithm

D. *Observation*

For irradiance value of 1000w/m^2, a maximum power of 248.90 watts at 34.14 volts.

TABLE II: TABLE DISPLAYING THE VALUES OF POWER AND VOLTAGE OF PV PANEL WITH INC ALGORITHM AT IRRADIANCE G=1000W/M^{2}CONDITIONS

Voltage in Volts - P-V Curve at G=1000W/m^2	**Power in Watts**	**Voltage in Volts**
1	7.8	1
2	15.7	2
4	31.3	4
5	39.2	5
6	47	6
7	54.8	7
8	62.7	8
10	78.3	10
11	86.2	11
12	94	12
13	101.8	13
14	109.7	14
15	117.5	15
16	125.3	16
22	172.2	22
23	180	23
24	187.8	24
25	195.5	25
26	203.1	26
27	210.7	27
28	218.1	28
29	225.2	29
30	231.9	30
31	238.1	31
32	243.2	32
33	247	33
34	248.6	34
35	247	35

The above simulation results show that the InC algorithm tracks the MPP at different irradiance levels effectively.

The Incremental Conductance method has less performance during clear sky and cloudy sky conditions but has better performance in partly cloudy conditions.

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Simulation Results: The P-V Characteristics with InC algorithm at variable irradiance values is shown in Fig. 8. It is seen that both the MPP techniques are only tracking the local MPP but not the Global MPP.

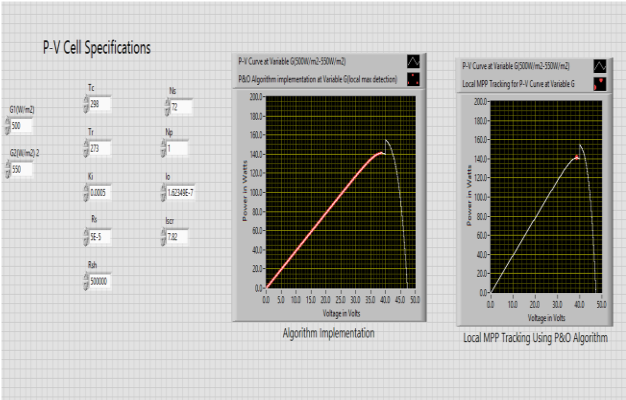

Fig. 8. PV characteristics for a InC algorithm

IV. CONCLUSION

In this paper, the MPPT algorithms i.e., InC techniques for a PV system are simulated at different irradiance conditions using LabVIEW. With the simulation results, the performance of the algorithm for MPP tracking of PV system has been observed. The P&O is simple but has a limitation of drift which is reduced in InC method. It has also been observed that InC method cannot track the global MPP but only tracks the local MPP under partial shaded conditions.

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BIOGRAPHIES

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