Performance Investigation of a Grid-Tie Pv System Under Iraqi Solar Circumstances Based on MATLAB/Simulation

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ABSTRACT

Due to the longer days and yearly sunlight hours, solar photovoltaic (PV) power systems are one of Iraq's greatest alternative energy sources. The on PV power system is described in this study as one that runs in parallel with the local grid (only during daylight hours) to either supply household appliances or back-feed the grid when the PV system's output power exceeds household requirements. The key issue of creating the suggested system is an ability toward integrate energy converters with the relevant control mechanism to get the greatest performance. For obtaining optimum power and controlling AC voltage, a current controller and a voltage controller are proposed. This study aims to show how on-grid PV systems function under real-world daily irradiance in Baghdad in July. According to the simulation findings, the PV array's percentage power yield is 95 per cent when the MPPT algorithm is used. Furthermore, the load current waveform is sinusoidal, having a low total harmonic distortion (THD), 0.49 per cent for current and 0.58 per cent for voltage

Keywords:

Introduction

The great development of the usual economy is a crisis element for energy and environment, necessitating a reduction in the demand for conventional energy and a steady increase in the usage and expansion of energy resources such as renewables [1], [2]. Solar photovoltaic (PV) could be regarded among the most significant contributors to energy sources because of its endless offer aspects of energy production and its cleanliness (pollutant-free and considered100 % eco-friendly) [3]. Thus, it might be completely a natural resource that has offered a development potential in connection to the world's fastest industry development [4].

The photovoltaic systems (PV) are based on the photoelectric effect and uses a solar cell to convert solar energy to electricity; this system is essentially a cell and can be divided into monocrystalline, Nano PV cells polycrystalline, amorphous and organic. PV technology is now being employed in various applications, including solar energy, power communication, PV grid connected, home-produced PV, satellites and, most recently, airplane and electric vehicle implementations. [5]-[7].

Building an inclusive system toward engage a (SCs) solar cells and optimal circumstances, also the highest efficiency in photovoltaic (PV) applications is required. Because the maximum power point varies substantially based on the direction of sunlight on cell temperature and the panel surface this MPP may not be regarded as the PV system's load operating point. PV systems can be configured to include many needed modules to provide grid-reliable electricity. [8], [9]. PV systems that are linked to the grid send electricity directly into the electrical grid and operate in tandem with a traditional energy source. During the past decade, these systems have been evolving exponentially. Growing attention to changes in climate, financial incentives, and decreasing the cost of PV systems has resulted in rapid evolution. The biggest drawbacks of PV solar energy are fluctuating power output during the day and constantly changing climatic settings [10]. As illustrated in Figure 1, a typical PV grid-connected system consists of a PV array, an inverter, and a controller.

2.15mH, 0.5 m

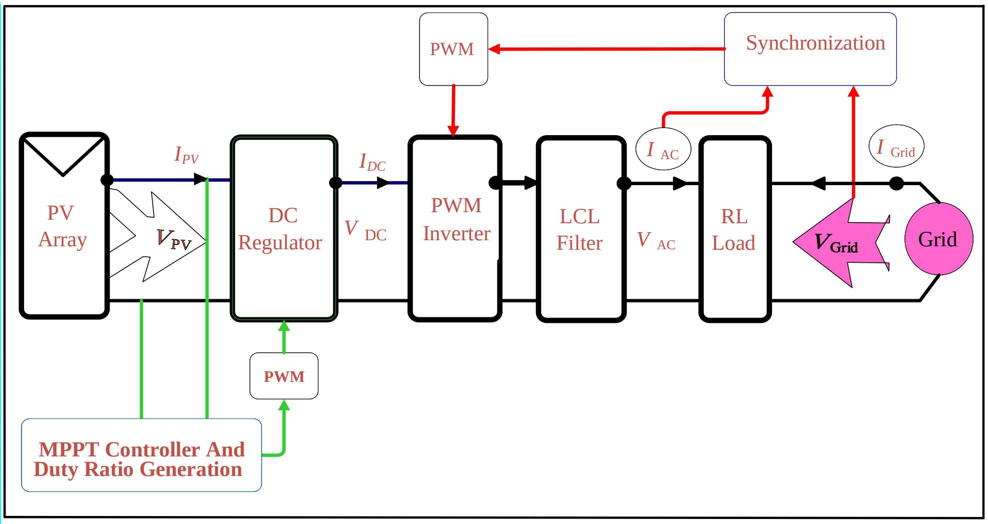

Figure 1. The framework of the Photovoltaic system

It may be the nature of a PV system with grid connection since it includes tracking controllers for optimum power and a “synchronization waveform”, which can be generated by reversing the power into the existing sinusoidal injector. This controller tracks maximum PV power point to manage the inverter's current grid-connected to the network for power transmission waveforms, as well as the maximum power phase equilibrium in a PV array [12]. Manyl studies have been carried out to build and study solar power systems that are connected to the grid that include or do not include energy storage technologies. In [13], a grid-connected mini-solar power plant was planned and built to anticipate the grid's performance under various operational conditions; each component of the solar plant is modeled and studied [13]. In [14], To deliver AC power with a high-power factor, power electronic circuits" featuring a full-bridge inverter and buck-boost converter were proposed. In [14], To minimize extra input inductor current, the waveform of the output AC voltage was enhanced by using a buck-boost converter with a high switching frequency operating the (DCCM) discontinuous-current conduction mode. It's worth mentioning that the majority of on-grid PV inverters have been evaluated using fictitious solar irradiation profiles like ramps and steps or triangular ramps.

