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Development of Simulink Model for Green Hydrogen Production using Power to X Technology using Matlab

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ABSTRACT

In light of the impending energy revolution including the threat of rising temperatures, hydrogen energy is seen as a vital element in the development of a society that is environmentally conscious. Of the most vital elements on Earth, hydrogen may be produced utilizing a variety of methods with both sustainable and non-renewable sources of energy. However, attempts to find and execute sustainable hydrogen production pathways are greatly hampered by the requirement for a slow transition to renewable energy sources. As a result, the goal of this work is to present a technological evaluation of the techniques for producing hydrogen via solar energy using several kinds of water electrolyzers. The current article begins with a brief primer on the various manufacturing strategies. Following an in-depth contrast of different types of water-based electrolyzers and a thorough explanation of solar and wind-powered hydrogen fuel manufacturing procedures with scenarios, an economical evaluation of environmentally friendly gas hydrogen production is provided by contrasting the expenses of the addressed renewable energies with those of conventional manufacturing techniques. Finally, the current analysis sheds light on the difficulties that the aforementioned manufacturing techniques encounter.

Keywords: Proton Exchange Membrane (PEM), Alkaline Water Electrolyser (AWE), Electrolysis of Water, Hydrogen Production System (H2PS)

1. Introduction

1.1. HYDROGEN ENERGY

In light of the impending energy shift along with the imminent danger of environmental degradation, hydrogen power is seen as an important contributor to the development of a society that is environmentally friendly. Among the most vital compounds on the planet, hydrogen might be generated through a variety of methods with both nonrenewable and environmentally friendly energy resources. Yet efforts to identify and implement green hydrogen production pathways are significantly hampered by the requirement for a gradual shift to alternative power sources.

Nomenclature

PEM of Proton Exchange Membrane

AWE of Alkaline Water Electrolyser

AEM of Anion Exchange Membrane

SOE of Solid Oxide Electrolyser

PV of Photovoltaic and UV of Ultraviolet

WG of Wind Generator and WT of Wind Turbine

The element with the greatest abundance within our solar system is hydrogen (H2), and that can be found mainly in water and organic matter on the surface of the earth [16,18]. Being the smallest as well as most light element, it is made up of just one proton with a single electron [16] and behaves as a colourless, odourless, flammable gas [197]. The atomic mass of hydrogen is 1.00794 atomic mass units, turned up to 1.008. The US celebrated National Hydrogen and Fuel Cell Day on October 8th (10/08) in honour of this element's atomic weight (1.008) [207]. The Fuel Cell and Hydrogen Energy Technology Organisation first acknowledged the ceremony in 2015 to promote knowledge concerning fuel cell and hydrogen technologies and the enormous potential they have both now and shortly, as shown in Fig.

1.2. Water Electrolysis

The usage of an electrolytic water device and an energy source that is renewable are two crucial elements of an environmentally friendly hydrogen system. Using a device known as an electrolyzer & energy, water breaks into a mixture of hydrogen and oxygen throughout water electrolysis. This electrolyzer is often suggested as the most practical and practical technology for producing hydrogen and storing energy when used together with renewable energy because of its intermittent nature. According to these data points, the proton exchange membrane electrolyzer (PEM), the alkaline water electrolyzer (AWE), the alkaline anion exchange membrane (AEM), and the solid oxide electrolyzer (SOE) are the most popular electrolyzers.

1.3. TECHNIQUES FOR PRODUCING HYDROGEN

Hydrogen may be discovered in a variety of natural compounds. Of all the prevalent of these is water, which occurs naturally as briny (sea waters), river or stream, rain or groundwater. Hydrogen may also be recovered using biomass, sulphide of hydrogen, fossil petroleum products, and other elements. Once hydrogen is generated from fossil fuels, every bit of carbon dioxide has to be treated (separated, sequestered, etc.) to qualify for the entire procedure to be considered "green" and for there to be no release of GHG or contaminants into the earth's atmosphere.

The energy types required for the extraction of hydrogen through the resources of nature mentioned above may be divided into four groups: thermal, electrical, photonic, and biological. As will be shown later, several types of energy may be gained from renewable sources of energy.

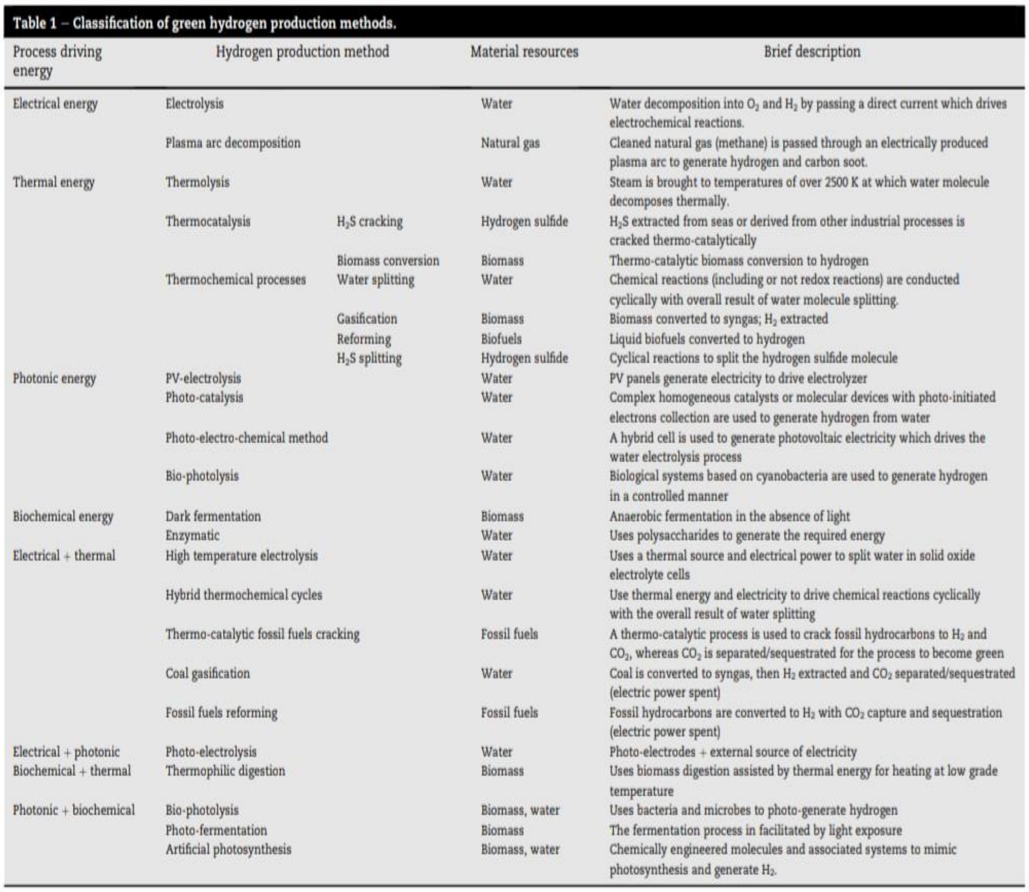


Table 1 – Classification of green hydrogen production methods.

