MISR JOURNAL OF AGRICULTURAL ENGINEERING ISSN-Print: 1687-384X
https://mjae.journals.ekb.eg/ ISSN-Online: 2636-3062

Misr J. Ag. Eng., 41 (4): 341 – 358 **DOI:** 10.21608/mjae.2024.308306.1142

A NEW HYBRID SYSTEM WITH A SOLAR PV AND A HYDROGEN FUEL CELL

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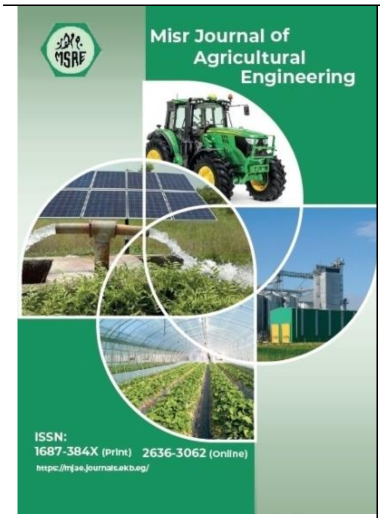


Keywords:
Photovoltaic; Electrolyzer; PEM fuel cell; Modeling; Performance assessment.

ABSTRACT

This research focuses on developing a hybrid energy system using photovoltaic cells and hydrogen fuel cells. The system provides electricity during the day and produces electricity at night without batteries. The study was conducted at a testing station for tractors and agricultural machinery, Alexandria Governorate latitude 31°11' 34.6'N, longitude 29°54' 17.5"E, and 15 meters above sea level. The tilt angle was adjusted 46 ˚. The hybrid system consists of three main units: PV solar panel, electrolyzer, and fuel cell units. The project intends to create a hybrid energy system capable of meeting specified system requirements both during the day and at night. A computer program will explain the system and calculate the energy of the solar panels, fuel cell stacks, and the flow rate of hydrogen from the electrolyzer. It will also compute the number of units required in all phases of the hybrid system. The study found great harmony between experiment results and mathematical models at each phase of a hybrid energy system using solar panels and fuel cells, including power generation, hydrogen production, and energy production.

1. INTRODUCTION

The ever-increasing demand for petroleum-based such as natual gas, Petroleum crude, and burning coal is driving society's development of renewable energy sources (Rusdianasari et al.). Many sources of energy that is sustainable, such as wind turbines (W T) and solar photovoltaic, clean and abundant in nature, are now sophisticated, cost-effective, and widely used, while others, such as proton exchange membrane fuel cells (PEMFC), to convert hydrogen's chemical energy directly to electricity, leaving only pure water and potentially valuable heat as byproducts.**(Touati et al., 2012).** PV applications have become more prevalent in both industrialised and underdeveloped countries. The primary energy consumed globally is only 1/10,000 of the available consumption on the surface of sunny countries. Egypt is geographically located in the heart of the global solar belt between latitudes 22° and 32° north of the equator, and, therefore, if solar energy is adequately exploited, it may become powerful enough to provide enough energy for humanity in the future. Whereas natural changes in solar radiation and temperature cause energy fluctuations in the PV system, making it difficult to store the energy generated by the PV system for backup. So, The greatest solution to this issue is to suggest a hybrid energy system that incorporates energy-efficient practices **(Kamal & Hassan, 2016)**. Hydrogen is an adaptable energy carrier that may be used to satisfy virtually any end-use energy need. **(Roy & Pramanik, 2023)**. A fuel cell is a type of electrochemical gadget. Employs fuel source, such as hydrogen, and an oxidant to generate electricity. A fuel cell, like the batteries found under the hoods of vehicles or in flashlights, transforms chemical energy to electrical energy. Fuel cells have various advantages over traditional power sources such as internal combustion engines and batteries. Fuel cells can reduce pollution resulting from the combustion of fossil fuels; only byproduct of hydrogen fuel cells at the time of use is water. They are more fuel-efficient, make less noise, and emit no hazardous pollutants at the time of use. **(Chakraborty et al., 2022)**. Several research works have been reported in literature on fuel cell systems depending on methanol fuel cell. The aim of this research is to develop a hybrid PV/fuel cell system for remote desert areas in Egypt, where the remote desert area lacks both electricity and other sources of energy. In addition, all the traditional sources of energy harm the environment by increasing the carbon dioxide in the environment, which may cause the destruction of the ozone layer. Due to the above obstacles in the Egyptian desert, the hybrid PV/fuel cell will offer a good environment-saving solution It also aims to create a mathematical model that simulates the hybrid energy system of solar energy and hydrogen fuel cells, as it was used to a simulation software, or model, was created for the system using a mathematical approach. Using various mass fluxes of air and salt water, the HF membranes' performance was evaluated in order to maximize the system's operational efficiency **(Elewa et al., 2023)**.

The work aims to develop a hybrid energy system that can meet specific system requirements both day and night. A computer program will describe the system, determine solar panel energy, fuel cell stacks energy, and hydrogen flow rate from electrolyzer. It will also calculate the number of needed units in all phases of hybrid system.

2. MATERIALS AND METHODS

2.1. Materials:

Figures 1 show the hybrid solar-proton exchange membrane fuel cells system as a renewable energy system consists mainly of five main units a photovoltaic panels unit, an inverter unit, hydrogen electrolyzer, hydrogen tanks, and a fuel cell.

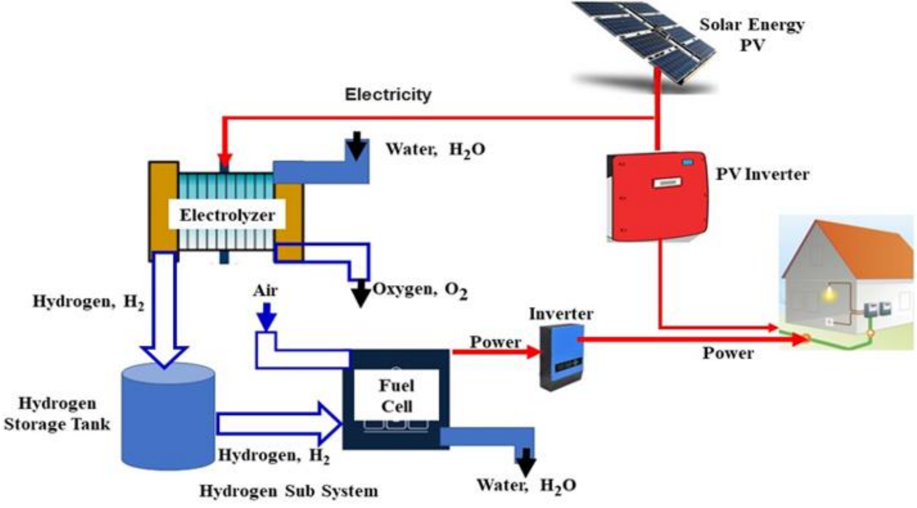


Fig. (1): Diagram of hybrid solar-fuel cells system

2.1.1. The photovoltaic Solar Cell module:

A photovoltaic module manufactured by Trina Solar company model TSM-325-DD06M.05. Table 1 show solar panel specifications.

