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Study and Evaluation Performance the Modeling of photovoltaic PV System using MATLAB Simulink

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ABSTRACT

This abstract presents a Simulink-MATLAB PV modeling system designed to generate 60 watts of power**.** Photovoltaic (PV) systems harness solar energy to produce electricity, and accurate modeling is crucial for system design. The PV panel model in the system accurately represents the behavior of the panels based on factors such as temperature, irradiance, and performance analysis. The developed modeling system incorporates various components, including PV panels, DC-DC converters, maximum power point trucking MPPT and battery**.** The proposed model can be very useful for PV engineers and experts who require simple and accurate PV simulator to design their systems**.**

Key words: Photovoltaic (PV), Simulink-MATLAB, (DC-DC) converter, maximum power point trucking (MPPT).

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دراسة وتقييم أداء نمذجة ومحاكاة لوح كهروضوئي باستخدام برنامج ماتلاب

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الملخص

يعرض هذا الملخص نظام نموذج من لوح الكهروضوئي المصمم باستخدام (**Simulink-MATLAB**) لتوليد 60 واط من الطاقة الكهربائية. حيث انه تستخدم الأنظمة الكهروضوئية **(PV)** الطاقة الشمسية لإنتاج الكهرباء، وتعد النموذجة الدقيقة أمرًا بالغ الأهمية لتصميم ومحاكاة الالواح الفولت ضوئية. وتم محاكاة نموذج اللوحة الكهروضوئية ودراسة سلوكها بدقة بناءً على عوامل عدة ، منها درجة الحرارة والإشعاع الشمسي وتحليل اداء اللوح الكهروضوئي ودراسة خصائصها. ويشتمل نظام النموذجة المحاكاة للوح الكهروضوئي على مكونات مختلفة ، بما في ذلك الألواح الكهروضوئية ، ومحولات**DC-DC** ، ونقطة الطاقة القصوى للنقل بالشاحنات **MPPT** والبطارية. ويمكن أن يكون النموذج المقترح مفيدًا جدًا لمهندسي وخبراء الطاقة الكهروضوئية الذين يحتاجون إلى جهاز محاكاة كهروضوئي بسيط ودقيق لتصميم أنظمتهم .

الكلمات المفتاحية: الالواح الكهروضوئية و برنامج المحاكاة **MATLAB** , **SIMULINK** , نقطة الطاقة القصوى للنقل بالشاحنات **MPTT** ، محولات التيار **DC-DC**.

Introduction

Renewable energy is a key priority due to rising demand for electricity, the global energy crisis, environmental degradation, fossil fuel pricing, and climate change [1]. PV technology has emerged as a promising solution, converting sunlight directly into electrical energy. To optimize the performance of PV systems and ensure reliable power generation, it is essential to study and understand their power characteristics [2]. Despite of the high initial

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cost and low efficiency, PV system has small operation and maintenance costs as it is a stationary source of energy fabricated from semiconductor material. Compared with the oil prices, the solar energy is a feasible energy supply with great long-term benefits [3].

PV cell is considered to be the essential power conversion unit of a PV-power system Solar model, while insulation materials, temperature, and output voltage of PV are the basic parts factors that affect to the output characteristics of a PV cell. Since the PV has a nonlinear current-voltage (I-V) characteristic.

The other advantages of PV system are modular nature, short time to design, construct, and install, reliable, easy to use, long life, and lightweight. The PV system is also silent and no special cooling since there is no moving parts. In addition, it has modular nature leading to the capacity of supplying from only a few watts to MWs of electricity. It can be attractively and architecturally beauty if designed carefully. Meanwhile the disadvantages of PV system are taking a lot of space, working only when the sun shines, leading to high cost when build on the ground because of higher cost for massive area of land [5]. The power characteristics of PV systems refer to the behavior and performance of these systems in converting solar energy into electrical power. By examining and analyzing these characteristics of PV array (I,V) the researchers and engineers can gain valuable insights into the factors that influence power generation evaluate system efficiency and identify methods to enhance performance and maximize energy output of PV system [6].