Process driving energy	Hydrogen production method		Material resources	Brief description
Electrical energy	Electrolysis		Water	Water decomposition into O_2 and H_2 by passing a direct current which drives electrochemical reactions.
	Plasma arc decomposition		Natural gas	Cleaned natural gas (methane) is passed through an electrically produced plasma arc to generate hydrogen and carbon soot.
Thermal energy	Thermolysis		Water	Steam is brought to temperatures of over 2500 K at which water molecule decomposes thermally.
	Thermocatalysis	H_2S cracking	Hydrogen sulfide	H_2S extracted from seas or derived from other industrial processes is cracked thermo-catalytically
		Biomass conversion	Biomass	Thermo-catalytic biomass conversion to hydrogen
	Thermochemical processes	Water splitting	Water	Chemical reactions (including or not redox reactions) are conducted cyclically with overall result of water molecule splitting.
		Gasification	Biomass	Biomass converted to syngas; H_2 extracted
		Reforming	Biofuels	Liquid biofuels converted to hydrogen
		H_2S splitting	Hydrogen sulfide	Cyclical reactions to split the hydrogen sulfide molecule
Photonic energy	PV-electrolysis		Water	PV panels generate electricity to drive electrolyzer
	Photo-catalysis		Water	Complex homogeneous catalysts or molecular devices with photo-initiated electrons collection are used to generate hydrogen from water
	Photo-electro-chemical method		Water	A hybrid cell is used to generate photovoltaic electricity which drives the water electrolysis process
	Bio-photolysis		Water	Biological systems based on cyanobacteria are used to generate hydrogen in a controlled manner
Biochemical energy	Dark fermentation		Biomass	Anaerobic fermentation in the absence of light
	Enzymatic		Water	Uses polysaccharides to generate the required energy
Electrical + thermal	High temperature electrolysis		Water	Uses a thermal source and electrical power to split water in solid oxide electrolyte cells
	Hybrid thermochemical cycles		Water	Use thermal energy and electricity to drive chemical reactions cyclically with the overall result of water splitting
	Thermo-catalytic fossil fuels cracking		Fossil fuels	A thermo-catalytic process is used to crack fossil hydrocarbons to H_2 and CO_2, whereas CO_2 is separated/sequestrated for the process to become green
	Coal gasification		Water	Coal is converted to syngas, then H_2 extracted and CO_2 separated/sequestrated (electric power spent)
	Fossil fuels reforming		Fossil fuels	Fossil hydrocarbons are converted to H_2 with CO_2 capture and sequestration (electric power spent)
Electrical + photonic	Photo-electrolysis		Water	Photo-electrodes + external source of electricity
Biochemical + thermal	Thermophilic digestion		Biomass	Uses biomass digestion assisted by thermal energy for heating at low grade temperature
Photonic + biochemical	Bio-photolysis		Biomass, water	Uses bacteria and microbes to photo-generate hydrogen
	Photo-fermentation		Biomass	The fermentation process in facilitated by light exposure
	Artificial photosynthesis		Biomass, water	Chemically engineered molecules and associated systems to mimic photosynthesis and generate H_2.

Figure 1. Depiction of different hydrogen-producing methods

1.4. ELECTROLYSIS OF WATER

The motion of electrons that are continually cycled across a separate circuit provides the energy that drives the reaction in water electrolysis which is among the simplest ways to produce practically pure hydrogen.

The Gibbs energy deviation, considered at an ephemeral scale is dG 14 Pdmihi sdT vdP, which may be used to measure the amount of work. Mi is the main chemical potentially of specie "I," and he is the degree of mols; it should be evident that the species engaged in the electrolysis are H2O, H2, and O2. Normal electrolysis happens at identical pressure and temp; as a result, the work energy transferred to the process as the flow of electrons (electric flow) is dG 14 Pdmihi. The equilibrium constant, viz is, the response's Gibbs independent energy affects the equilibria of the process.

The power supplied to a procedure among the simplest processes to produce virtually pure hydrogen is water electrolysis.

Proton exchange membrane (PEM) along with the alkaline mechanism constitute the two methods used to perform electrolysis with water. The major attributes of acidic and electrolytes from PEM systems are shown in the table. Efficacy and current densities are two crucial factors. The optimum energy and practical energy required to power the process are characterized as the electrolytic effectiveness of the cell. The amount of energy needed for the process of water splitting may be established using thermodynamics with convenience; that corresponds to the heat for the creation of liquid fluid. A portion of this energy can be delivered thermally near the temperature of the response using a surge in entropy.