Table (1): PV module's characteristics:

PV Module's Characteristics	Values
manufacturer	Trina Solar.
Model number	TSM-325-DD06M.05(II)
Solar cell number	60 cells.
Cell Type	Monocrystalline
Peak Power Watts- PMAX (Wp)	325 W
Related efficiency	19.1%
Maximum PowerPoint Current. (Impp)	9.85
Maximum Power Voltage- Vmpp (V)	34 V
Short Circuit Current (Isc)	10.48 A
Open Circuit Voltage (Voc)	40.4 V
Operating Temperature	-40 to +85 °C
Dimension LxWxH.	1698 mm x 1004mm x 35mm
Weight	18.7 kg

2.1.2. Inverter unit:

Regarding the inverter, as shown in figure 2 that is manufactured by generic, type B09KNWWPWD, it has already been reported with more details as Power Inverter 1000 Watt. The home and outdoor inverter transforms 12V DC battery power into conventional 220V AC power output with two continuous 220V AC outlets, two USB ports, and two AC outlets.

Fig. (2): Perspective view of e Inverter unit.

2.1.3. Wet Electrolyzer unit:

An electrolyzer was used as shown in figure 3 to produce hydrogen, which is collected and then used when needed. The wet electrolyzer was used like a dry electrolyzer unit in the case of design, but it is encircled by an outer box that permits the electrolyzer unit to be submerged in water. Which increases the efficiency of electrolyzer.

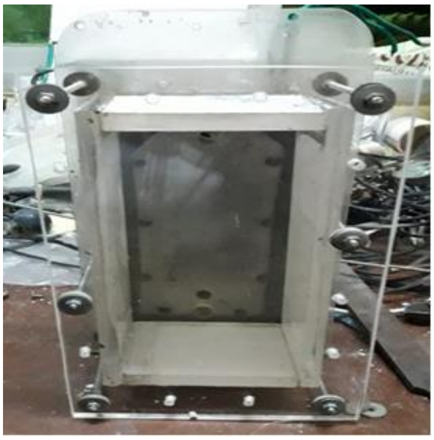


Fig. (3): The manufactured wet type electrolyzer.

2.1.4. Hydrogen tanks unit:

As depicted in figure (4) a hydrogen tank is a container used to store hydrogen in its gaseous state. They may also go by the name hydrogen cans, cartridges, or cylinders It’s has specification:

- The Composite Overwrapped Pressure Vessel (COPV) H2 Max 29L hydrogen liquid has superior fast-filling capabilities.
- Perfect for harsh environments and cryogenic applications
- A working pressure of 3.5 bar for the custom cylinder.

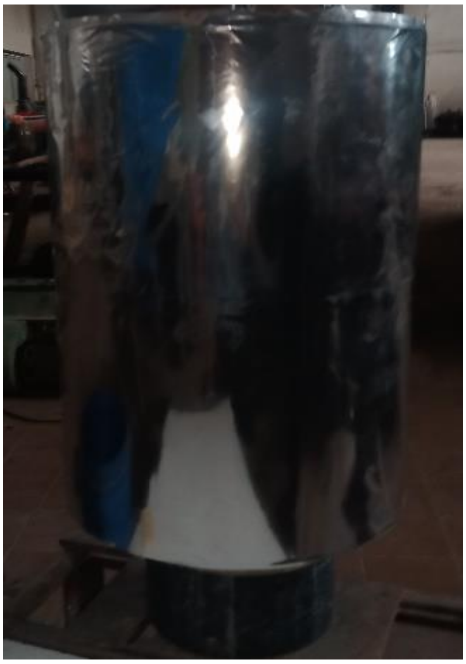


Fig. (4): Hydrogen cylinder tank.

2.1.5. Proton Exchange Membrane Fuel Cells (PEMFC) unit:

An apparatus for producing electricity that directly transforms the chemical energy of hydrogen and oxygen is a hydrogen fuel cell. The reversible reaction of water electrolysis is the fundamental idea. The anode and cathode receive supplies of hydrogen and oxygen, respectively. Electrons are delivered to the cathode by external convection after hydrogen diffuses through the anode and interacts with the electrolyte. Proton Exchange Membrane Fuel Cell parameters are displayed in Table (2) and Figure 5, respectively.

Fig. (5): Proton Exchange Membrane Fuel Cells (PEMFC).

Table (2): The specifications of Proton Exchange Membrane Fuel Cells:

Fuel Cell. Characteristics	Values
Type of fuel cell.	PEM
Numbers of cells.	26
Rated power	500 W
Efficiency	18 V 27.5A
Reactants	Hydrogen and Air.
External operating temperatures	5-30 ?
Maximum temperature of the stack	65 ?
H_2 operating Pressure	0.45 – 0.65 bar
Hydrogen purity	>99.995 % dry hydrogen
Humidification	Self-humidifying.
Cooling	Air (with integrated fan) 12V 0.1A
Dimension of the membrane	660mm x 199mm x 356mm
Start time	30 s. at room temperature.
Flow at maximum efficiency	7 l/min 50% (18V).
Efficiency of the stack	50 % (18V)
Over temperature shut down	65 ?

2.2. Theory of the system methodology work:

The Theory of the system methodology work depends on three aspects:

1. Solar radiation is captured by photovoltaic cells that convert solar radiation into electrical energy. The electrical energy obtained is used to operate the required electrical loads.
2. Electrical energy and an increase in operating need is also used to use it in the electrical analyst for water, where the water molecule (H_2O) is available as a molecule of hydrogen (H_2) and a molecule of oxygen (O_2). These molecules are stored in tubes or hydrogen tanks.
3. The stored hydrogen can also be used in the period of the sun's absence to feed the fuel cell to supply the farm with the necessary electrical energy.

At the end, each unit is studied separately to reach the best results and specifications for each group, then they are combined to reach the best results and specifications for the required system. A number of solar panels are used that are sufficient to operate the loads during the day and sufficient to operate the electrolyzer to produce hydrogen, which must be of a size Sufficient hydrogen is able to feed a sufficient amount of hydrogen fuel cell units that operate the loads at night during the absence of the sun.

2.3. Mathematical Hybrid Power System consideration:

2.3.1. Mathematical consideration of a PEMFC:

The theoretical power request (P_{ld}) from the stack for a given external load resistance (R_{stk}) is computed by **(Altork, 2010)** :

$$P_{stk} = \frac{V_{ld}^2}{R_{stk}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where:

V_{ld} : The external load voltage (18 V).

External load resistance (R_{stk}), which is affected by the change in the operating temperature of the fuel cell, which is also affected by the change in operating loads, can be calculated as in the following equations **(Carmo et al., 2011)**.

$R_o = \frac{\sigma * L}{A}$ ……………………………………………………………………………..(2)

$R_{stk} = R_o\,(1+\alpha\,\Delta T)$ …………………..………………………………………...……..(3)

Where:

R_o: the initial load resistant in (Ω).