PV Model by MATLAB Simulink

An ideal PV-cell was modeled by the current source parallel with diode. There are losses as together with hung the operation of a PV cell or solar cell. The pressure drop about the series and shunt resistor will display voltage drop. By the external contacts here, it can be an equivalent circuit of a solar cell or photovoltaic cell as shown in Figure 1.

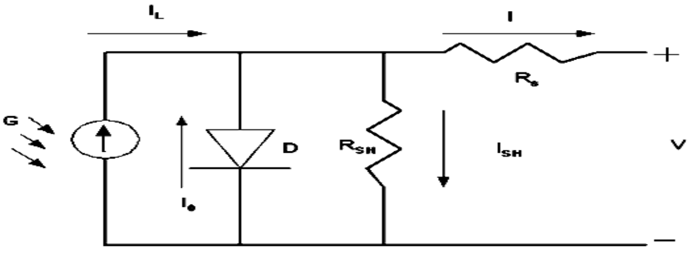

Figure .1. Photovoltaic cell

The PV module used in this paper has properties as follows:

- PV Module ND- 60 W
- Maximal power P max is 60 W.
- Open circuit voltage is 22V.
- Short circuit current is 3.9 A.
- Voltage at point of max power is 17.4 V.
- Current at point of max power is 3.45 A.
- Over current protection is 7.5 A.

PV model by Simulink

Solar cell or photovoltaic cell consists of a p-n junction fabric in a thin slice of semi-conductor. There are two commonly used materials for solar cells, i.e. mono and poly crystalline silicon. The voltage across a solar cell depends mainly on the design and materials of the cell, while the current mainly depends on the incident solar radiation and the cell area. The mathematical equations of a solar cell can be formulated by[2][7]:

$$I = I_L - I_d - I_{sh} \quad (1)$$

Where, I_L is the photocurrent or the current generated by sunlight imposed on the PV cell. I_d is the diode current. I_{sh} is the current through the shunt resistance and described by:

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$$I_L = \left(\frac{I_{sc.stc} * S}{1000}\right) + [(T - T_r)K_i] \tag{2}$$

Where is the $I_{sc.stc}$ is the short circuit current of the PV cell at standard test condition (S = 1000 W/m^2, T = 25 °C).
K_i is the temperature coefficient for I_{SC}. T_r is the reference temperature. T is the ambient temperature. S is the solar irradiance (W/m^2). The diode current is:

$$I_{D} = I_O\left[\exp\left(\frac{q}{AKT(V+R_S)}\right) - 1\right] \tag{3}$$

$$\frac{AKT}{q} = V_T \tag{4}$$

Where I_o is the reverse saturation current of the diode; q is the charge of electron (1.6×10^{-19}). K is the Boltzmann constant (1.38×10^{-23} J/K). A is the quality factor (lies between 1.2 and 1.6 for crystalline silicon). V_T is the thermal voltage of diode. V is the terminal voltage of the PV cell. I_o can be expressed by:

$$I_o = I_{rr}\left(\frac{T}{Tr}\right)^3 \exp\left[\frac{qE_g}{KA\left(\frac{1}{T_r} - \frac{1}{T}\right)}\right] \tag{5}$$

Where E_g is the band gap energy (1.12 ev for crystalline silicon). I_{rr} is the I_o at standard test condition (STC) and the shunt current (I_{sh}) is as follows:

$$I_{Sh} = \frac{(V+IR)}{R_{Sh}} \tag{6}$$

Then combining the equations (3.2) to (3.6) and putting the minus of equation (3.1), we get the total output current source. The PV cell temperature depends on the ambient temperature and the solar insulation in this way.

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$$T_{cell} = T_{ambient} + (T_{NOCT} - 25)\frac{s}{1000} \quad (7)$$

Where T_{NOCT} is the cell temperature at 23 °C and irradiation of 1000 W/m^2 [2][7].