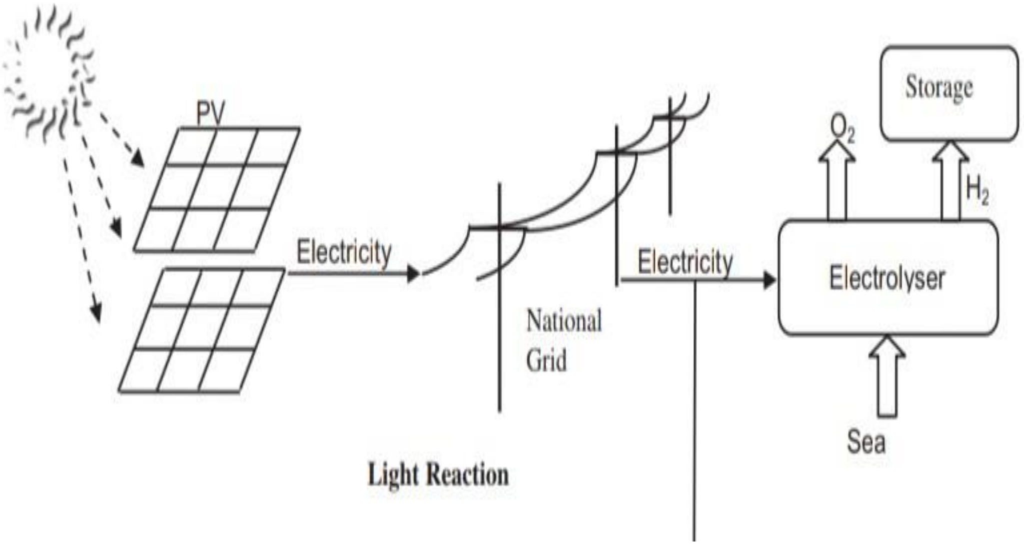


Figure 2. DEPICTION OF WATER ELECTROLYSIS FOR H2 PRODUCTION

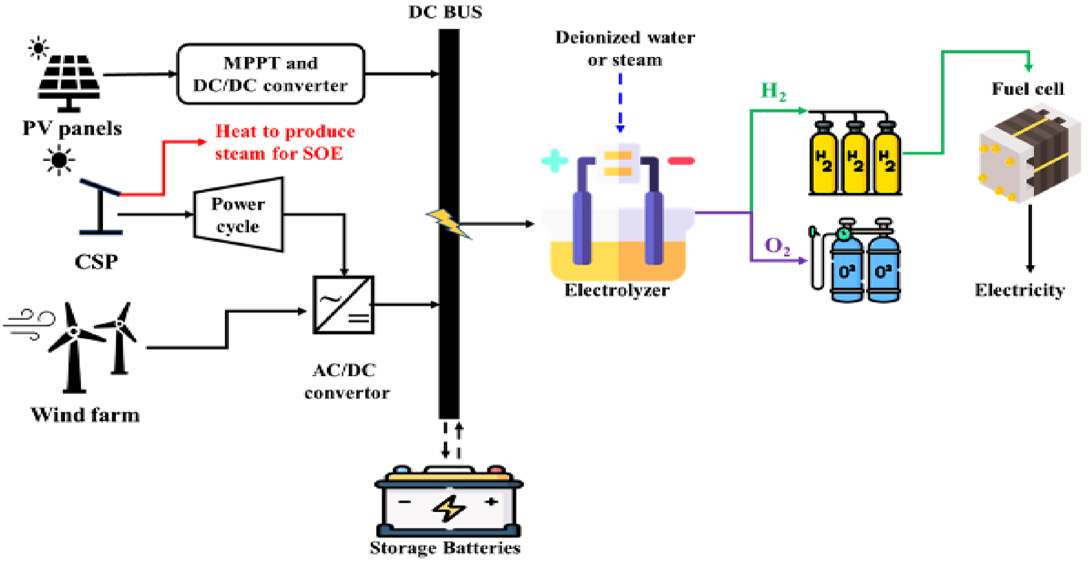


Figure 3. /WIND HYDROGEN PRODUCTION SYSTEM

1.5. HOW GREEN HYDROGEN PRODUCTION IS EFFECTIVE?

Energy consumption has significantly increased as a consequence of the worldwide population, economic growth, and urbanization expanding at an exponential rate.

The traditional pattern of energy production is dependent on the depleting hydrocarbon (fossil fuel) reserves that are geographically dispersed and difficult to extract.

Since the beginning of the industrial age, humans have been using fossil fuels as our main form of energy, which has resulted in an enormous rise in the amounts of CO2 along with additional greenhouse emissions (GHG) in the air we breathe, which are the primary contributors to the phenomenon of global warming.

Thus, for long-term energy resilience and safety worldwide, decarbonization of the energy supply through the use of alternatives such as neat, viable, and energy sources that are renewable is crucial.

Sources of energy produced from renewable sources are going to be crucial in the shift to a green and environmentally friendly energy system.

The fluctuating and sporadic character of all of these assets presents the greatest obstacle in making the move to 100% RE.

This calls for technological adjustment, particularly in terms of harmonizing the fluctuating demand and supply factors for energy.

The demand for massive systems for energy storage to handle the unpredictability and intermittency of RE sources grows as renewable energy sources become more integrated into the world's energy infrastructure.

By changing the created energy over different timelines (hourly, regularly and periodically), storage facilities have to separate supply and demand.

1.6. POWER TO X TECHNOLOGY

A zero-carbon society that can supply the increasing requirement for energy requires Power-to-X.

Power-to-X can enable carbon-neutral strategies that reduce unwanted emissions from industry, such as via catching concentrated carbon dioxide (CO2) flows from anaerobic digestion systems or biomass-fired thermal power plants thru electrolysis with CO2 reutilization.

Additionally, it provides a cost-effective solution for preserving energy.

In addition to offering a low-capital-intensive carbon reduction route to manufacture sustainable fuels and substances, regenerative power-to-X (P2X) is growing as an achievable framework for holding excess renewable energy for later dispatch towards end-use.

P2X uses surplus and unused resources from the sun and wind to drive technology that may transform readily available, plentiful compounds like water into hydrogen; Air and water combine to form hydrogen peroxide (H2O2) and ammonia, whereas CO2 and water combine to form methane, syngas, and oxy-hydrocarbons.

Such energy transporters plus chemical commodities offer a great deal of flexibility in terms of collection (to address intermittent energy supply from renewable sources), transportation, and eventual transformation to reduce carbon emissions in the power network.

Additionally, they have several benefits over other energy storage technologies now under investigation like batteries and boosted hydro, which are scale, time, and location-specific and can't be utilized to move energy across enormous distances.

Deployment of P2X innovation and goods will make it easier to incorporate green energy into numerous power-consuming industries that are important contributors to the worldwide economy, which include manufacturing, shipping, and the farming industry, essentially replacing the need for fossil fuels.

The sector-specific attachment advantages of P2X are significant because, at the moment, solely the electricity sector—which accounts for nearly a third of all global CO2 emissions—is enhancing its CO2 traces using the adoption of green energy, while the other sectors are decarbonizing more slowly.

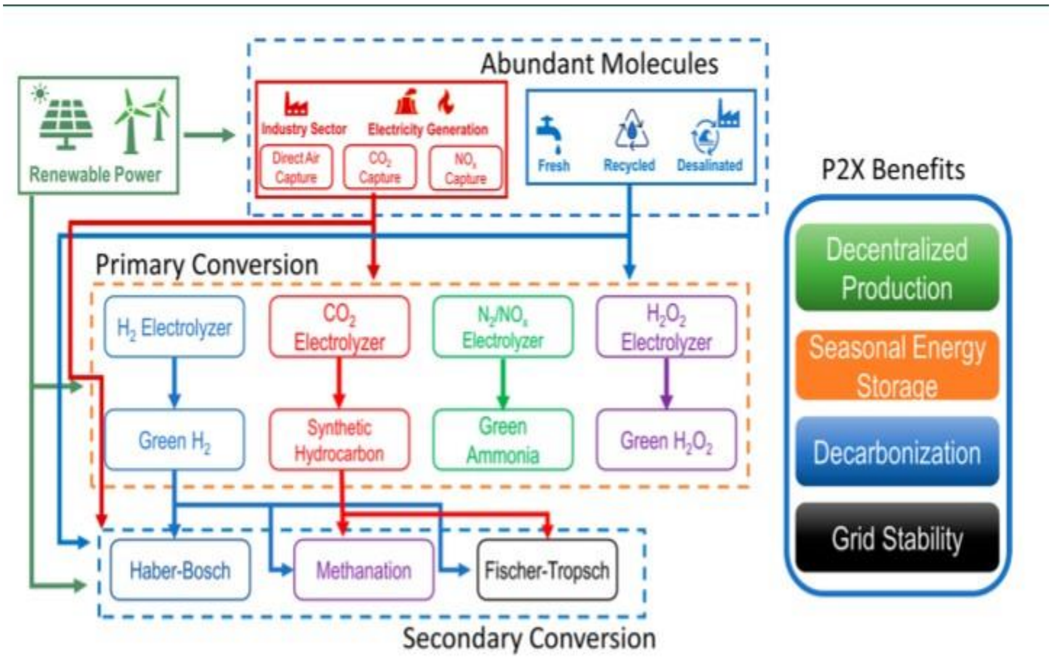


Figure 4. DEPICTION OF P2X BENEFITS AND CONVERSIONS

2. Literature Review

2.1. INTRODUCTION

The direct transmission of green energy to electrolysis, notably using solar energy (PV) and windy generator (WG) systems, has been the subject of numerous studies.

The most recent development in renewable energy sources is the creation of hydrogen (H2) using solar energy.

To examine the advantages and drawbacks of various solar energy-based hydrogen manufacturing systems, they are provided.

Numerous methods (photochemical systems, photocatalysis mechanisms, photo-electrolysis frameworks, bio-photolysis structures, the process of thermolysis systems as a whole thermochemical instalment the steam the procedure of electrolysis combination procedures, and concentrated ultraviolet (UV) systems) can be used to decompose water using sources of environmentally friendly energy to produce hydrogen.

This study provided an appraisal of the various hydrogen generation techniques centred around PV and WG technologies.

Additionally, a comparison of several electrolyzer models was provided and debated.