σ : The specific resistance of the wire material in Ω.m is (0.0000172 Ω.m) for copper.

L: Length of the wire in m (0.485m)

A: wire section area in m^2, (the radius r 0.002 m)

α: coefficient of resistivity in $℃^{-1}$ (0.1)

ΔT: temperature change in ℃.

The efficiency of the fuel cell stuck (η_{stk}) According **(Omran et al., 2021)** , stuck (ηstk) can be calculated by dividing its output power (Pout) by its input power.

The stuck efficiency is calculated by:

$$\eta_{\,stk} = \frac{P_{stk} - P_{aux}}{P_{H2}} = \frac{P_{stk} - P_{aux}}{\dot{V}_{H2}\,Q_{LHV,H2}} \quad\text{………………………………………………(4)}$$

Where:

P_{H2} is the hydrogen's power input (W), which is calculated by multiplying the lower heating value QLHV, H2 (Wh/l) by the hydrogen's flow rate V̇_H2 (l/h).

$P_{H2} = \dot{V}_{H2} * Q_{LHV,H2} = 2.8\ \dot{V}_{H2}$ …………………………………………….……………….…(5)

Where: 2.8 is a constant equivalent the value of LHV_{H2} (Wh/l).

2.3.2. Mathematical consideration of wet electrolyzer:

One promising approach for producing green hydrogen using renewable energy is water electrolysis **(Shen et al., 2011)**.

$$H_2O + Electricity = H_2 + \frac{1}{2}\,O_2 \quad\text{………………..………..…………………...(6)}$$

To ascertain the overall rate of hydrogen production in the electrolyzer, which is made up of many parallel cell connections, the **(Koundi & EL FADIL, 2019)** equation for operation is stated below.

$$V_{ez\,H2} = \frac{n_c\,R\,a\,I_{ez}\,T}{z\;P\;F} * 3600 * 1000 \quad\text{…………..………………………………...(7)}$$

Hydrogen production rate (L/h) can be determined

n_c = the number of electrolytic slices in parallel

I_{ez} = the electrolyzer current (0.2 A/cm^2).

a = the area of electrolytic slices (cm^2).

F = the Faraday constant, (96485.33 C mol^{-1} coulombs per mole)

R = the gas constant (8.3144 $m^3 \cdot pa \cdot K^{-1} \cdot mol^{-1}$)

T = Operating temperature of the electrolyzer (298.15 K)

z = the number of electrons (2 for hydrogen and 4 for oxygen)

P = pressure of the electrolyzer (101325 pa)

2.3.3. Mathematical consideration of a PV system:

According to **(Zhang et al., 2023)** the following is the worldwide formula to calculate the electricity produced in the output of a solar system:

$$P_{PV} = A \times r \times H \times PR \ldots\ldots(8)$$

P_{PV} = photovoltaic Power generated (W), A = Area of all solar panels combined, (m^2) (1.6 x 3 = 4.8 m^2)

r = solar panel yield or efficiency, (%) (The term "Watt-peak" refers to the nominal power of the solar panel in these circumstances (Wp or kWp=1000 Wp or MWp=1000000 Wp). where the solar panel's yield is calculated by dividing the electrical power (measured in kWp) of a single panel by its area.

For instance, the solar panel yield of a 1.6 m2 PV module with a 325 Wp capacity is ((325/1.6)/1000) * 100 = 20.3%.

H = Annual average solar radiation on tilted panels (shadings not included),

PR = Performance ratio, coefficient for losses (range between 0.5 and 0.9, default value = 0.75) is a very important value to evaluate the quality of a photovoltaic installation because it gives the performance of the installation independently of the orientation, inclination of the panel. It includes all losses.

2.3.4. Estimating the rate of hydrogen production from the electrolyzer:

Under laboratory circumstances, the water displacement metering device Figure (6) was used to volumetrically measure the hydrogen generation rate (l/h) by cumulated hydrogen per replication.

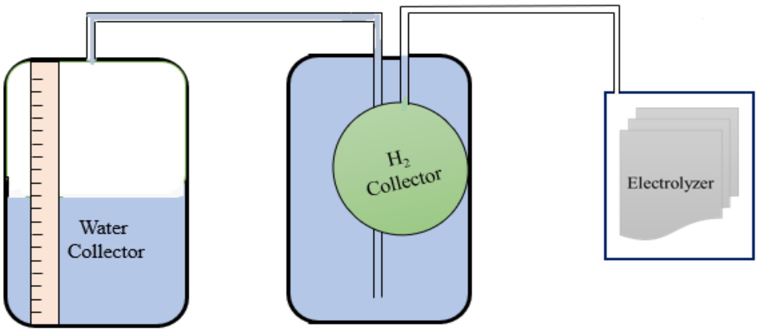


Fig. (6): The water displacement system.

2.3.5. System modeling:

Mathematical model equations were solved using the MATLAB software. Matrix and array mathematics are directly expressed in MATLAB, a high-level programming language designed for scientists and engineers. Moreover, there are numerous uses for MATLAB, from simple interactive commands to large-scale application development. The Simulink module offers direct access to mathematical, graphic, and software resources via the MATLAB GUI (Graphical User Interface). On the other hand, using the Symbolic Math toolbox to generate analytical solutions, create interactive simulations with user interface control, and produce stand-alone applications using the MATLAB Compiler and the MATLAB C and C++ Library **(Petrov et al., 2020)**. The simulation tool MATLAB is a popular and potent software suite. Because of its easy-to-use GUIs, extensive compatibility across several computing systems, Simulink libraries, graphical capabilities, interactive mode of operation, and straightforward programming, MATLAB was selected as the programming tool for this project. These characteristics make MATLAB a formidable research and useful problem-solving tool, as well as an outstanding language for teaching. Simulink, Dynamic system simulation software, such as a MATLAB toolbox, offers an easy-to-use interface for building equation-based system models. GUIDE, a tool used by MATLAB to develop GUIs, lets users design gueridons that incorporate graphical elements. A graphical user interface program (GUI) consists of buttons, text fields, sliders, and menus, among other graphical features. These definitions are not unfamiliar to most computer users. GUIs control how the user and the MATLAB computational engine communicate **(Altintas, 2011)**.

To demonstrate the system and validate the experimental results, a computer program was developed, and a software program was created using MATLAB R2021a version 9.10.0.16. In this application, the system consisting of three stages was implemented: the fuel cell unit, the electrolyzer unit, which produces hydrogen, and the solar cell unit. The equations for each unit or each stage were applied. Of the three stages, the three stages were also linked as a single system to achieve the goal, which is to produce an integrated renewable energy system during daylight hours and night hours without the need to connect to the electricity grid or use batteries and produce the energy required for a specific energy load. The flow chart of our hybrid system shows the diagram and flow of equations, inputs, and outputs. For each stage, as shown in Figure (7).