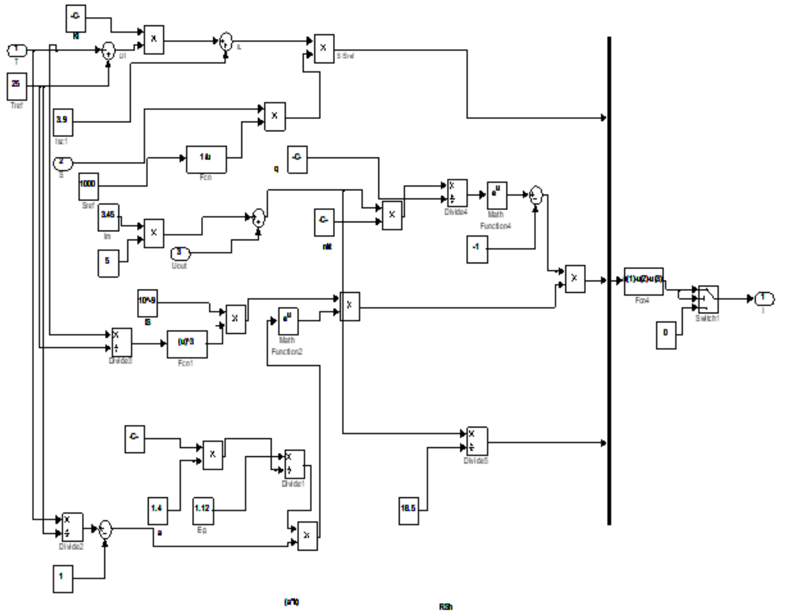

Figure .2. PV model by MATALB SIMULINK

DC-DC Boost Converter

A boost converter is a switch mode of power supply that has a higher output voltage than its input voltage. The switching in a boost converter is done through a MOSFET or IGBT. The current flows only in the first loop and the current through the inductor increases when the switch is closed. The switch then opens leading to the voltage across the inductor and the input combine in series to charge up the output capacitor to a higher voltage than the input. The duty cycle of the switching signal determines the output voltage. The longer the switch is closed, the higher the output voltage will be expected A sample of a boost converter is shown in Figure 3.

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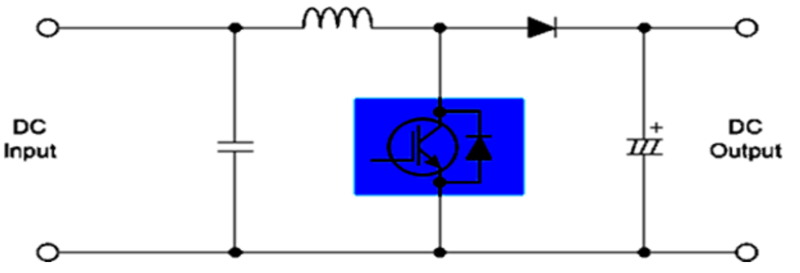

Figure .3. shows the Boost converter

Design of the Boost Converter

According to IEC harmonics standard, CRP should be bounded within 30%.

$$ie\frac{\Delta I_1}{I_1} = 30\% \tag{8}$$

Voltage Ripple Factor (VRF)

$$\frac{\Delta v_0}{v_0} = 5\% \tag{9}$$

Switching frequency (fs) [8]

fs = 100 KHZ (10)

Output PV Model connected to battery and DC-DC converter

The output of PV system with DC- DC converter, MPPT, battery, and resistance load 50 W was modelled in MATLAB SIMULINK. Maximum Power Point Tracker (MPPT) is a power electronic DC-DC converter inserted between the PV module and its load to achieve optimum matching. By using an intelligent algorithm, it ensures to operate the PV module in its maximum power point. A number of tracking algorithms have been used and a number of DC-DC converter 12/25 V topologies are possible.

The load was presumed to be a 24 V battery. Furthermore, three possible connections between source and load were considered. The most typical arrangement in a simple system as described is a single series blocking diode between the PV module and the battery. A shunt regulator was placed in parallel with the battery to prevent

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overcharging when the battery reaches its fully charged "float" voltage by shunting excess charge around the battery. A more typical modern regulator arrangement places a series MOSFET switch between the PV module and battery. This regulator disconnected the module when the module current felled to zero and reverses, or when the battery was fully charged. These methods are the advantages of very low forward voltage drop when the IGBT switch is closed. These arrangements were modelled as a direct connection between module and battery. The voltage of the PV module was set by the battery voltage and the battery current and hence power delivered which is determined by the PV module operating point.