Lastly, a financial analysis of the generation of renewable hydrogen is presented.

The price of producing hydrogen is affected by several variables, including the use of clean energy sources, the kind of electrolysis used, the environment, the cost of setting up, and the daily manufacturing of hydrogen rate.

These wind/H2 and PV/H2 solutions are suited for distant and dry locations.

There is very minimal upkeep required, and electricity may be generated without an electricity cycle.

A complete power cycle is required for the intensified CSP/H2 system.

Utilizing wind and the generation of hydrogen is more expensive than utilizing solar and hydrogen.

Multiple uses of green energy include the manufacture of hydrogen, the operation of heating and air conditioning mechanisms, and the desalting of water.

The majority of nations have relied on the generation of energy using energy sources such as fossil fuels in the recent past.

Numerous countries have turned to alternate, clean energy sources as a result of the exponential rise in energy demand and the damaging environmental impact of fossil fuels.

A fresh power for the modern day that fosters economic growth and does away with the issues associated with present fuels may be hydrogen.

It can serve as an environmentally friendly fuel source and has been touted as a potential solution to the planet's present power and sustainability challenges.

The generation of ecologically sound hydrogen benefits the environment and has qualities of long-term growth.

Green hydrogen may be produced using sources of clean power like solar panels and wind turbines (WT).

A hybrid system as a whole that integrates the output of several different sources of power, for instance, solar and wind energy, ranks as one of those technologies with the fastest growth potential globally.

To overcome the inconsistent character of natural resources and produce pristine Hydrogen through water-based the use of electrolysis a hybrid approach has been created.

Hydrogen may be produced from a variety of materials, including water and oils.

Hydrogen is extracted from these fuels using a variety of techniques, including the use of electrolysis gas extraction, and reforming by steam.

Additionally, a power source is required for the creation of power.

Carbon dioxide is released when energy sources are converted into hydrogen, much like when those same fuels are burned to provide electricity.

Hydrogen may be produced using wind, solar, and hydropower in an environmentally friendly production chain with no releasing CO2 into the natural environment.

Because of this, the renewable energy sources that power the water's surface electrolysis operation are of relevance to people all over the entire world.

Green hydrogen may be produced using sources of clean electricity like solar panels and turbines that generate wind (WT)

A combination of technology that is one of the most rapidly changing technologies in the world.

The quantity of electricity produced by the photovoltaic (PV) array utilized for making hydrogen is substantially influenced by the weather.

The effectiveness of the photovoltaic cells is significantly impacted by fluctuations in the temperature around them.

As the ambient temperature declines, the system's total efficacy often gets better.

Whenever solar power production rose, it was discovered that the production of hydrogen increased by 10% and capital expenditure expenses by 0.1%.

The Pvd Hydrogen generation system has an electric yield that is a maximum of 14.15 ml/min.

2.2. Literature

[Mohamed Nasser 1, 2, Tamer F. Megahed 3, 4, and Shinichi Ookawara Hamdy Hassan (1, 5, 6).

In light of the impending energy renaissance plus the threat of a warming planet, the use of hydrogen is seen as a vital factor in the development of an environmentally friendly culture.

A number of the most critical chemicals on the globe, hydrogen may be produced utilizing a variety of methods with both sustainable and non-renewable sources of energy.

However, attempts to find and execute green hydrogen production pathways are greatly hampered by the requirement for a gradual switch to renewable energy sources.

As a result, the goal of this work is to present a technological evaluation of the systems for producing hydrogen from solar and wind energy using several kinds of water electrolyzers.

The current article begins with a brief introduction to the various production methods.

Following an in-depth examination of distinct kinds of water electrolyzers and a thorough explanation of solar and wind-powered hydrogen manufacturing procedures with illustrations, an economic assessment of environmentally friendly hydrogen production is offered by contrasting the expenditures of the addressed renewable energies with those of other manufacturing techniques.

Lastly, the present-day analysis sheds light on the obstacles that the aforementioned manufacturing techniques encounter.

https://doi.org/10.1007/s11356-022-23323-y]

[Hamdy Hassan, Tamer F. Megahed, and Mohammed Nasser]

Throughout this study, environmentally friendly hydrogen is produced by water electrolysis, which is done using a hybrid structure made up of solar energy systems (PV) and windmills (WT)

. The impact of five different electrical power-generating situations on the system's operation and hydrogen fabrication expenses is taken into account.

The sun irradiation, the velocity of the wind, and the temperature outside for Mersa-Matruh in Egyptian are used in this study.

During the course of a year, MATLAB-Simulink is used to study the software's functionality.

Techno-economic evaluation of environmentally sound hydrogen generation utilizing various arrangements of turbines that spin and solar panels.

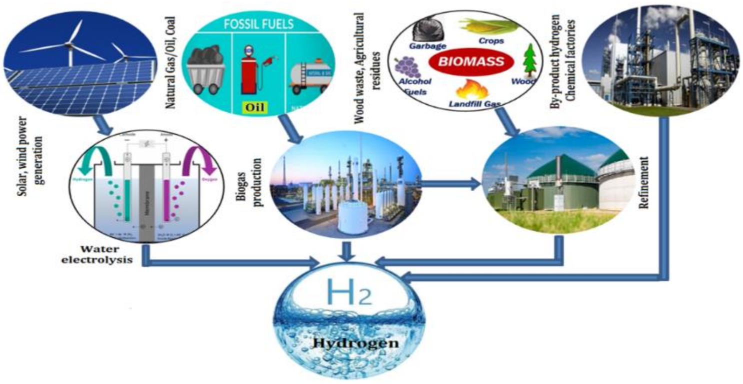
[Nasser, M., Megahed, T.F., Ookawara, S., & Hassan, H., Revue of Energies, 2022.; 6(4):

560-572, DOI: 10.30521/jes.1132111]

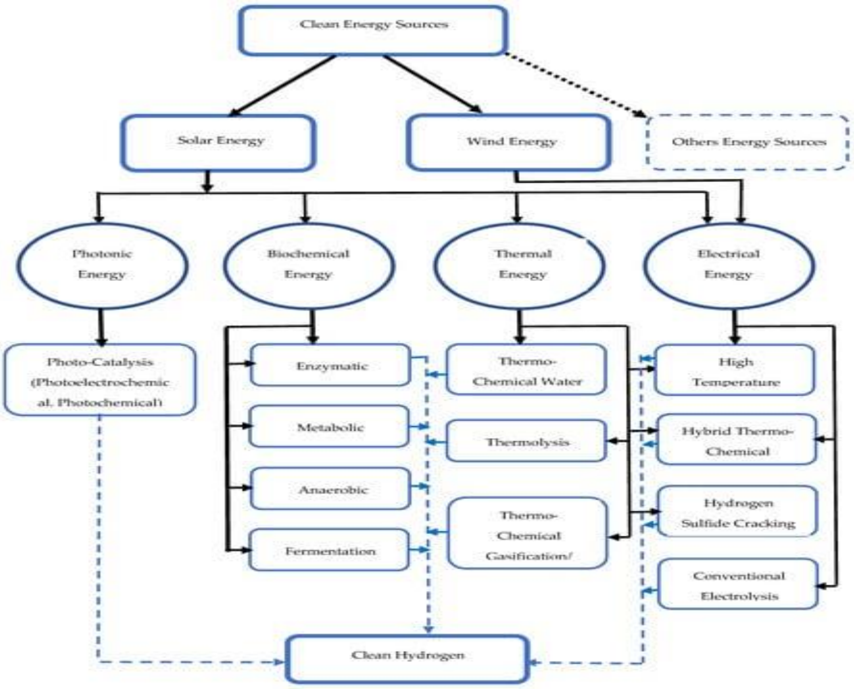
3. Methodology

3.1. METHODOLOGY

Utilizing energy from natural sources including the sun, wind, geothermal, biomass, hydropower, ocean thermal energy, tidal, wave, and nuclear radiation, there exist several techniques that allow for the synthesis of hydrogen through the thermal breakdown of water. The manufacture of hydrogen from wind and solar power is the main focus of the current effort. The processes for producing hydrogen described above are summarized in Figure.