Figure (8) also shows the graphical interface of the implemented application for the hybrid energy system of solar and hydrogen fuel cell energy, which shows the 22 buttons of inputs to the program, which consists of five inputs for the solar energy unit, which are solar panel Area (A) in m^2, solar radiation on tilted panels (H) in W/m^2, number of PV panel units (n_{pv}), Performance Ratio of PV panel (PR) and Power of one Panel (P_{panel}) in W. seven inputs for the hydrogen production unit, which are number of electrolyzer slices (n_c) in parallel from 1 to 10, Area of electrolytic slices (a) in cm^2, number of electrolyzer units (n_{ez}), consumed power of one electrolyzer unit (P_{ez}) in W, electrolyzer current (I_{ez}) in A/cm^2, operating temperature (T) in K° and operating pressure (P) in pa. nine inputs for the hydrogen fuel cell unit contain three Parameters of Load resistance (R_{stk}) the specific resistance of the wire material (σ) in Ω.m, Wire length (L) in m and Wire radius (r) in m, three Parameters show the effect of temperature in resistance (ΔT) the initial operation temperature (T_i) in ℃, final operation temperature (T_f) in ℃ and Coefficient of resistivity (α) in $℃^{-1}$, other Parameters like number of fuel cell stakes units, stake voltage (V) in volt and minus power consumption of one fuel cell unit ,in addition to Average load usage (L) in W.

The output data consists of 10 data which are the power of one photovoltaic panel generated (P_{pv}) in W was calculated as shown in equation (8), total power of photovoltaic system generated (TP_{pv}) in W, hydrogen production rate from one electrolyzer unit (V_{ez_H2}) in l/h was calculated as shown in equation (7), hydrogen production rate from all electrolyzer units (TV_{ez_H2}) in l/h, Power of one fuel cell unit (P_{stk}) in W was calculated as shown in equation (1), total Power of fuel cell units (P_{fc}) W, Fuel cell efficiency % (η_{stk}) was calculated as shown in equation (4), number of designed fuel cell units(n_{fc}), number of designed electrolyzer units (n_{ez}) and number of designed PV panels (n_{pv}). There is also a graph showing the relationship between the efficiency of the fuel cell stack and the actual power produced from the fuel cell unit.

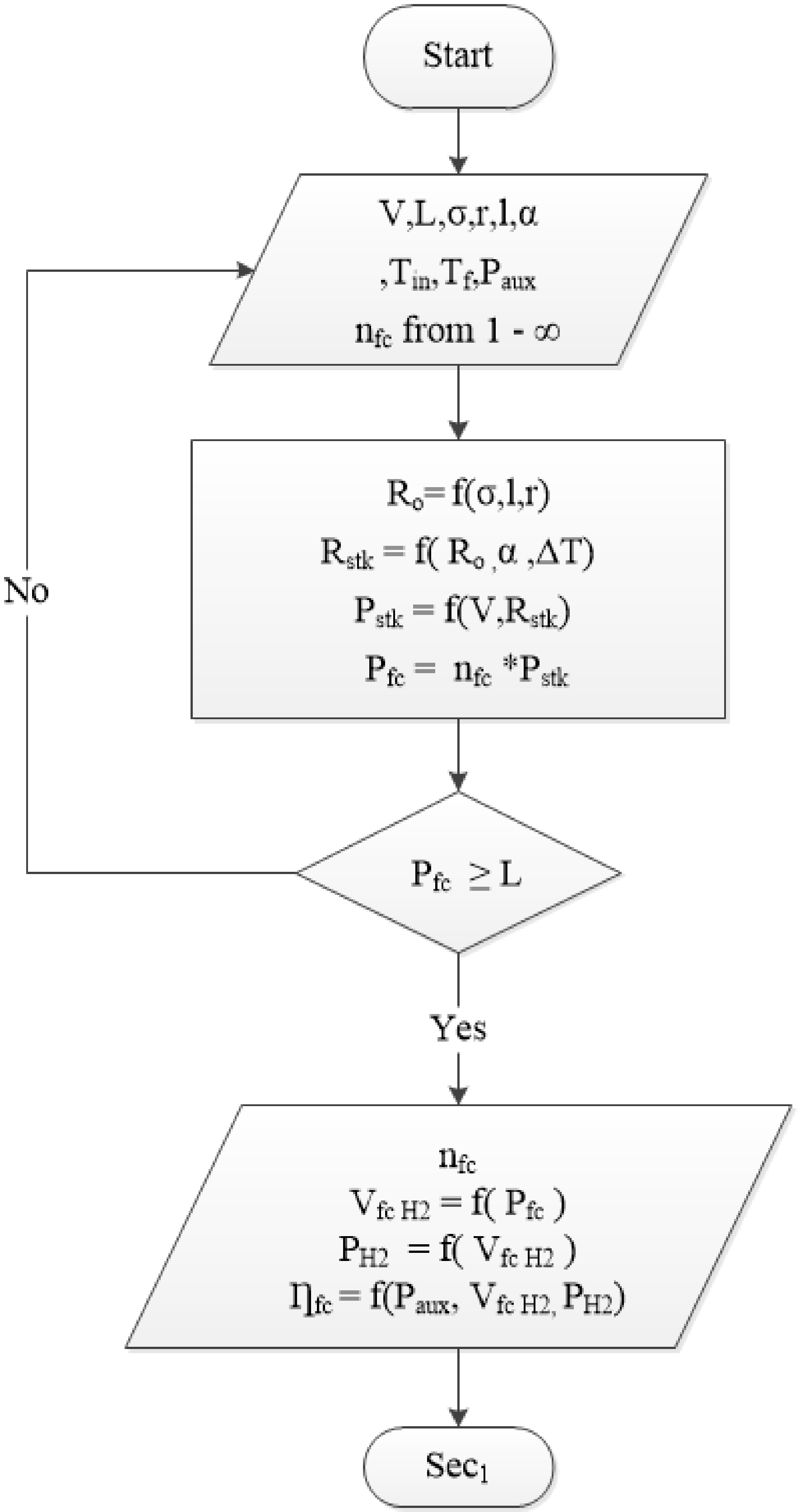


Fig. (7): hybrid system PV/FC Renewable Energy Flow Chart.