The other arrangement is the use of a MPPT DC-DC converter inserted between the PV module and battery. The ratio of the input and output voltages is controlled by varying the on-off duty cycle of the converter switching device, typically an IGBT. Since the battery fixed the output voltage of the converter, the input voltage and the module operating point were controlled . Thus, the PV system with whole system is in Figure 4.

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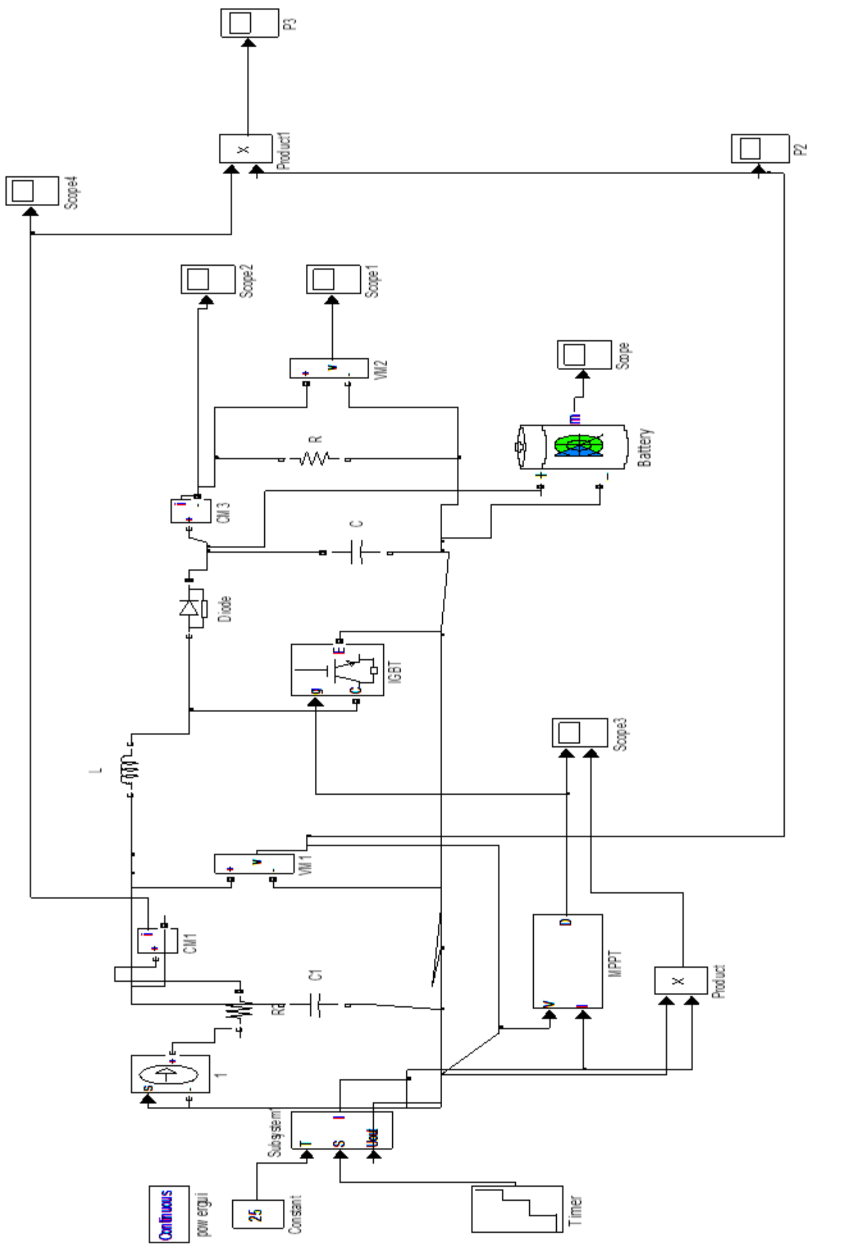

Figure .4. The PV system with whole system

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Simulation Result and Discussion

The PV panel is characterized by PV and I,V where the constant temperature (T=25°C) and varying radiation with maximum power point tracker (MPPT) topologies and (battery 24V), fixed resistance load 50W.