The methods for producing pure hydrogen from pure sources are shown in Figure.



3.2. Mechanism for PV-Electrolysis

As seen in Figure, this structure is made up of solar cells that generate the electrical power needed to run the electrolytic unit.

According to the illustration, electrolysis is an electrolytic water-splitting technique that enables water, or H_2O, to break down into hydrogen and oxygen (O_2) gas.

H_2 and O_2 ions move through water as well and end up at the anode and cathode electrodes, respectively.

The generated H2 may be used for a variety of purposes, including applications in fuel cells including welding when combined with O2.

This process generates considerable quantities of pure hydrogen without harming the surroundings.

Solar-generated electricity powers the process of producing hydrogen as well.

Given that the efficacy of the electrolytic systems is now close to seventy-five per cent the goal is to increase it to more than ninety per cent.

When renewable energy sources are used to generate electrical energy, the electrolyzers create hydrogen without emitting any gases.

A three-junction solar panel and 2 electrolysis (PEM) modules are connected in series to form the PV-electrolysis apparatus shown in Figure.

A water-based cooling system was employed to chill the cell until it reached an ambient temperature of 25 degrees Celsius.

A xenon arc lamp was then used for illuminating the cell beneath a sun simulator that produced white light, simulating irradiation from the sun.

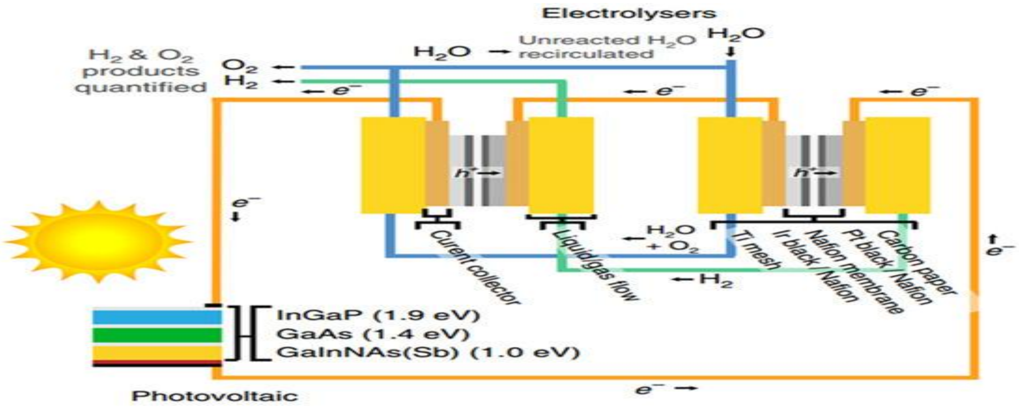


FIGURE- Depiction of PV electrolysis apparatus

The photovoltaic cell was bifurcated in series alongside the two electrolysis modules.

The initial electrolysis section's anode compartments received water via a pumping mechanism, but the cathode section received no input stream at all.

Water and oxygen from the first electrolysis section's anode section moved into the next electrolysis section's anode chamber.

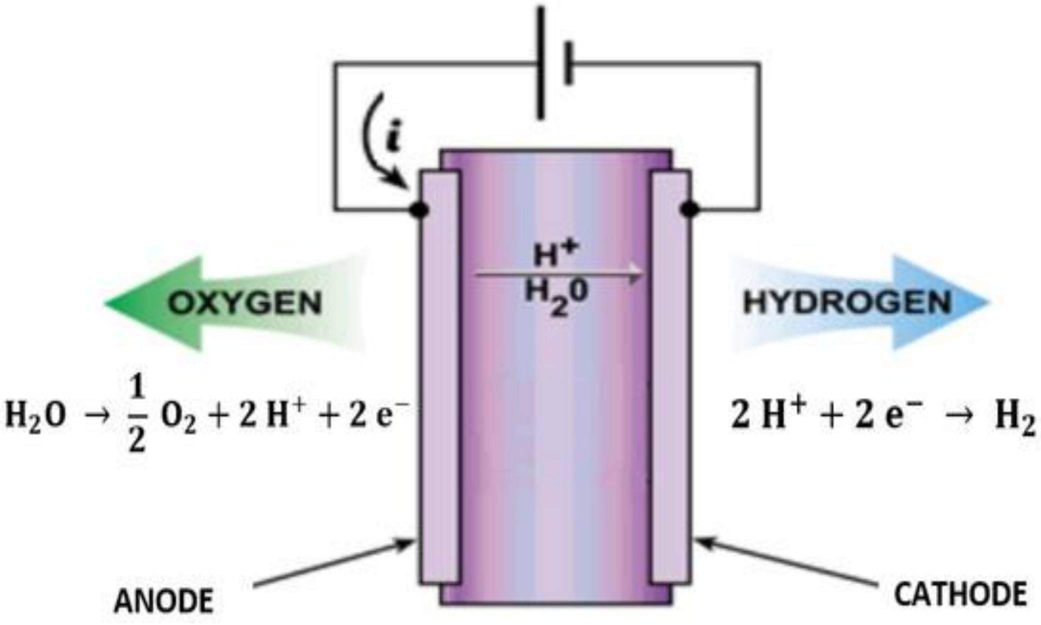


FIGURE- Depiction of electrolysis of water

H2 passed from the first electrolysis section's cathode side onto the secondary electrolysis unit's cathode side.

The residual water had been gathered in the tank and subsequently recycled back into the system together with the H2 and O2 that were created from the subsequent electrolysis cell.

The electrolysis unit had a set temperature of approximately eighty °C, which matched the norm for professional water electrolysis.