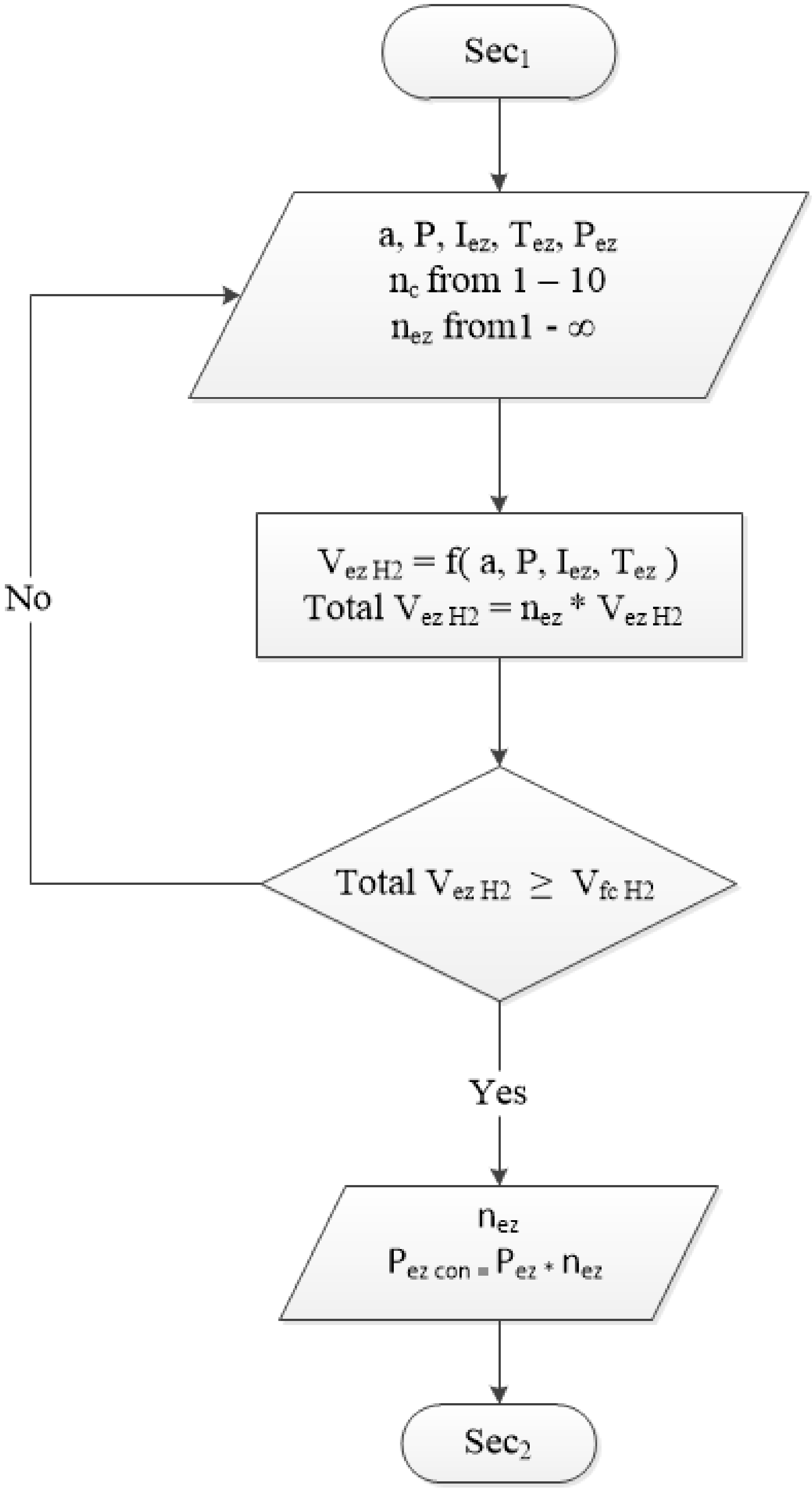


Fig. (7): hybrid system PV/FC Renewable Energy Flow Chart (continued).

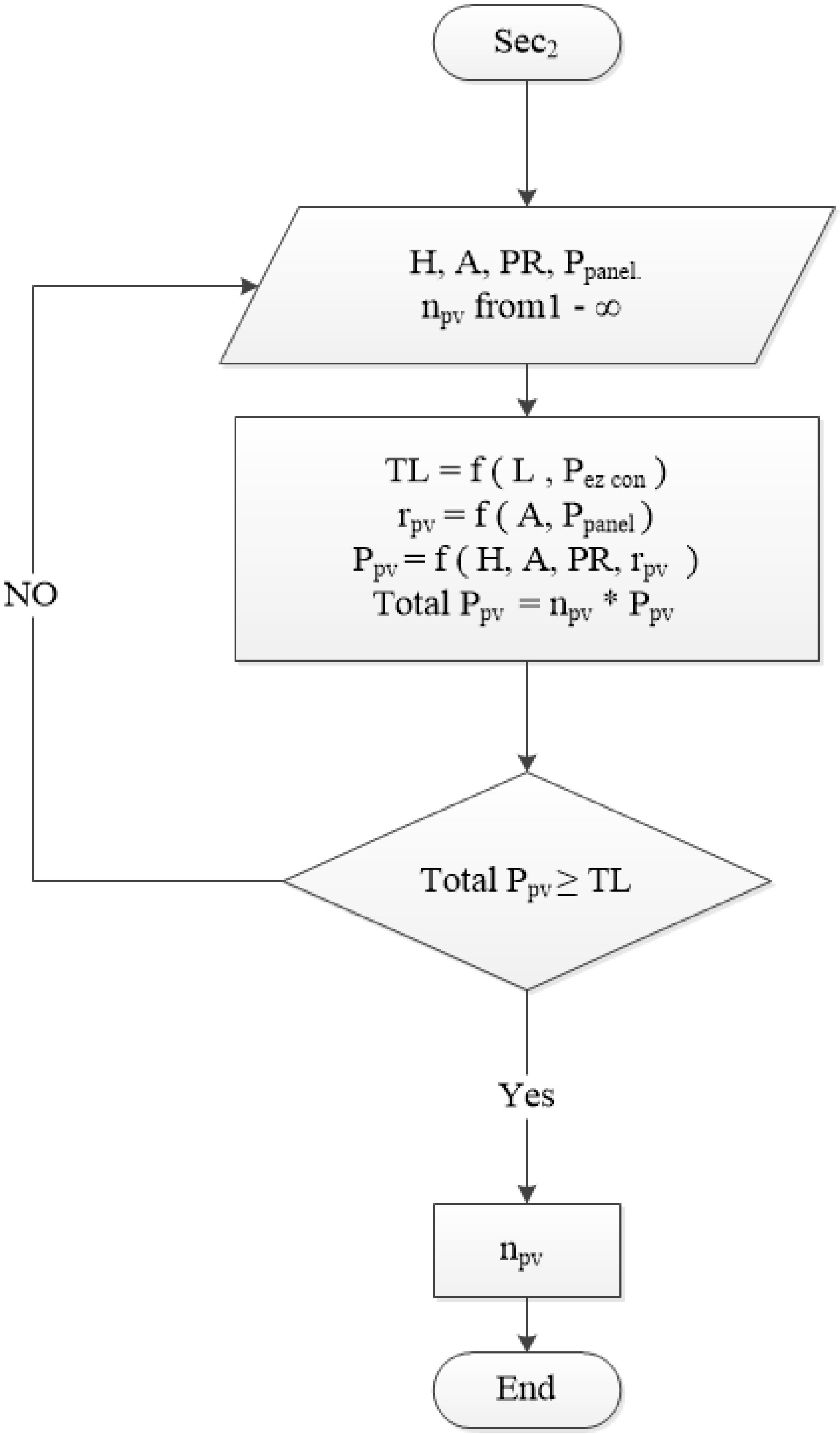
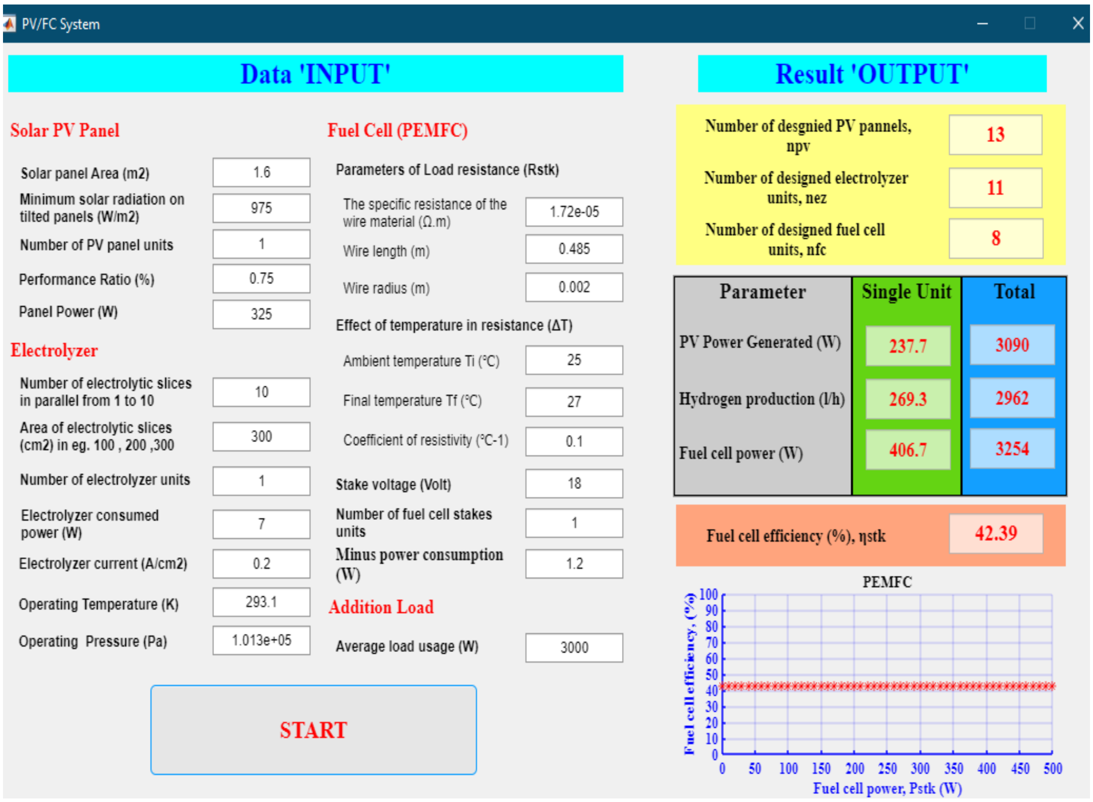


