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Analysis of P&O and INC MPPT Techniques for PV Array Using MATLAB

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Abstract: *Maximum power point tracking (MPPT) techniquesare used in photovoltaic (PV) systems to maximize the PV array output power by tracking continuously the maximum power point (MPP) in the P-V curve of a photovoltaic array.The maximum power is tracked with respect to temperature and irradiance levels by using DC-DC converter. The perturbation and observation(P&O) and Incremental Conductance(INC)algorithms are applied here for maximum power point tracking (MPPT) purpose. These algorithms are selecteddue to its ability to withstand against any parameter variation and having high efficiency as well as ease of implementation.Here, the output of the system is connected to a grid so that the proposed system works as a solar generator on sunny days, in addition to working as an active power line conditioner on rainy days. Finally, computer simulations and experimental results demonstrate the superior performance of the proposed technique.*

Key Words: *Maximum power point tracking (MPPT), Perturb and Observe (P&O), Incremental Conductance (INC), Photovoltaic (PV), DC-DC converter.*

I. Introduction

Photovoltaic generating systems need maximum power point tracker because the output of the PV array depends on the operating terminal voltage and current. As the intensity of the light falling on the array varies, its internal resistance as well as its voltage also varies.

A Photovoltaic (PV) array under uniform irradiance exhibits a current-voltage characteristic with a unique point, called the maximum power point (MPP), where the array produces maximum output power [1].

PV is not a constant dc energy source in which its output power is varied strongly depending on the currentdrawn by the load. We know that, PV characteristics changes with temperature and irradiation variation. Hence, the output voltage (V) as well as current (I) varies of a PV array. For this we have to track voltage or current by MPPT. Thus, the output power as well as its efficiency can be increased. To achieve maximum power the internal resistance of the array should be equal to the load resistance. A dc-dc converter is incorporated between SPV arrayand the load to adjust the internal resistance by varying the duty cycle using MPPT algorithm[2].

There are different types of methods to implement maximum power point tracking (MPPT) such as P&O, PSO, incremental conductance, fuzzy logic, neural network, pilot cells, DSP based method. The P&O and INC techniques are widely usedespecially for low cost.

The P&O algorithm is mostly used for its ease of implementation. It depends on the following criterion: if the operating voltage of the PV array is perturbed in a given direction and the power drawn from the PV array increases which means that the operating point moves toward the MPP and therefore the operating voltage must be further perturbed in the same direction. Otherwise, the operating point has moved away from the MPP and therefore the direction of the operating voltage perturbation must be reversed [3].

A drawback of MPPT technique is that the operating point oscillates around the MPP giving rise to the waste of some amount of available energy. Several improvements of the P&O algorithm have been proposed in order to reduce oscillation and improve the efficiency of the system [4].

The proposed incremental conductance method is based on the principle that at the maximum power point $\frac{dP}{dV} = 0$ andsince P = VI, it yields [5-6]:

$$\frac{dI}{dV} = -\frac{I}{V} \quad (1)$$

Where, P, Vand I are the PV array output power, voltage andcurrent respectively. A PI controller is used to regulate the PWM controlsignal of the dc/dc converter until the condition: (dI/dV) + (I/V) = 0is satisfied. This method has the disadvantage thatthe control circuit complexity results in a higher system cost [7].

II. Modeling of Solar Cell

Figure 1 shows the equivalent circuit diagram of a solar cell. It consists of a constant current source in parallel with a shunt resistance and a diode. The ideality factor of the diode is taken into account for the recombination in the space charge region.

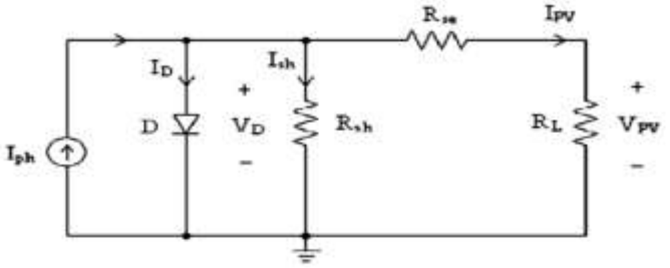


Fig. 1. Electrical equivalent circuit of a solar cell

If the internal shunt resistance is neglected, the characteristics of a PV array can be given as [8-9]:

$$I = I_g - I_{sat}\left\{exp\left[\frac{q}{AKT}(V + IR_s)\right] - 1\right\} \quad (2)$$