4. Results

4.1. Results from Simulink Model:

4.1.1. File name saved with Start_Up:

The following code is typed in MATLAB to insert the data, images, parameters and physical components in the Simulink model. Data, parameters and some physical components of solar power and electrolyzer have a separate file which needs to be inserted in this model. Figures are also needed for the visibility of the solar power and electrolyzer. Therefore, the reason is clear from this that bellow gave code need for whole these above necessity.

```
%%% Add path to all sub-folders

Add path(cd,'data\');

Add path(cd,'images\');

Add path(cd,'parameters\');

Add path(cd,'physical_components\');

%%% Execute the parameter file

Parameter_File;
```

4.1.2. Solar

Figure 7. Solar Panel

4.1.3. MPPT CODE:

The MPPT code is applied here due to the maximum power point tracking and then use this power in the electrolyser. Same as above, this code is written in MATLAB to get maximum power. The methodology used for this system is Perturb & Observe algorithm.

```
function D =PandO(Param, Enabled, V, I)

% MPPT controller based on the Perturb & Observe algorithm.

% D output = Duty cycle of the boost converter (value between 0 and 1)

% Enabled input = 1 to enable the MPPT controller

% V input = PV array terminal voltage (V)
```

```
% I input = PV array current (A)
% Param input:
Dinit = Param (1); %Initial value for D output
Dmax = Param (2); %Maximum value for D
Dmin = Param (3); %Minimum value for D
delta = Param (4); %Increment value used to increase/decrease the duty cycle D
% (increasing D = decreasing Vref)
persistent VoldPoldDold;
dataType = 'double';
if is empty(Vold)
Vold=0;
Pold=0;
Dold=Dinit;
end
P= V*I;
dV= V - Vold;
dP= P - Pold;
 if dP ~= 0 &Enabled ~=0
%     if dP>1e-9  &dP<-1e-9 & Enabled ~=0
    if dP< 0
        if dV< 0
            D = Dold - deltaD;
        else
            D = Dold + deltaD;
        end
    else
        if dV< 0
            D = Dold + deltaD;
        else
            D = Dold - deltaD;
        end
    end
else D=Dold;
end
if D >= Dmax | D<= Dmin
    D=Dold;
end
Dold=D;
Vold=V;
```

```
Pold=P;
```

The following given figure used in the function block for justification of the MPPT block.

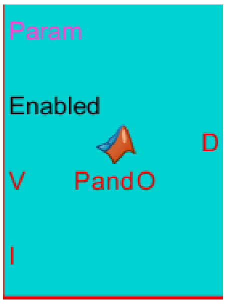


Figure 8. MPPT Function Block.

4.1.4. Block diagram of the system:

In the following given figure, a diagram of this thesis is shown, which is used as a base system diagram for the Simulink model.

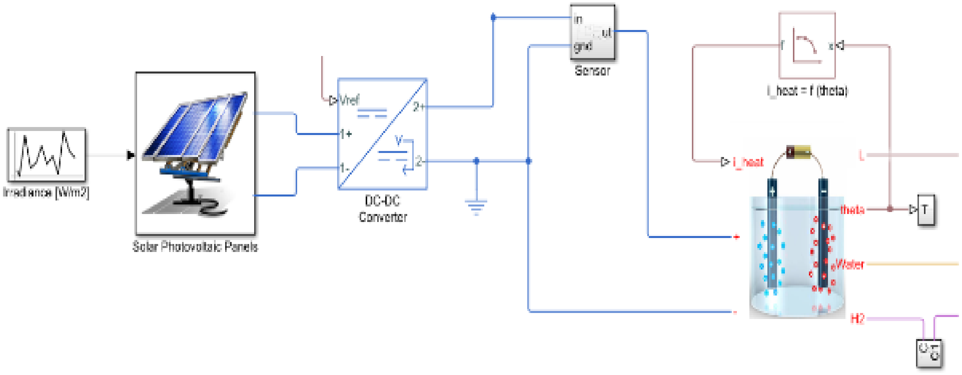


Figure 9. Proposed System block diagram

4.1.5. Parameter_File.mfile coding for parameter:

```
%%%% Data for properties of hydrogen
load('h2_data.mat');
%%% Hydrogen properties (Semiperfect)
T_vect = [-75 -50 -25 0 25 50 75 100]+273.15; %K
h_vect = [2532 2875 3224 3578 3936 4295 4655 5017];%kJ/kg
nu_vect = [6.77 7.34 7.88 8.42 8.94 9.44 9.93 10.41]; %s*uPa
cond_vect = [132.4 146.8 160.5 173.4 185.6 197.5 210.1 222.0]; %mW/kg/K
cp_vect = [13.57 13.87 14.08 14.23 14.33 14.4 14.45 14.47]; %kJ/kg/K
%%% Hydrogen properties (Perfect)
R_h2 = 4.12; %kJ/kg/K
h_h2 = h_vect(5); % kJ/kg;
cp_h2 = cp_vect(5); %kJ/kg/K
nu_h2 = nu_vect(5); %s*uPa
cond_h2 = cond_vect(5); %mW/m/K
```

Sdfsf:

```
%%% Hydrogen Properties
Hydrogen_Prop_File;
%%% Solar Data
load('solarProfile.mat');
%%% Thermodynamic Energy
TDS = 48.7e3;                % Entropy Reaction (@298K)
DH = 285.8e3;                % Enthalpy Water (@298K)
theta0 = 298;               % Reference Temperature (K)
dT_setpoint = 8;
%%% Stack Properties
Plate.X = 50; %cm
Plate.Y = 100; %cm
Plate.Z = 100; %cm
Electrolyzer.Np_electrodes = 3; %pair
Electrolyzer.N_cell = 50;
Electrolyzer.Temp_vect = linspace(273.15, 353.15, 5);
Electrolyzer.Efficiency_vect = space(0.55,0.9,5);
Electrolyzer.AreaMembrane = (Plate.Y*Plate.Z)*Electrolyzer.Np_electrodes;
Electrolyzer.Xd = 2.0; %cm
%%% Tank Properties
Tank.Area = (Plate.X*Plate.Y)*Electrolyzer.Np_electrodes;
Tank.Volume = Tank.Area*(Plate.Z*1.25);
H2_Tank.Volume = 100*100*100; %cm^3
H2_Tank.T_storage = 273.15;
%%% Electric Properties
Electric.Resistance = 0.25; %Ohm
Heat.Resistance = 25; %Ohm
%%% DC-DC converter Properties
DCDC_converter.I_vect = [0, 400, 1000];
DCDC_converter.eff_vect = [90, 95, 98];
Solar.Area = 25*25; %m^2
Temp_vect_heat = [0 50 75 100]+273.15;
I_vect_heat = [100 75 0 0];
%%% Control Parameters
Control.InitVoltage = 100;
Control.Slope = 750/(10*60);
Control.T_filter = 30;
Control.Vnom = 1000;
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%% Parameters used for green_hydrogen_Battery model
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
irradiance = 1000;
temperature = 25;
Ts = 10;
Ts_Control = 1;
%%% Battery Data
Battery.Qn = 50000;
Battery.Qinit = 50000;
Battery.Q1 = Battery.Qn*0.5;
Battery.Rs = 0.2;
Battery.Un = 240;
Battery.U1 = 210;
Operation_Ref.Ie = [100 95 75 12.5 12.5];
Operation_Ref.Isolar = [0 500 700 750 1000];
Converter.Iout = [40 80 120];
Converter.Efficiency = [95 98 100];
```

4.1.6. Hydrogen_Prop_File.mfile coding for parameter:

```
%%%% Data for properties of hydrogen
load('h2_data.mat');
%%% Hydrogen properties (Semiperfect)
T_vect = [-75 -50 -25 0 25 50 75 100]+273.15; %K
h_vect = [2532 2875 3224 3578 3936 4295 4655 5017];%kJ/kg
nu_vect = [6.77 7.34 7.88 8.42 8.94 9.44 9.93 10.41]; %s*uPa
cond_vect = [132.4 146.8 160.5 173.4 185.6 197.5 210.1 222.0]; %mW/kg/K
cp_vect = [13.57 13.87 14.08 14.23 14.33 14.4 14.45 14.47]; %kJ/kg/K
%%% Hydrogen properties (Perfect)
R_h2 = 4.12; %kJ/kg/K
h_h2 = h_vect(5); % kJ/kg;
cp_h2 = cp_vect(5); %kJ/kg/K
nu_h2 = nu_vect(5); %s*uPa
cond_h2 = cond_vect(5); %mW/m/K
```