Fig. (7): hybrid system PV/FC Renewable Energy Flow Chart (continued).



Solar PV Panel

Solar panel Area (m2): 1.6
Minimum solar radiation on tilted panels (W/m2): 975
Number of PV panel units: 1
Performance Ratio (%): 0.75
Panel Power (W): 325

Electrolyzer

Number of electrolytic slices in parallel from 1 to 10: 10
Area of electrolytic slices (cm2) in eg. 100 , 200 ,300: 300
Number of electrolyzer units: 1
Electrolyzer consumed power (W): 7
Electrolyzer current (A/cm2): 0.2
Operating Temperature (K): 293.1
Operating Pressure (Pa): 1.013e+05

Fuel Cell (PEMFC)

Parameters of Load resistance (Rstk)
The specific resistance of the wire material (Ω.m): 1.72e-05
Wire length (m): 0.485
Wire radius (m): 0.002
Effect of temperature in resistance (ΔT)
Ambient temperature Ti (°C): 25
Final temperature Tf (°C): 27
Coefficient of resistivity (°C-1): 0.1
Stake voltage (Volt): 18
Number of fuel cell stakes units: 1
Minus power consumption (W): 1.2

Addition Load

Average load usage (W): 3000

Number of desgnied PV pannels, npv: 13
Number of designed electrolyzer units, nez: 11
Number of designed fuel cell units, nfc: 8

Parameter	Single Unit	Total
PV Power Generated (W)	237.7	3090
Hydrogen production (l/h)	269.3	2962
Fuel cell power (W)	406.7	3254

Fuel cell efficiency (%), ηstk: 42.39

Fig. (8): MATLAB graphical user interface of the hybrid energy system of solar and hydrogen fuel cell energy.

3. RESULTS AND DISCUSSION

3.1. Comparing the results of experimental hydrogen production with the model result:

When comparing the results of hydrogen production resulting from applying the rates to MATLAB and the results obtained from the experiment, we find that in general there is a great agreement between the experimental results and the model results is showing in Figure 9.

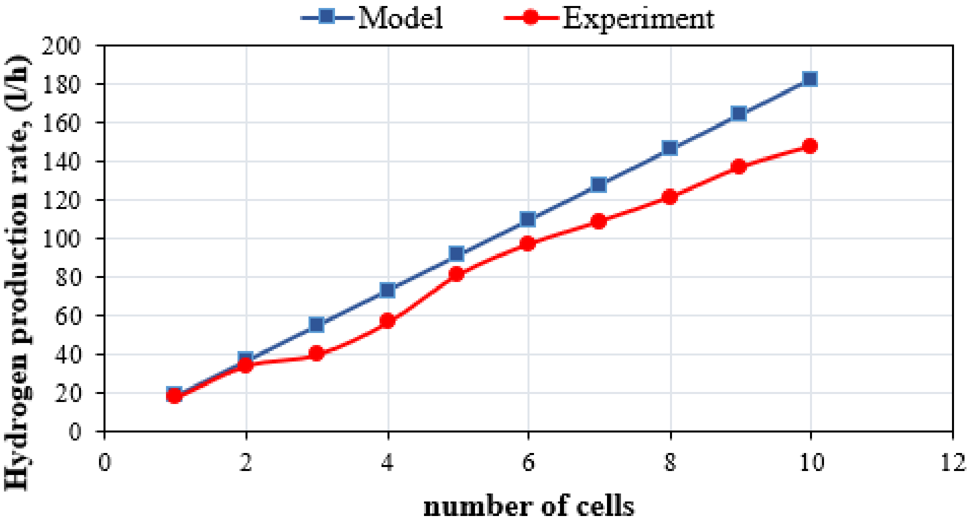


Fig. (9): Comparing the hydrogen production rate of the model and the experimental results.

3.2. Mathematical and experimental PV system results:

Solar radiation was measured in W/m^2 during the day, as shown in Figure (10) The highest radiation was at 1 p.m., with a value of 975 W/m^2,. These data were measured using the meteorological station at the Horticultural Research Institute in Sabahia, where the sun rose and set at 4.59 and 19.08, respectively, and the number of daylight hours was about 14.09 hours.