Where,

I_g Light-generated current;
I_{sat} PV array saturation current;
q Charge of an electron;
K Boltzmann's constant;
A Ideality factor of the p–n junction;
T PV array temperature (K);
R_sIntrinsic series resistance of the PV array;

Since the series resistance R_s can be neglected, hence equation (2) can be simplified as:

$$I = I_g - I_{sat}\left[\exp\left(\frac{qV}{AKT}\right) - 1\right] \quad (3)$$

Figure 2 depicts the output characteristics of a PV array in varying atmospheric conditions.

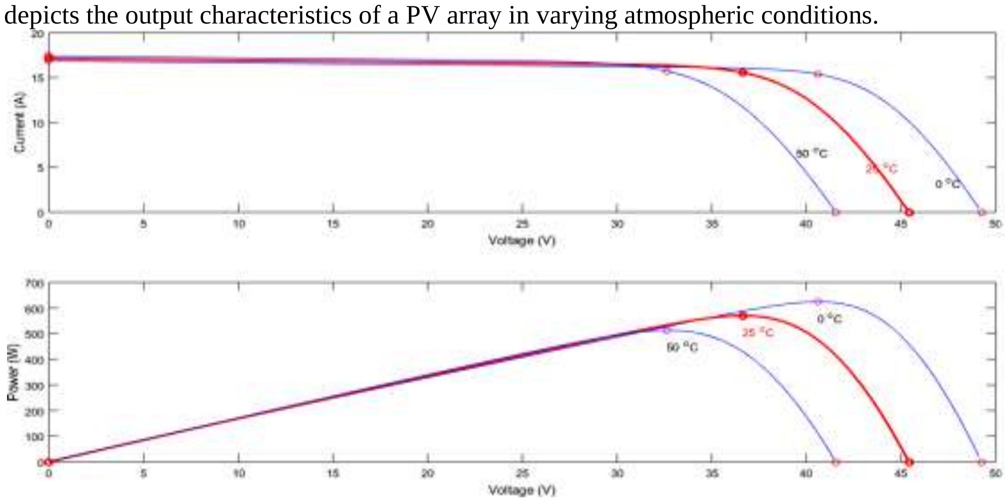


Fig. 2. I-V and P-V curve for the PV array considered

The output power of the PV array is expressed as:

$$P = VI \quad (4)$$

From (3) and (4), the differentiation of $P$with respect to Vcan be expressed as:

$$\frac{dP}{dV} = I + \frac{dI}{dV}V$$
$$= I_g - I_{sat}\left[\exp\left(\frac{qV}{AKT}\right) - 1\right] - \frac{qI_{sat}}{AKT}exp\left(\frac{qV}{AKT}\right)V \quad (5)$$

$$\frac{dP}{dV} \cong I + \frac{\Delta I}{\Delta V} V \quad (6)$$

WhereΔI and ΔV are the increments of output voltage and current respectively. Equation (5) is the function of V that can be employed to simulate the characteristics of dP/dV versus V. From equation (6), it is found that the termdP/dV can be replaced by $I + (\Delta I/\Delta V)V$.

III. Implemented MPPT Algorithm

In the literature, various MPPT algorithms are available in order to improve the performance of photovoltaic system by effectively tracking the MPP. However, most widely used MPPT algorithms are considered here, they are:
1. Perturb and Observe (P&O)
2. Incremental Conductance (INC)

3.1 Perturb and Observe (P&O) Method

The most commonly used MPPT algorithm is P&O method. This algorithm uses simple feedback arrangement and little measured parameters. In this approach, the array voltage is periodically given a perturbation and the corresponding output power is compared with that at the previous perturbing cycle [10]. The perturbation and observation method measures ΔP and ΔV to judge the momentary operating region and then according to the region, the reference voltage is increased or decreased such that the systems operates close to the maximum power point. As the methodincreases or decreases only the reference voltage, the implementation is simple. However, the method cannot readily track immediate and rapid changes in environmental conditions.The algorithm can be easily understood by the following flow chart which is shown in figure3.