4.1.7. Green_H2_Battery_Solar1 = Proposed system:

File diagram of Green_H2_Battery_Solar.sex

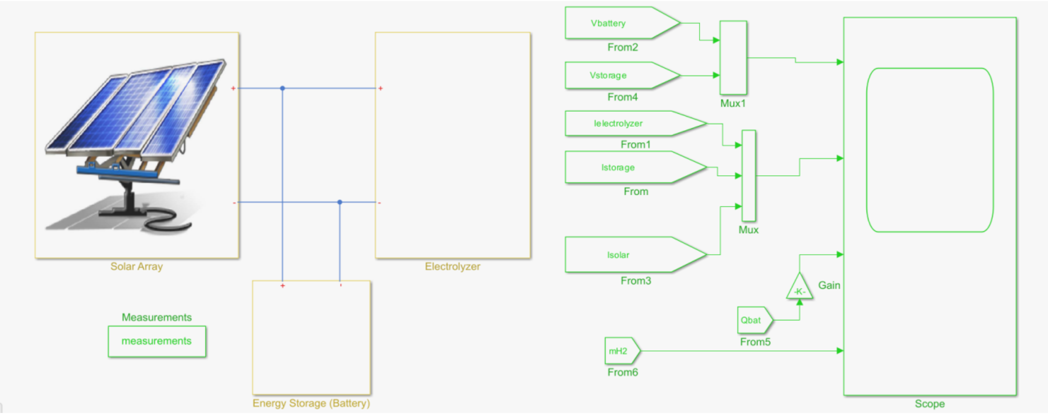


Figure 10. Matlab System model

4.1.8. Simulation procedure:

Run the Start_Up file.

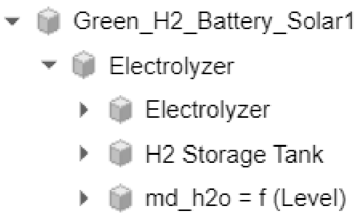
Start_Up can automatically run Parameter_File.m and Parameter_File.m

This is done by the parameter assigned in Matlab.

Now run Green_H2_Battery_Solar.slx file

The results are the following.

4.1.9. Results parts:


- Green_H2_Battery_Solar1
  - Electrolyzer
    - Electrolyzer
    - H2 Storage Tank
    - md_h2o = f (Level)

Part 1:

This figure shows the Electrolyzer outputs in the graphical waveform.

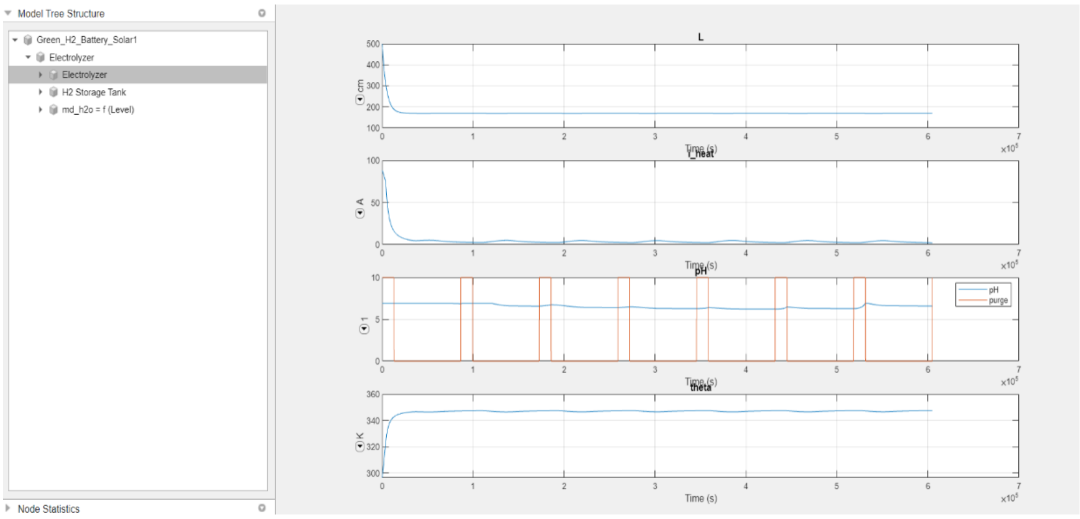


Figure 11. Waveform for Electrolyser

Part. 2:

This figure shows the hydrogen tank outputs in the graphical waveform. This tank stores the hydrogen gas.

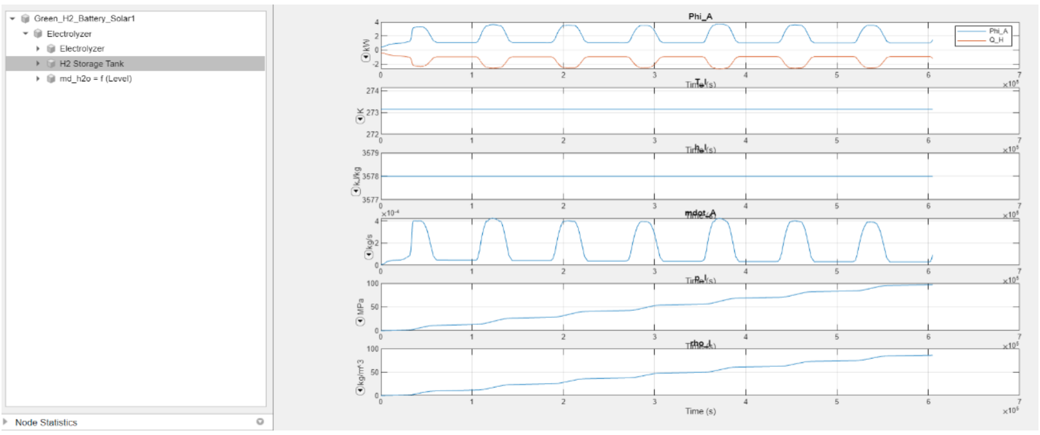


Figure 12. Waveform of H2 Storage Tank.

P3:

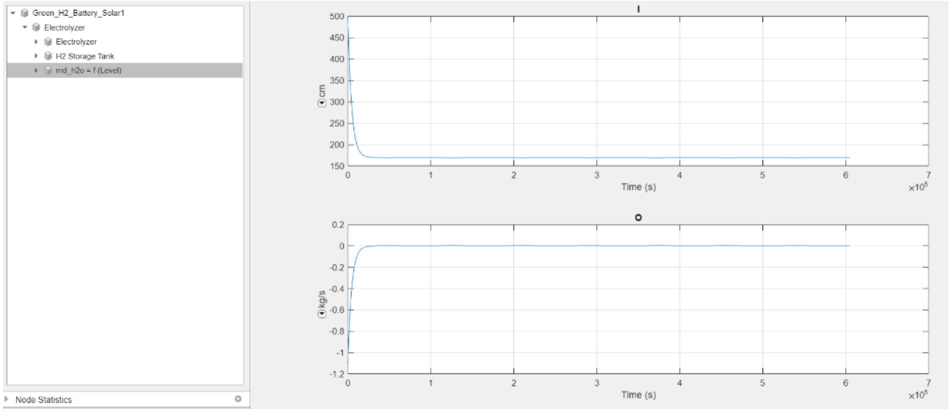


Figure 13. the waveform of md h2o.