Even though this test assessment is simple to carry out, it might not accurately reflect the system's dynamic behavior under real-world settings. [15 The PV power system with on-grid is set up in this study to provide steady AC power without batteries. An LC and a boost inverter filter connect the PV array to the grid. Modifying a boost converter's duty cycles and the modulation index of an inverter adjusts both the array current and the boost DC voltage. Managing the DC voltage and input current is to avoid over-current in a PV array and provide a consistent ac voltage, respectively. As in case study, the proposed PV array system is assessed by Matlab/Simulink in real-world solar irradiances for Baghdad (e.g., measured sun irradiances during a day in July 2021).

2. The Proposed PV Power System's Modeling and Design

2.1 The Principle Working of Photovoltaic Cell

It is essential to understand how the photovoltaic system is connected and when sunlight falls on the solar panel. As described earlier, the photovoltaic section PV Cell is the power resource in the system. The function of the photovoltaic part is immediate conversion of the solar irradiance into electricity, and the physics behind this conversion will presently be investigated. Solar systems that have been scaled down can offer adequate energy for domestic and commercial usage [19,20,21]. The solar cell is analogical to the diode, also an operable example of a solar cell [20] is depicted in Figure (2). The milliohm stage resistance displays the parallel kilo ohms stage resistance, and the collector traces and external wires is the crystal's internal resistance [20]. For the PV cell represented in Figure (2), the photovoltaic current generated by a PV cell is presented by equation (1, 2, 3, 4, 5 and 6) respectively [19]:

$$I_{pv} = N_p I_{ph} - N_p I_{sat} \left\{ e^{\frac{q(V_{pv}+I_{pv}R_S)}{N_S A K T_a}} \right\} - 1 \qquad (1)$$

$$I_{ph} = [I_{sc} + K_i(T - T_a)] \frac{K}{1000} \qquad (2)$$

$$I_{sat} = [I_{rs}[\frac{T}{T_a}]]^3 \left\{ e^{\frac{q(E_{g0})}{AK}(\frac{1}{T_a}-\frac{1}{T})} \right\} \qquad (3)$$

$$I_{rs} = [\frac{I_{s.c}}{e^{\frac{q(E_{g0})}{AK}\left(\frac{1}{T_a}-\frac{1}{T_{Ref}}\right)}}] \qquad (4)$$

$$R_s < 0.001 \frac{V_{o.c}}{I_{s.c}} \qquad (5)$$

$$R_p > 100 \frac{V_{o.c}}{I_{s.c}} \qquad (6)$$

Where: I_{sat} it's the saturation current; T_{Ref} Ref. temperature and T_a latest temperature; $N_p no.$ of cell in parallel;$N_S no.$ of cell in series; A constant=1.5; K Boltzmann factor; q its electron charge; E_{g0} its gap energy (1.1). R_s it's a resistance in series with the diode cell. R_p it's a resistance in parallel with the diode cell [19,20].

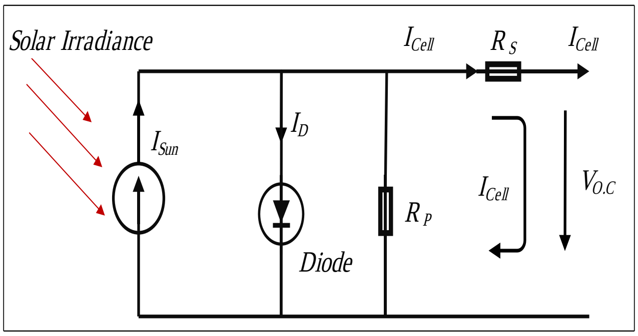

Figure (2) The equivalent circuit of photovoltaic cell

Equation (1) [19] is used to calculate the PV cell output current. Solar irradiation determines the source current. The PV result current is connected to the temperature since the thermal voltage and opposing saturation current are both temperature dependent. As a result, the PV output current is a function of irradiance and ambient temperature.

2.1. Real Irradiance Profile

In this study real solar irradiances were obtained in Baghdad for a day in July 2021, as shown in Fig. 2. The curve depicts how the sun's irradiance fluctuates throughout the day. At 1:00 PM, the sun is at the peak point, the sun irradiance is approximately 940 W/m^2. But, at 8:00 AM and 5:00 PM, the sun irradiances are about 250 W/m^2 and 330 W/m2, respectively. It is worth noting that the average sun irradiance is above 650 W/m2, which is considered a sunny day [15].

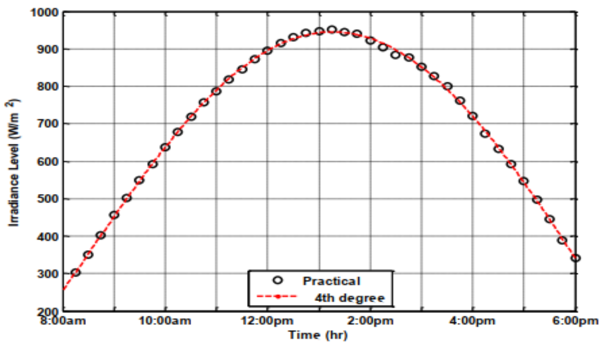

Fig. 2 Measured sun irradiances over a day in June, 2014 in Baghdad.