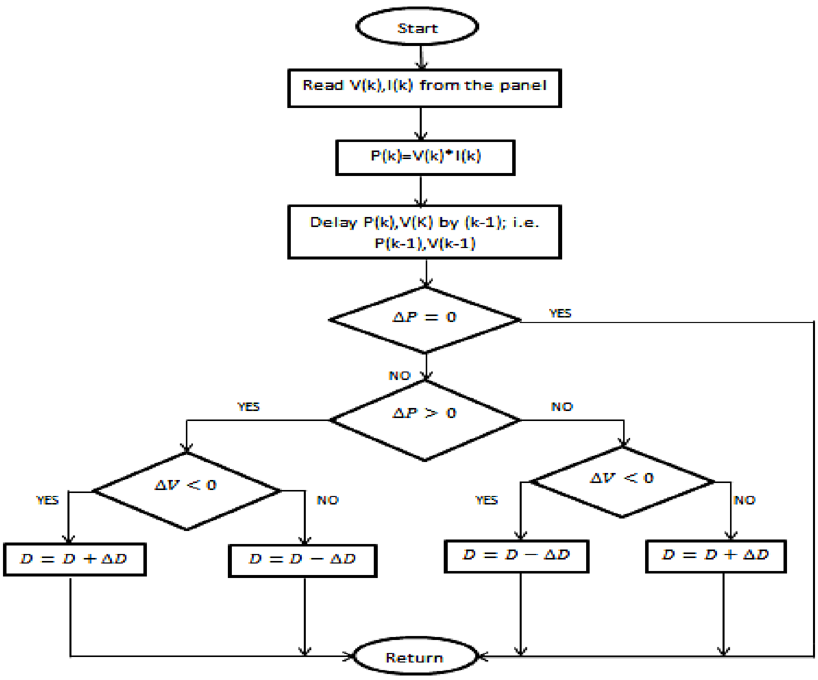


Fig.3. Flowchart of Perturb and Observe (P&O) method algorithm

3.2 Incremental Conductance (INC) Method

Under fast varying atmospheric condition the problem associated with P&O methods is overcome by Incremental Conductance (INC) method. The Incremental Conductance method can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dI/dV and –I/V .This relationship is derived from the truth that dP/dV is negative when the MPPT is to the right side curve of the MPP and positive when it is to the left side curve of the MPP. This algorithm determines when the MPPT has reached the MPP, whereas P&O oscillates around the MPP. This is clearly an advantage over P&O.The

incremental conductance method tracks the maximum power point accurately by comparing the incremental conductance and instantaneous conductance of a PV array [11].Incremental conductance method can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe method [12]. The disadvantage of this algorithm is that it is more complex when compared to P&O. The algorithm can be easily understood by the following flow chart which is shown in figure 4.

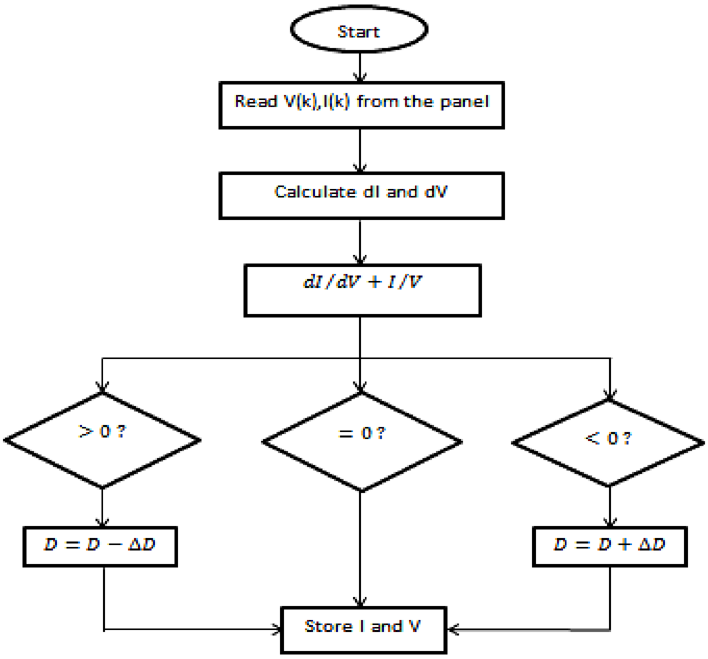


Fig.4. Flowchart of incremental conductance (INC) method algorithm

IV. Simulation and Result

Figure 5 shows a grid connected PV system adopted for experimental measurements.The boost MPPT converter supplies an inverter for 220 V/50 Hz grid connections.