The boost converter is shown to have a slight advantage it can always track the maximum power point to examine the PV cell , and study the Characteristics of power (voltage, current) generated from PV module output power from simulation in PV cell the power for all radiations 400,600,800, 1000W/m^2 (See figure 5).

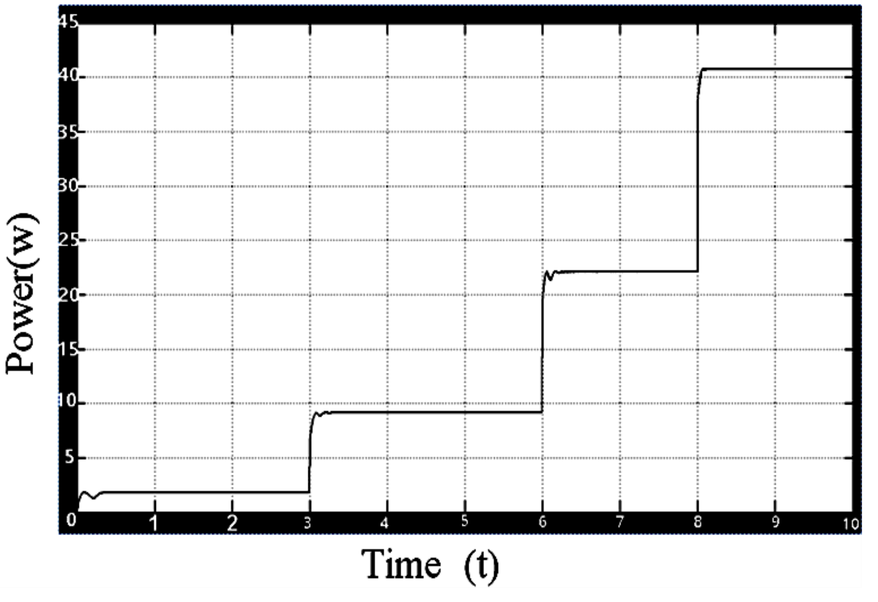

Figure.5. shows the total power in different radiation 400-600-800-1000W/m^2

The power of PV cell depends on the cell's terminal operating voltage and Temperature and solar insolation well. That with increase of solar insolation, the short-circuit current of the PV module increases, and the maximum power output increases as well. The reason is the open-circuit voltage is logarithmically dependent on the solar irradiance, yet the short-circuit current is directly proportional to the radiant intensity. In first radiation 400W/m2, the output power set up to 1.74 W. In second radiation 600W/m2

The power increase during radiation and the output power set to 9.1W in radiation 800W/m2 the power still increasing and reached to 22 W in the last radiation 1000W/m2 maximum power set up to 41W that's the maximum power can generated from PV typical 60W at fixed resistance load 50 W. The current regarding to radiations 400,600, 800,1000W/m^2. (See figure.6).