3.2. PV Array Simulator

A PV panel is an equipment that converts solar irradiance directly into the DC electricity. Several silicon solar cells are often joined among glass and a supporting material [1]. The PV array is simulated using an integrated

Matlab code. The PV panel is simulated as a single diode exponential model, that provides very accurate current output, since this model doesn't really account for the influence of parallel resistance [16]. Eqs are used to simulate In this research, a PV panel was used as a logarithmic model (1) - (6) [17]. The 4 input parameters for this PV model are presented in Table 1.

Table (1) Characteristic of the panel used in the proposed design

Parameters at standard condition (1000W/m²and25°C)	Specifications
Nominal power for a PV panel	213.15 W
Open circuit voltage ($V_{O.C}$)	29 V
Short circuit current ($I_{S.C}$)	7.84 A
Voltage at MPP (V_{MPP})	36.3 V
Current at MPP (I_{MPP})	7.35 A
N_s n. of cell in series	60 Cells
N_p n. of cell in parallel	1 Cell

A Simulink model of a PV panel depending on an integrated Matlab task, the voltage-controlled sources is shown in Figure 3. To prevent overvoltage damage to the PV panel, because the PV panel's top voltage limit does not exceed the open circuit voltage. Figure four depicts the proposed PV array simulation, which connects 12-PV panels in series to enhance DC voltage, as a result, reduces the size as well as expense of the boost converter.

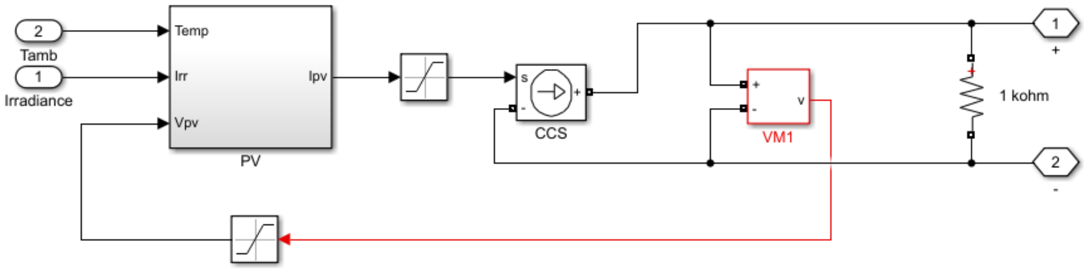

Figure 3. A PV cell circuit diagram in MATLAB/Simulink.

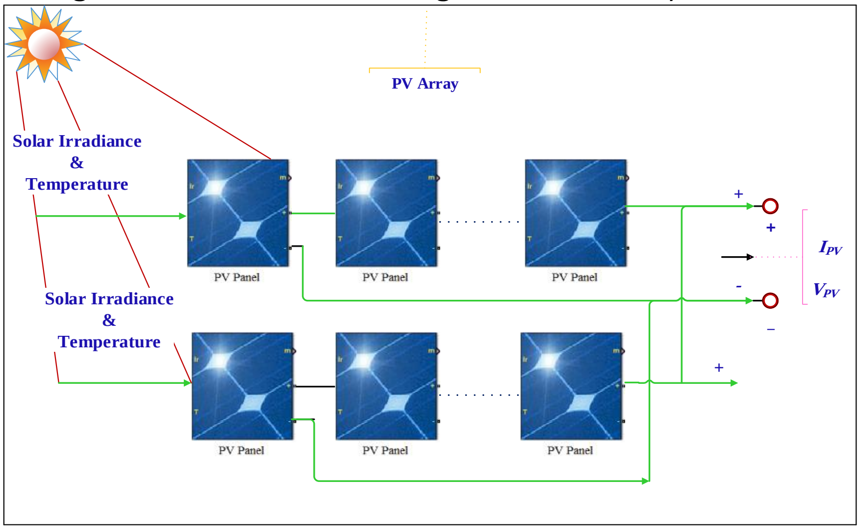

Figure 4. **Photovoltaic array**.

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. 3 Design of a Boost-converter

The boost converter consists of two semiconductors switches: (i) the diode. (ii) The transistor, as shown in Figure (3.5, a). The first component operating as a freewheeling diode from it ensures a path of the current at work. The second component is linked in series with the source voltage. The capacitor and inductor are used to make a filter to reduce the ripple current and voltage in the boost converter's output. Depending on the working principle of the boost converter, it depends on two distinct states, on-case and off-base. The first switch has closed an increase in the current for the inductor. The second a switch is open causes a decrease in the current for the inductor [20]. The equations which describe the performance of the boost converter are given below [21]: The boost-converter can be implemented in Equations (7, 8,9,10, 11, 12, and 13) as bellow:

1. Calculating Duty ratio D with minimum PV voltage

$$D = 1 - \frac{V_{pv}}{V_{dc}} \quad (7)$$

2. Calculate an average value of DC Voltage and current, V_{dc} , I_{dc}.

$$V_{dc} = \frac{V_{pv}}{1-D} \quad (8)$$

$$I_{dc} = (1 - D)\, I_{pv} \quad (9)$$

3. Determining the minimum inductance, L_{min}.

$$L_{Min} = \frac{V_{DC}\, T_S\, (1-D)^2}{2\, I_{OB}} \quad (10)$$

Divide equation (3.8) over equation (3.9) to obtain R_{in} :

$$R_{in} = (1 - D).^2\, R_o \quad (11)$$

$$\Delta V_{dc} = \frac{D\, T_S}{R\, C}\, V_{dc} \quad (12)$$

4. Recurrent steps 1-3 for calculating the highest boost inductance, L_{max}, with highest PV voltage.

5. Finally, identifying the smallest capacitance, C_{min} , with highest duty cycle.

$$C_{min} = \frac{D}{\left(\frac{V_{dc}}{I_{load}}\right)\left(\frac{\Delta V}{V_{dc}}\right) f_{sw}} \quad \textbf{(13)}$$

Based on the mentioned steps, the inductance and capacitance minimum values are roughly 2.15mH and 12.5 µF correspondingly. It's important to note that these settings might result in continuous mode functioning. For DC to AC conversion, a standard full bridge inverter with 4 MOSFETs is employed in this study. The inverter frequency (the carrier signal's PWM frequency) is raised to provide a sinusoidal output voltage. In order to get a smooth sine wave output voltage, a sinusoidal filter (i.e., L,C filter) is also placed among an inverter as well as the grid. As previously stated, the cut-off frequencies of the L,C filter can be adjusted by raising the inverter frequency in order to reduce the size of the filter inductance, L, and filter capacitance, C. At 970.84Hz, Equation (14) is used to create an LC filter, and the values of L and C are listed in Table 2 [18].

$$f = \frac{1}{2\pi\sqrt{LC}}$$

4. Simulation Results:

The simulation parameters are summarized in Table 2.

Parameter	Value
Boost inductance, L, & resistance	2.5 Ω
DC-link capacitance, C	15.625 µF
Filters inductance, L_f, & resistance	12.5 mH, 1.25 mΩ
Filter capacitance, C_f	12.5 µF
R,L load	2+j3
Inverters frequency, finv	12 kHz

4.1 DC Side Controllers

In this paper, I have not dealt with the design of a new strategy, and a common way was used, is known as the classic method (fixed voltage) to fix the input dc voltage which input to the inverter also, need to estimate the solar irradiance levels by using solar irradiance sensor. Although the approach is straightforward to apply, it is not particularly precise since it does not account for the impacts of temperature and the difficulty in selecting the optimal sites (see Fig. 1). (5) [20].

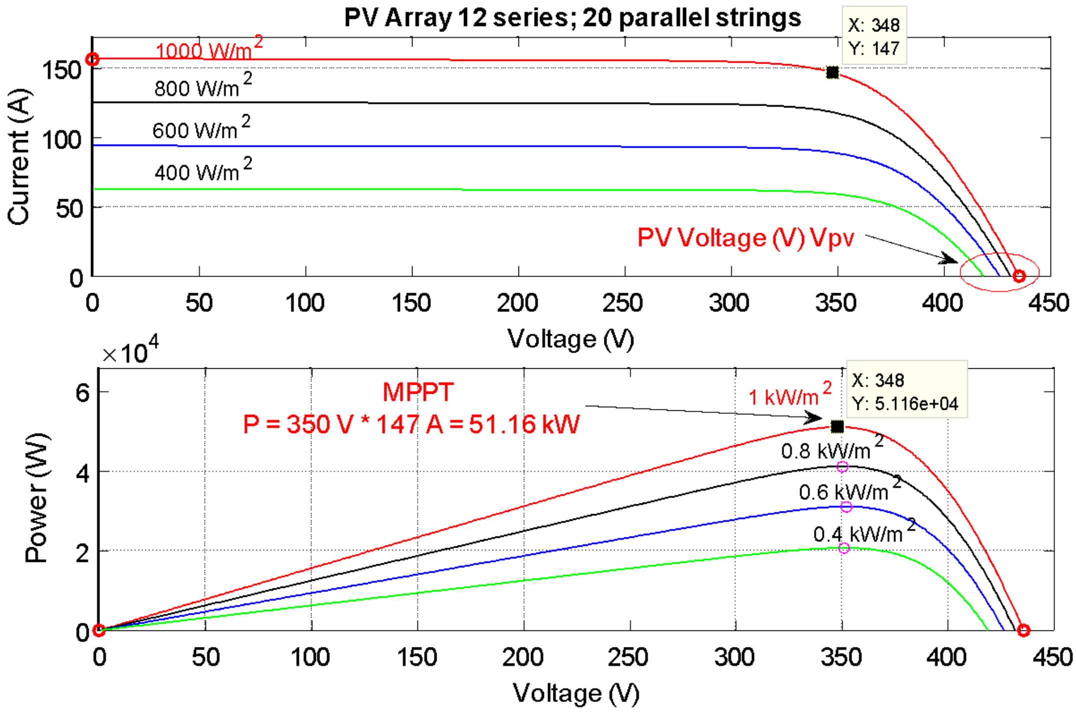


Fig. 5: PV Array curves (I-V) and (P-V)

Notice how voltage and current sensor (FB1-Bus) were used to get I the PV Array voltage and current; as demonstrated in Fig. 5 an (ii) the boost DC voltage as demonstrated in Fig. 6. Notice that DC-voltage is fixed on 450 V approximately. According to the [21], the continuous DC-voltages are equal or more of the sum of 230V adding the drop-voltage on the filter as shown below:

$\boldsymbol{V_{DC} > \{ V_{Inverter} + V_{drop}}$ ***in the Filter*** $\boldsymbol{\} > V_{grid}}$

At the solar irradiance equal to 1000W/m²:

⍰ V_{PV} =348V ⍰ 450V > 300V + 60V =360V > V_{grid} =230

At the solar irradiance equal to 400W/m²:

⍰ V_{PV} =272V ⍰ 450V > 300V + 60V=360V > V_{grid} = 230 V

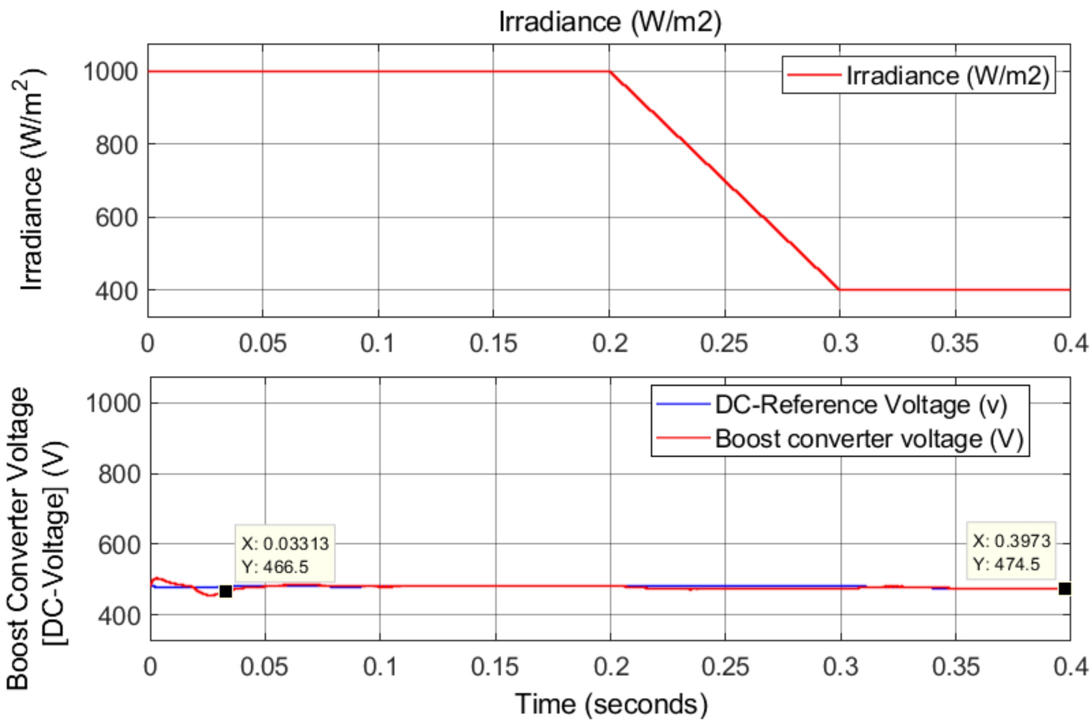


Fig. 5: Boost converter controller DC-Voltage

4.2 Grid Side Controllers

Simulations are carried out in this part to verify the efficacy of a suggested controller under Iraqi sun irradiances (figure 2). As illustrated in Fig. 4, the suggested PV system is built-in Matlab/Simulink applying the Simulink power system package. The signal which adjusted the synchronization between PV inverter and grid is shown in fig. 6. Finally, the complete PV system can be seen in fig. 7.