4.1.10. Scope:

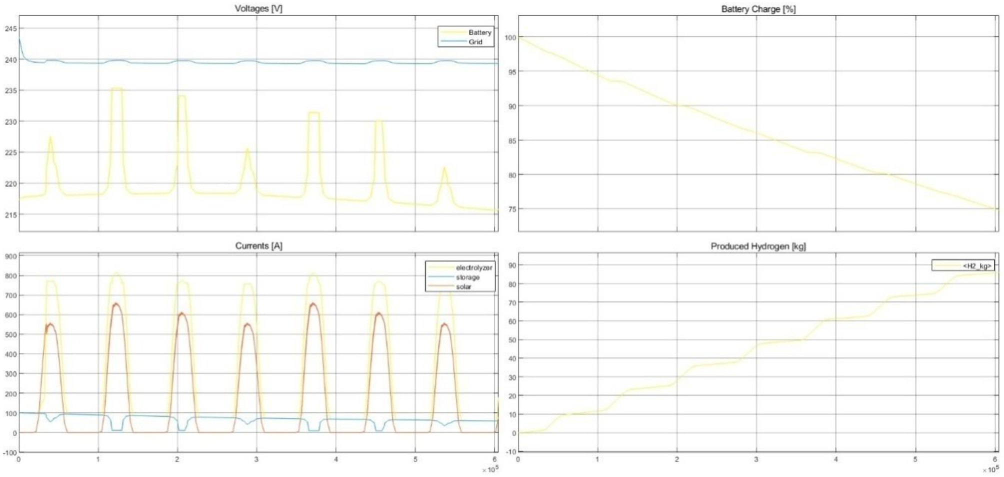


Figure 14. the waveform of voltage, current of Solar.

4.1.11. Solar Array:

This figure shows the SIMULINK model.

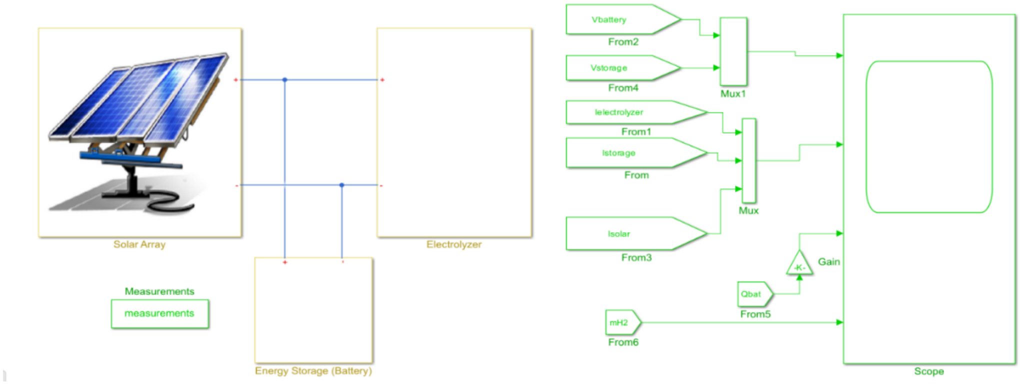


Figure 15. Proposed System block diagram

4.1.12. Energy Storage (Battery):

The following system shows about extra power storing method in the battery system. The purpose of this system is to save unnecessary power in the battery and also to give the same power in the form of input to the electrolyzer.

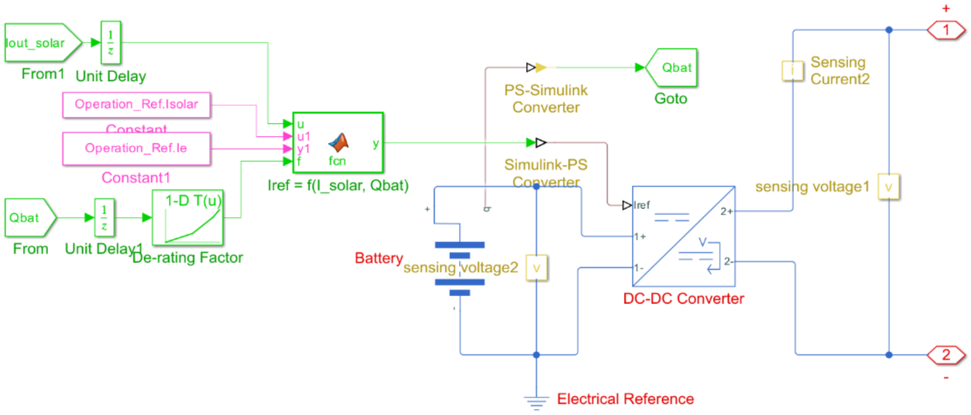


Figure 16. Battery storage System.

4.1.13. Electrolyzer:

An electrolyzer using a solar array and an energy storage system.

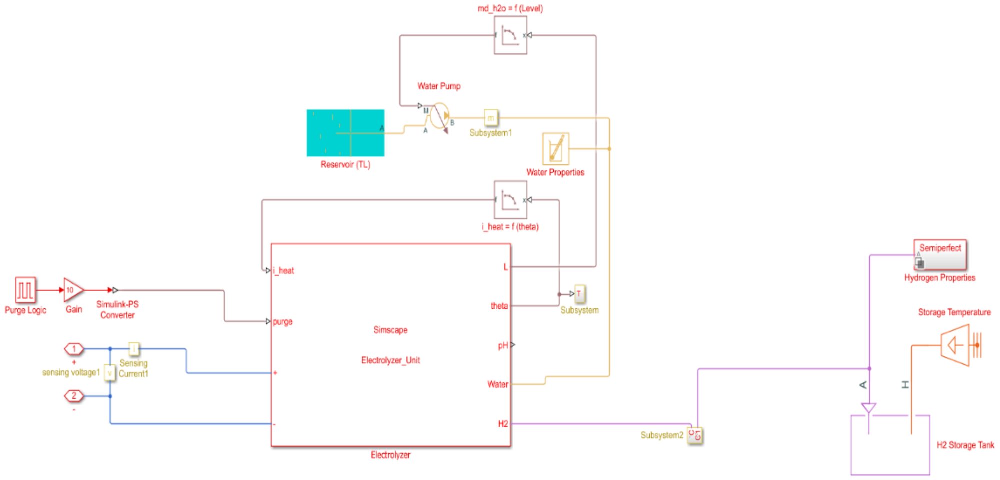


Figure 17. Storage system for Electrolyser

5. Discussions and Conclusions

This is a model of a DC microgrid that uses an array of solar panels and a system for energy storage to power an electrolyzer. With the use of a solar array alone or in conjunction with an energy storage system, this model may be used to assess the operative features of creating hydrogen that is green over 7 days. The electrical, thermal liquid and thermal gas domains are all included in the model. A time-series data irradiance input that is defined over 24 hours is what powers this solar array. A 'perturb and observe' greatest electricity-Point Tracking (MPPT) algorithm controls an average-value buck/boost converters to make sure that the electrolyzer receives the greatest amount of electricity from the photovoltaic array.

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