The Simulink model of PV array with dc-dc boost converter using perturb and observe (P & O) MPPT method is shown in figure 5 and its corresponding result is shown in figure 6.

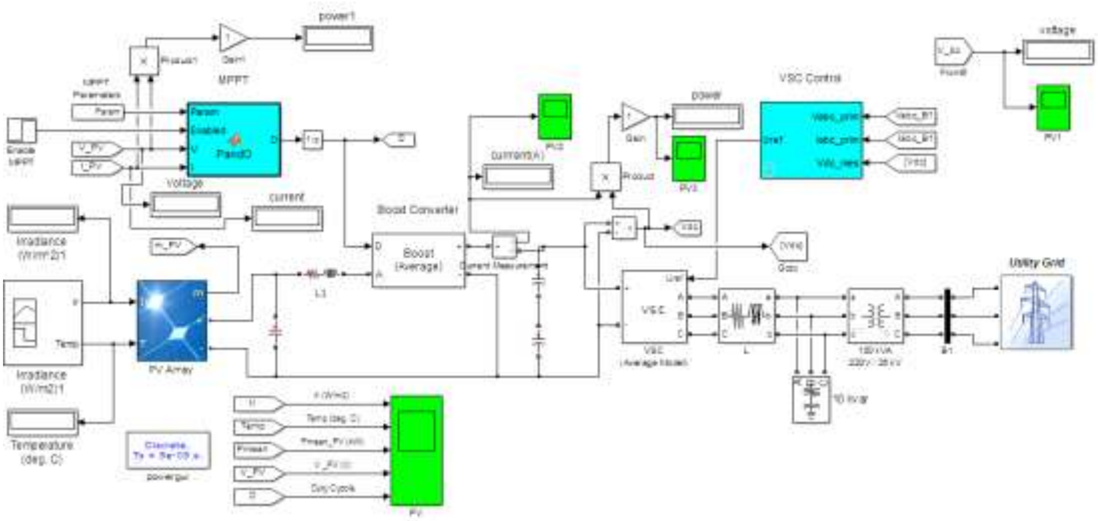
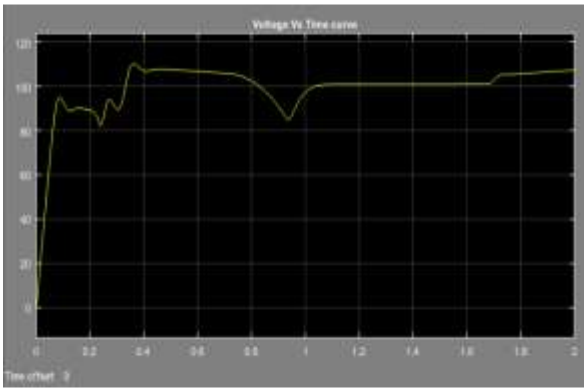
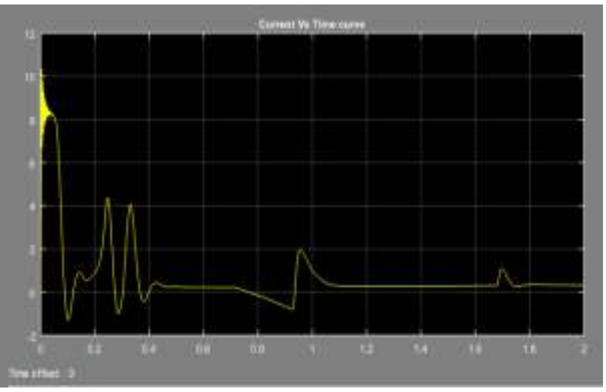