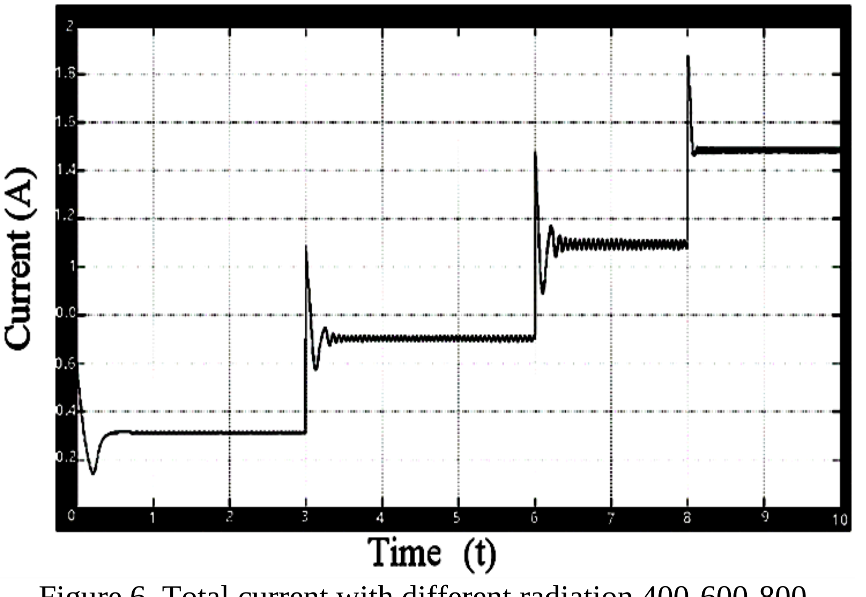

Figure.6. Total current with different radiation 400-600-800-1000w/m2 As the irradiance

As the irradiance increases the current increase linearly with little increases at constant cell temperature 25 C. The Cell temperature also affects the I-V characteristic of a PV For most single and poly-crystalline silicon PV cells; increasing cell temperature reduces voltage and power output. the results of PV shown the current with slight increase in current output that's as we mention the current with varying radiation in PV sell the current increasing a slight increase, In first radiation 400W/m2 the current set up to 0.3A in the second radiation 600W/m2 the current was 0.7 A in radiation 800 W/m2 the current set up to 1.1 A in the last radiation 1000W/m2 the current was 1.48 A .The output voltage regarding to radiations 400,600, 800, 1000 W/m2. (See figure.7).

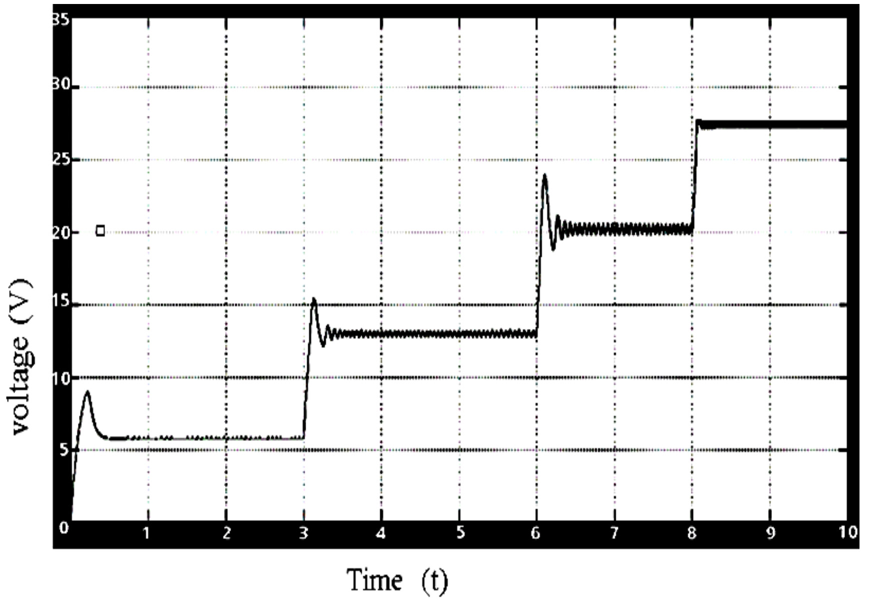

Figure.7. total voltage with different radiation 400-600-800-1000w/m2

The voltage in cell temperature 25 C the open-circuit voltage increases during varying radiations. At radiation 400 W/m2 the output voltage set up to 5.8V, at 600W/m2radiations the voltage is increase and reached to 13V, at 800 W/m2 radiation the voltage is increase and steady state at 20V and the last radiation 1000W/m2 the maximum voltage from PV typical 60W was 28V. the voltage increases with varying radiations at constant cell temperature 25C.

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Conclusion

The simulation of PV system has been studied well the characteristic of PV model indicated that the higher irradiation, the bigger power was achieved. At irradiation of 1000 W/m2, the produced current from PV system was 1.48 A and the produced voltage was 28 V. The efficiency of PV system at irradiation of 1000 W/m2 was 8.8%. The simulation showed good agreement for PV system.

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