Figure (11) show the value of the resulting power generated by the photovoltaic cell system generated from a single solar panel with a nominal capacity of 325 watts and an area of 1.6 m^2, The maximum power is generated during the day at one o'clock in the afternoon at 975 W/m^2 of radiation, with a value of 235.35 and 237.65 W for both the experimental and the model results, respectively, while the lowest power generated was at 100 W/m^2 of radiation at 7 p.m., with a value of 21.06 and 24.37 W for the results of the experiment and the model, respectively. This shows a great agreement between the experimental results and the results of the mathematical model used.

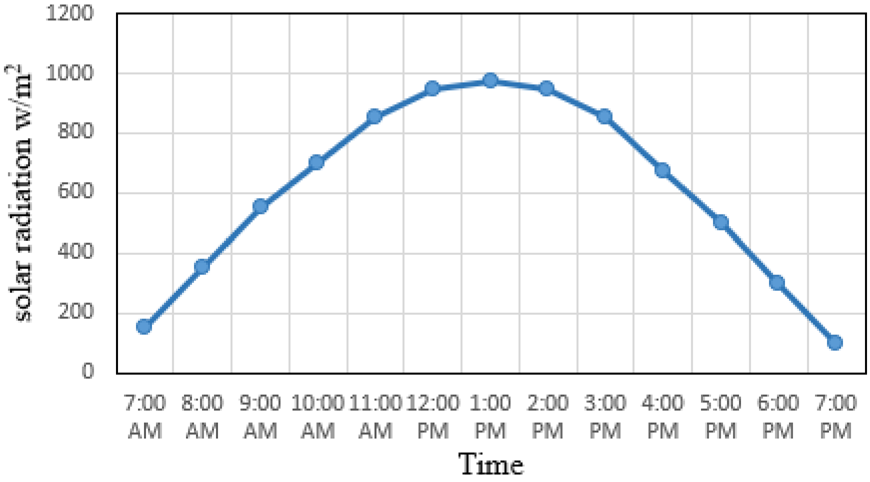


Fig. (10): shows hourly profiles solar radiation at the experimental site W/m^2 on August 1, 2021.

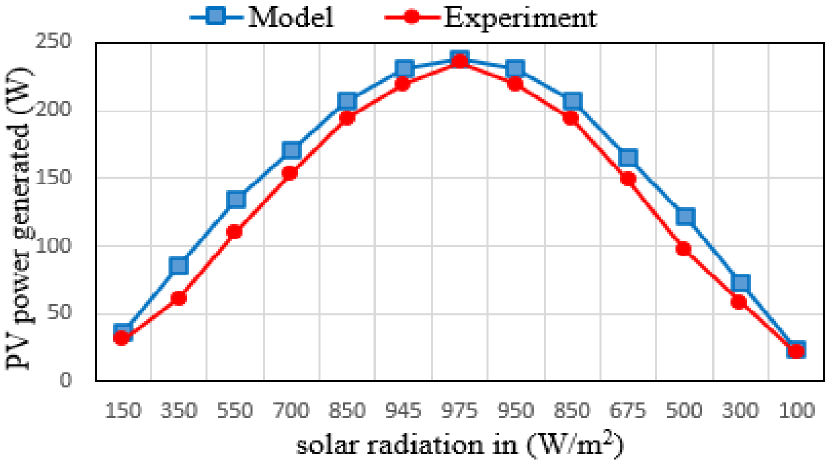


Fig. (11): The model and experimental PV power generated.

3.3. The PEMFC fuel cell experimental results:

3.3.1. Effect of external load resistance on stack power:

In Fig. (12) with decreasing external load resistance, the stack output power increases. The highest power produced by one stack was 406.58 and 488.26 W for both the experimental results and the model, respectively, at the lowest internal load resistance of 0.66 Ω, with a difference in power percent of 16.72 %. the lowest power produced was 94.36 and 97.65 W for both the experimental results and the model, respectively, with the lowest percentage difference in power estimated at 3.2 %.

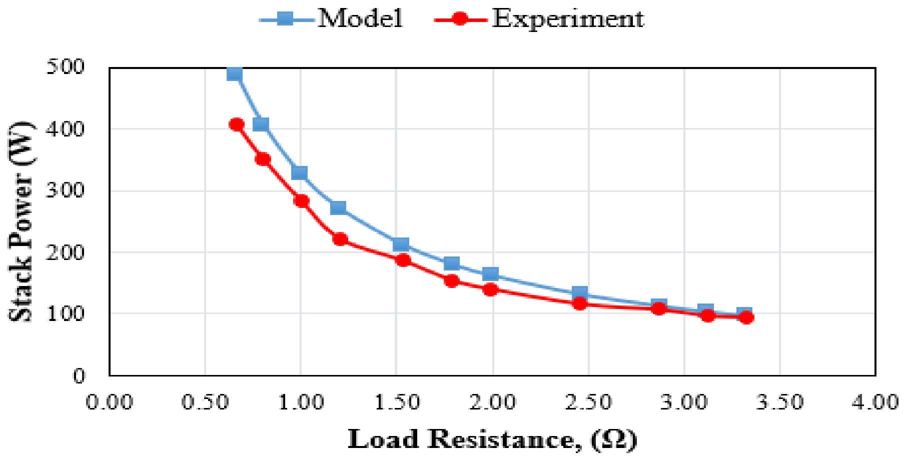


Fig. (12): Effect of external load resistance on output stack power.

3.3.2. Effect of output stack power on hydrogen flow rate.

Both the model and the measurements demonstrate correlation of hydrogen consumption on stack power, when producing large power, we need a higher flow rate of hydrogen. The greatest disparity Percent was 7.19 % at 147.3 W. Plotting hydrogen flow rate against output power shows increasing values, even when linearity is lost. A similar pattern has been noticed by other writers. Figure (13) demonstrate how hydrogen flow rate varies with output power.

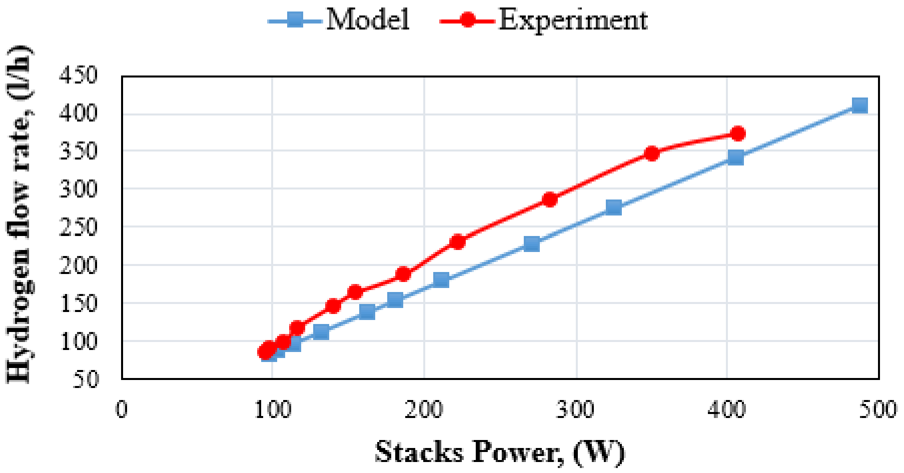


Fig. (13): Effect of stack power on hydrogen flow rate.