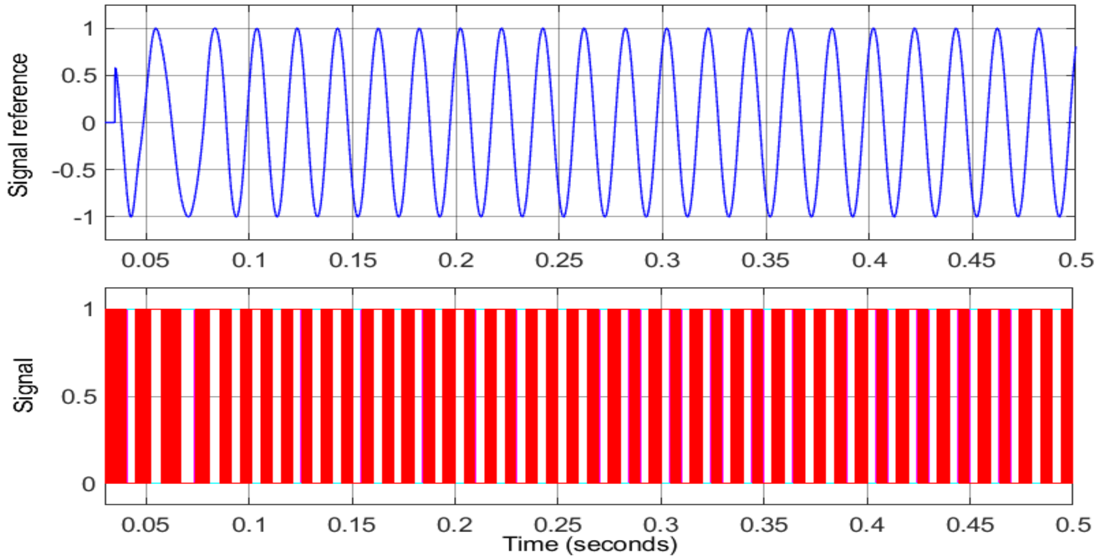


Fig. 6 **Signals reference.**

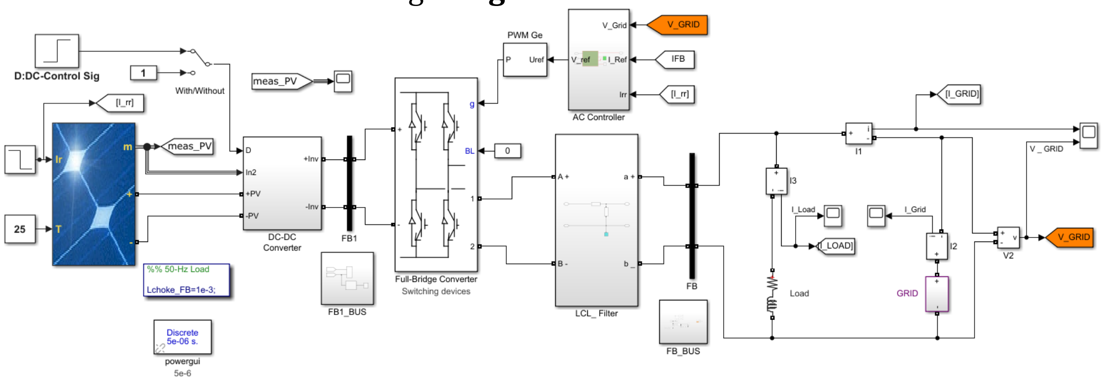