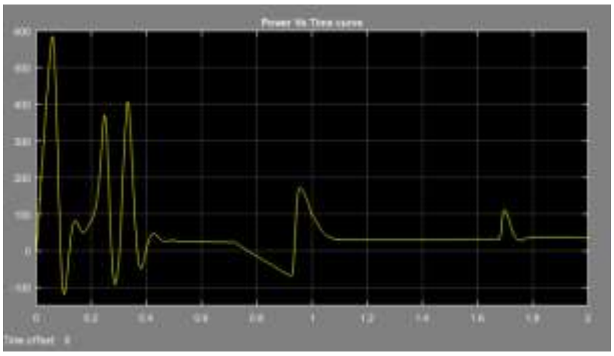
Fig.5. Simulink Model of P&O MPPT with dc-dc converter



(a)



(b)



(c)

Fig.6. Simulation results of P&O MPPT algorithm.(a) Voltage output. (b) Current output and (c) Power output.

The Simulink model of PV array with dc-dc boost converter using INC MPPT method is shown in figure 7and the simulation results of INC MPPT algorithm are illustrated in figure 8. The results show that the output current varies from 0.35A to 0.53A and the output voltage varies from 81.10V to 90.42V and an output power varies from 29.03W to 47.39W for a time period of 6 seconds.

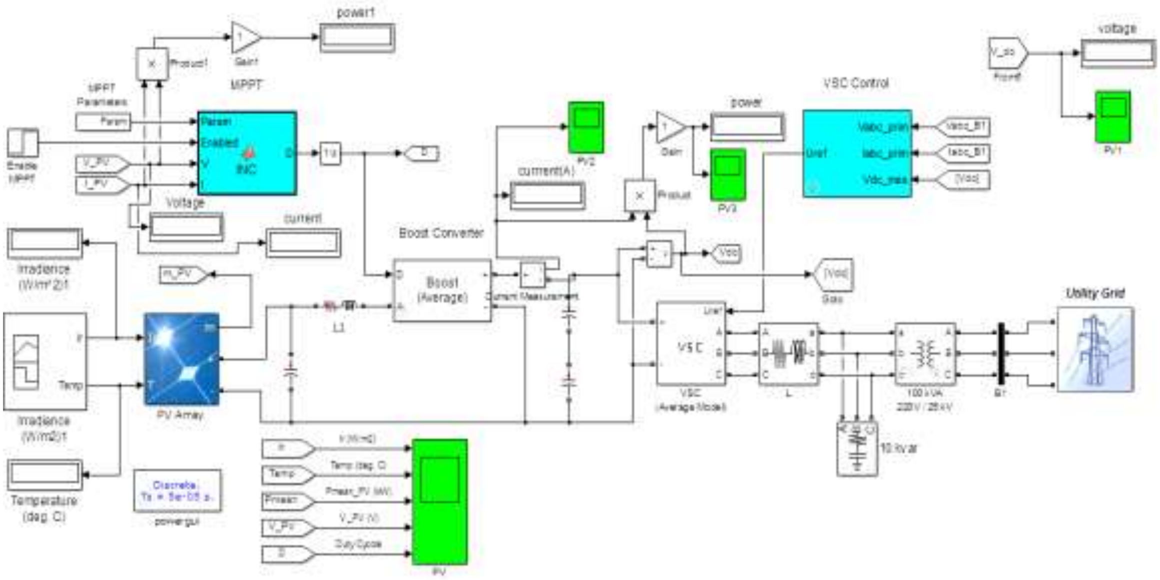
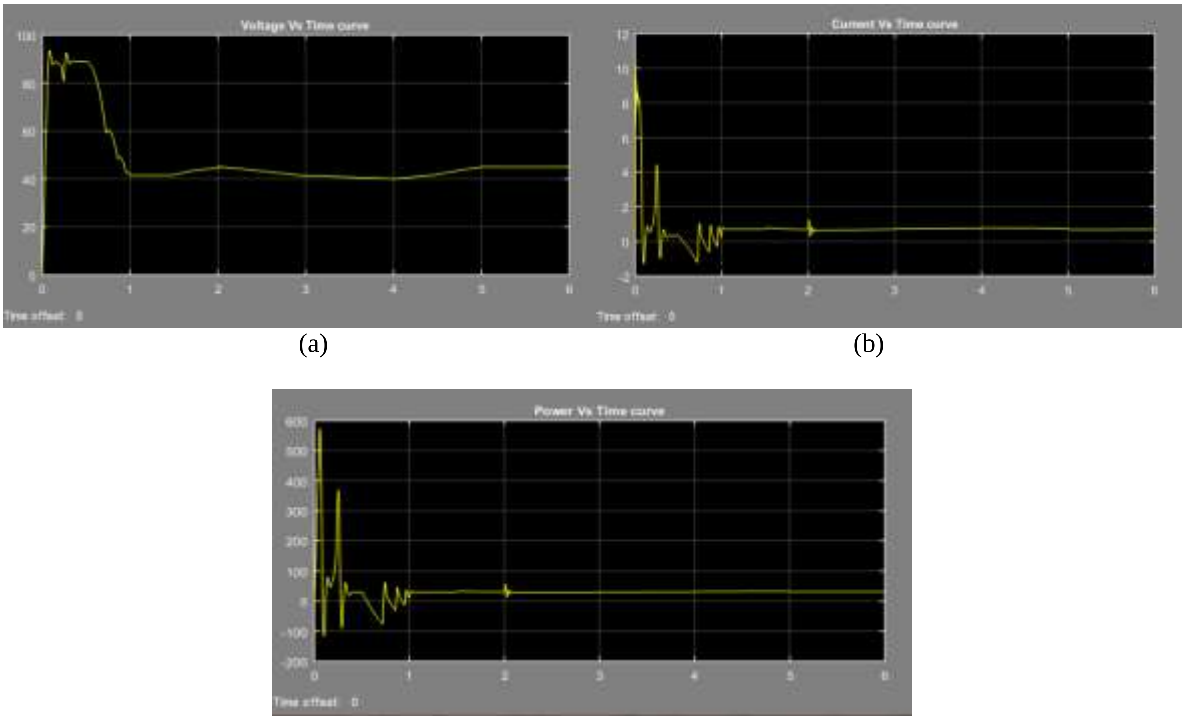