3.3.3. System efficiency.

Figures (14) demonstrate the overall model and system efficiency estimated from the experiments. Peak efficiencies of 42.41 % (model) and 38.82 % (experiments) were achieved at 487.06, 93.16 W, respectively.

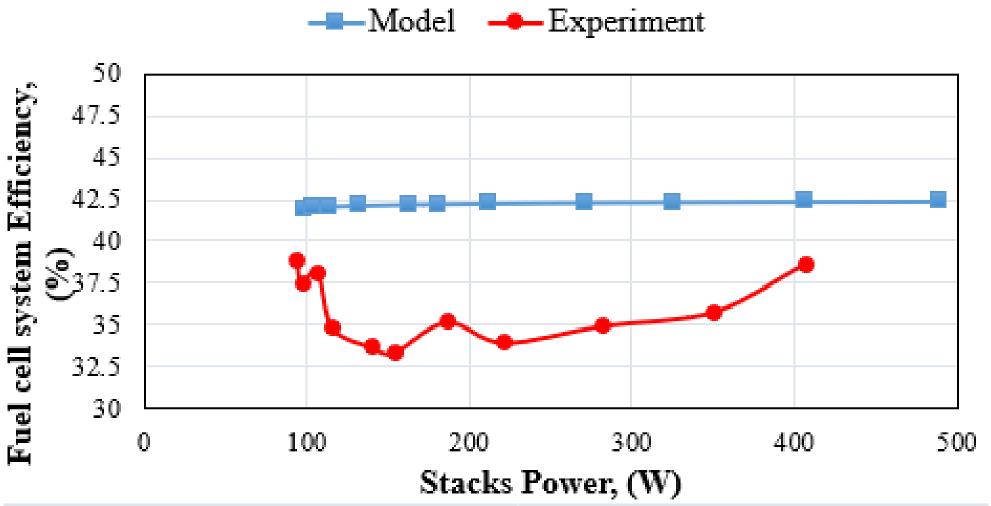


Fig. (14): PEMFC system efficiency with output stack power.

4. CONCLUSION

The research aims to develop a hybrid energy system capable of meeting the requirements of a specific system during the day and night. The hybrid system consists of three basic units: photovoltaic cells, an electrolyzer to produce hydrogen, and hydrogen fuel cells. During the day, the system relies on several photovoltaic cell units sufficient to produce the energy required to operate the system and sufficient to operate a number of electrolyzer units to produce the required hydrogen rate to feed the fuel cells at night. During the night and in the absence of sunlight, the system relies on hydrogen fuel cells to provide the energy required for the system. Thus, the hybrid energy system is suitable for providing energy even in remote areas far from the electricity grid because it relies entirely on renewable energy sources throughout the day. A computer program is implemented that can describe the hybrid energy system and determining the results obtained during each of the three stages and predicting the performance of each stage. The number of required and sufficient units of photovoltaic cells, electrolyzers, and fuel cells and their specifications can be determined. In general, at each stage there is a great agreement between the experimental results and the mathematical model used. This agreement includes the solar panel power generation stage used in the presence of sunlight, the hydrogen production stage from the water electrolyzer, and the hydrogen fuel cell power generation stage used in the absence of sunlight.

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نظام هجين جديد باستخدام الطاقة الشمسية الكهروضوئية وخلايا وقود الهيدروجين

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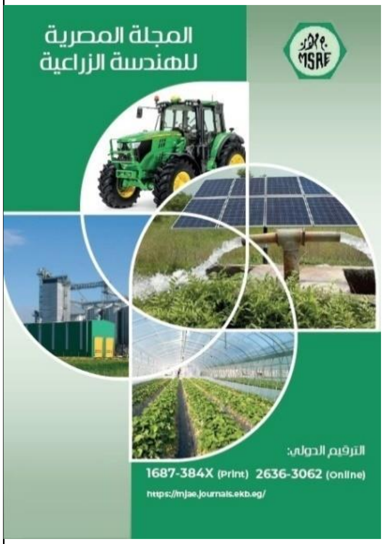

الكلمات المفتاحية:
نظام كهروضوئي؛ محلل المياه الكهربائي الرطب؛ خلايا وقود غشاء التبادل البروتوني؛ النمذجة؛ تقييم الأداء.

الملخص العربي

يهدف البحث الى تطوير نظام طاقة هجين قادر على تلبية متطلبات نظام معين ليس خلال النهار فقط ولكن خلال النهار والليل ايضا ، يتكون نظام الطاقة الهجين من ثلاث وحدات اساسية الخلايا الكهروضوئية ومحلل المياه الكهربي (الإليكتروليزر) لإنتاج الهيدروجين وخلايا الوقود الهيدروجينية ، فأثناء النهار يعتمد النظام على عدد من وحدات الخلايا الكهروضوئية يكفي لإنتاج الطاقة المطلوبة لتشغيل النظام ويكفي ايضا لتشغيل عدد من وحدات الإليكتروليزر لإنتاج معدل الهيدروجين المطلوب لتغذية خلايا الوقود ليلا واثناء الليل وفي غياب اشعة الشمس يعتمد النظام على خلايا الوقود الهيدروجينية في توفير الطاقة المطلوبة للنظام ، بذلك يكون نظام الطاقة الهجين صالح لتوفير الطاقة حتى في المناطق النائية البعيدة عن شبكة الكهرباء لأنه يعتمد بشكل كلى طوال اليوم على مصادر متجددة للطاقة .ويتم تنفيذ برنامج كمبيوتر قادر على وصف نظام الطاقة الهجين وتحديد النتائج المتحصل عليها خلال كل مرحلة من المراحل الثلاثة لهذا النظام الهجين والتنبؤ بأداء كل مرحلة ويمكن تحديد عدد الوحدات المطلوبة والكافية من الخلايا الكهروضوئية والإليكتروليزر وخلايا الوقود ومواصفاتهم لتصميم نظام طاقة هجين قادر على تلبية حمل طاقة معين مطلوب. وبشكل عام، في كل مرحلة من مراحل نظام الطاقة الهجين من الألواح الشمسية وخلايا الوقود، نجد تناغما كبيرا بين نتائج التجربة والنموذج الرياضي المستخدم. وشمل هذا الاتفاق مرحلة توليد الطاقة من الألواح الشمسية التي تستخدم في وجود ضوء الشمس، ومرحلة إنتاج الهيدروجين من محلل الماء الكهربائي، ومرحلة إنتاج الطاقة من خلايا الوقود الهيدروجيني التي تستخدم في غياب أشعة الشمس.