Fig. 7 Simulink model of PV system with controllers.

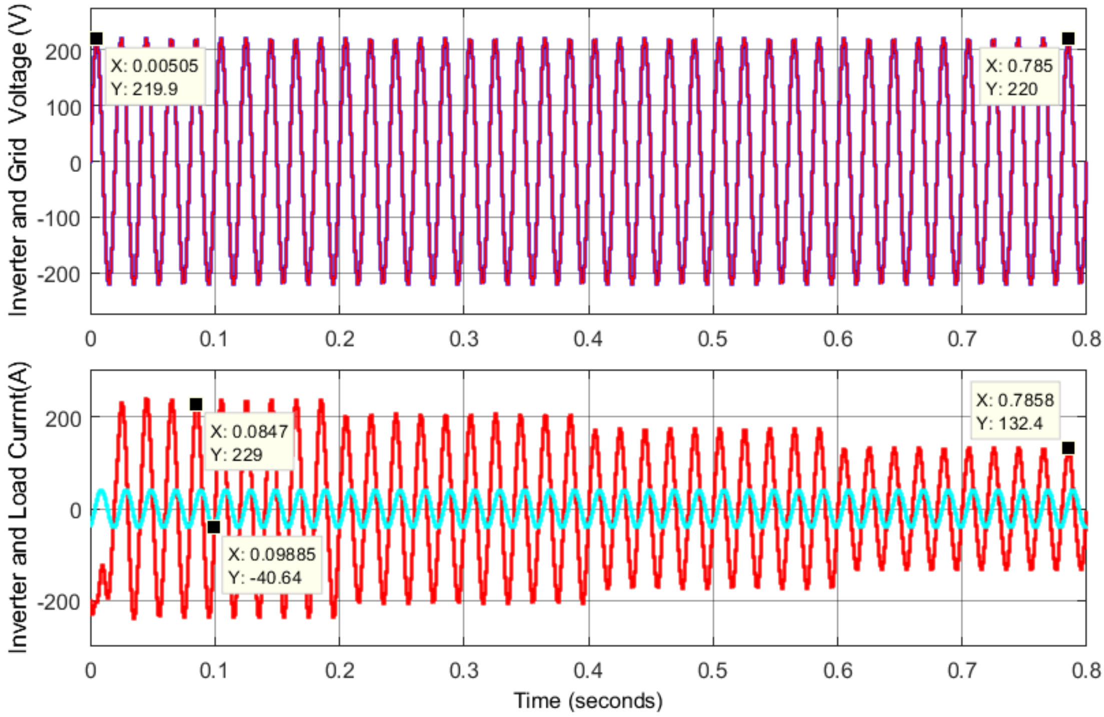
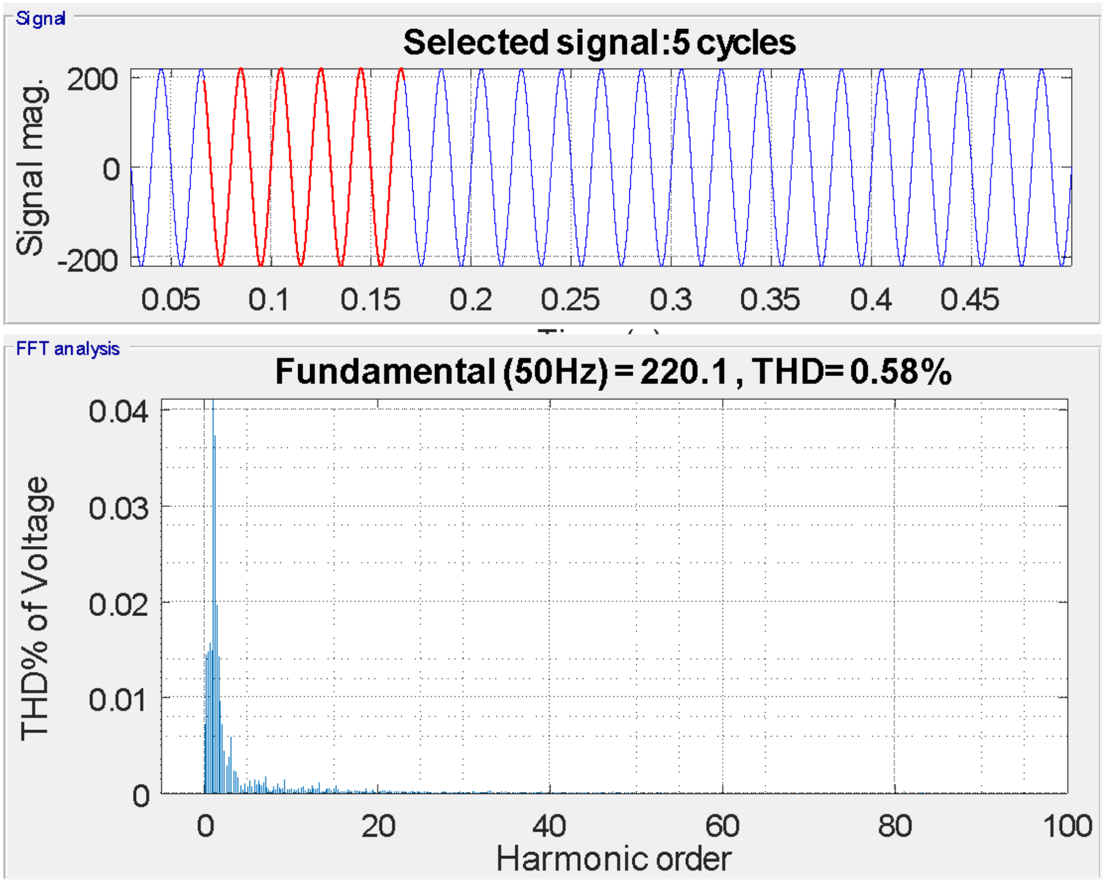