Fig.7. Simulink Model of INC MPPT with dc-dc converter



(a) (b)

(c)

Fig.8. Simulation results of INC MPPT algorithm. (a) Voltage output. (b) Current output and (c) Power output.

4.1 Comparison between P&O and INC MPPT Algorithms

The P&O and INC MPPT algorithms are simulated and compared using the same atmospheric conditions. When atmospheric conditions are constant or change slowly, the P&O MPPT oscillates close to MPP but in case of rapidly varying atmospheric condition P&O MPPT method is not effective but INCMPPT method finds the MPP accurately at rapidly changing atmospheric conditions also. Comparisons between the two algorithms for various parameters are given in table 1:

TABLE 1. Comparison between P&O and INC MPPT algorithm

G W/m^2	T^0C	Theoretical output of SPV array			SPV array output using P&O			SPV array output using INC		
		Voltage (Volts)	Current (Amps)	Power (Watts)	Voltage (Volts)	Current (Amps)	Power (Watts)	Voltage (Volts)	Current (Amps)	Power (Watts)
250	25	42.39	0.70	29.50	100.88	0.29	29.5	84.78	0.35	29.53
400	25	43.66	0.72	31.35	101.06	0.31	31.35	89.15	0.38	34.06
700	25	44.58	0.81	36.20	105.94	0.34	36.20	86.66	0.44	38.29
1000	25	45.10	0.96	43.18	107.73	0.40	43.29	90.42	0.53	47.39
800	30	44.12	0.90	39.87	103.95	0.38	39.79	86.95	0.45	39.07
600	35	42.50	0.87	37.65	100.72	0.37	37.65	85.32	0.44	37.86
700	50	40.50	0.70	28.27	96.34	0.29	28.27	81.10	0.36	28.91
800	50	40.80	0.70	28.55	97.20	0.29	28.55	81.62	0.36	29.03
900	50	41.10	0.70	28.65	97.78	0.29	28.69	82.18	0.35	29.09

V. Conclusion

The simulation result of MPPT of a solar PV array using P&O method and INC method is presented. Comparisons between two methods are also presented in the table. The result shows that INC method gives better resultsthan P&O method and INC method gives better performance under varying atmospheric condition. Hence INC technique can be employed for MPPT of solar PV applications.

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