Fig. 8. **Synchronization between Inverter and grid voltage**.

Inverter voltage and current are matching with the grid voltage in (Amplitude, Phase and frequency) when The PV system is connected to the grid.



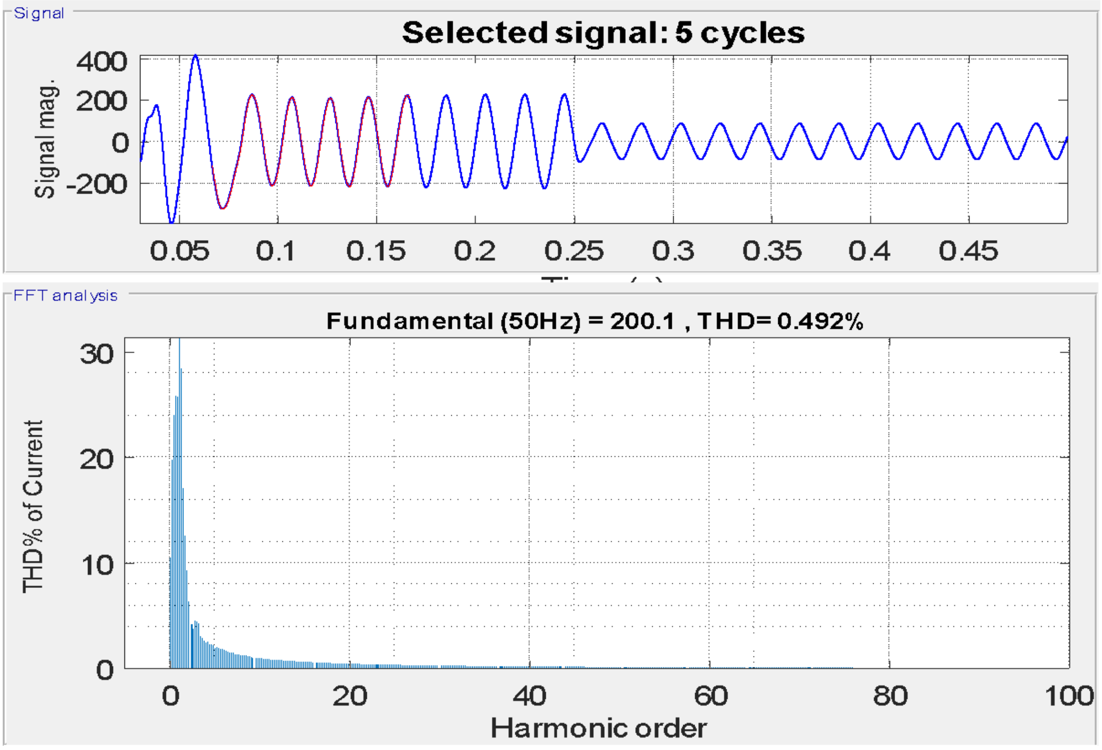


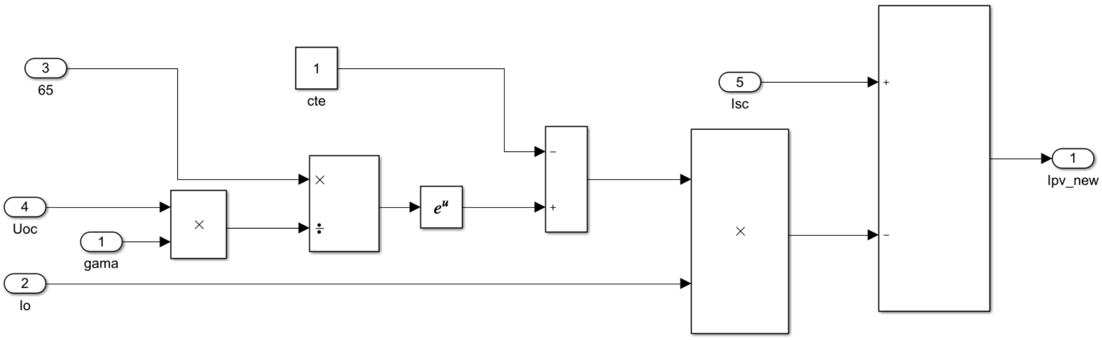
Figure (9) THD% for inverter voltage and current at LCL-filter.

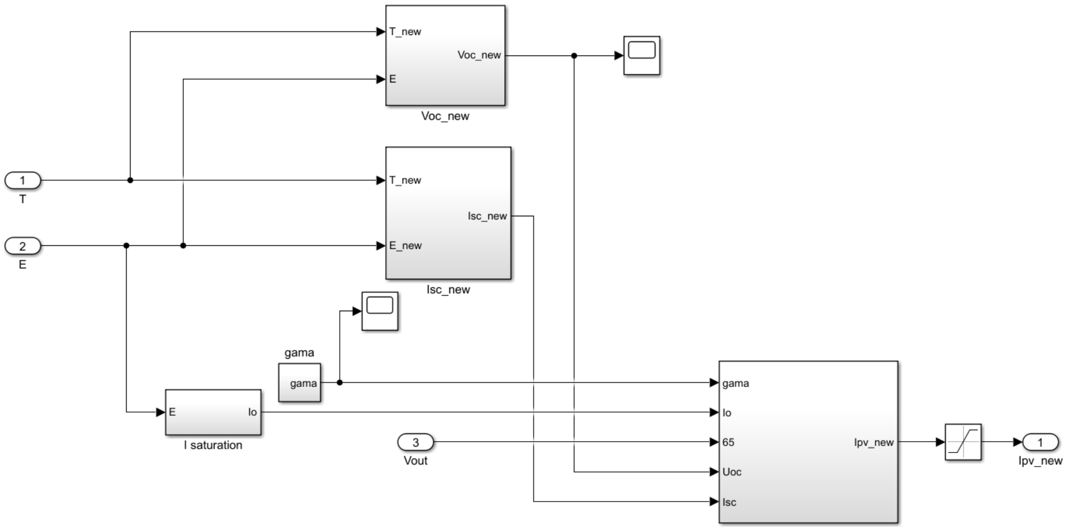
As it is visible in Fig. 9, The (THD%) for LCL-filter in range (0.58%) for voltage and in range (0.49%) for current, all results recorded for PV inverter connected with a grid. Therefore, the LCL-filter is the best choice for the grid connected PV system.

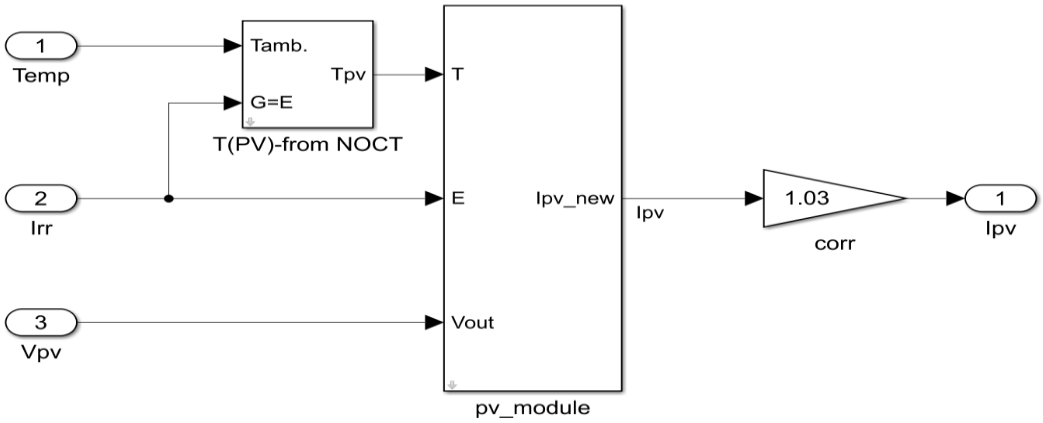
Conclusions.

As a case study, this study shows the performance of an on-grid PV array power system in Iraq under actual solar irradiances. A PV array is connected with a boost inverter to control the array current and load voltage (and frequency). A PV side controller and a grid side controller are implemented for improving the power performance of a proposed PV array system using total sun irradiance for Baghdad during July. It is found that in the case of using the proposed MPPT algorithm, the percentage power yield from the PV array system is 95%. In addition, the voltage THD is about 0.58%. Also, the current THD is about 0.49% when using an LCL filter.

Index (1):







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