Improve performance of Solar based Hydrogen Tank Pressure System by Fuzzy Logic Controller

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***Abstract*:- In this thesis, we investigates the energy storage technologies that can potentially enhance the use of solar energy. PV cells convert the sun electromagnetic rays into electrical energy .Convert electrical energy goes to the electrolyzer which separate the H_2 and O_2 ions and then store it in different tank for future use . The main comes for hydrogen storage . As we know gas take more volume as compare to solid and liquid . So it is difficult to transport the H_2 due to high volume .So we have to compress the H_2 at high pressure tank so that H_2 convert into liquid and can easy to transport . Water electrolysis systems are seen as the principal means of producing a large amount of hydrogen in the future. Starting from the analysis of the models of the system components, a complete simulation model was realized in the Matlab-Simulink environment. In this research we are improving the performance of the hydrogen Tank storage. We are improving the hydrogen storage tank pressure by use Fuzzy logic . As the pressure of the H_2 tank get increase it get easy to transport and in storage also .**

Keywords—Electrolyzer, Fuzzy logic ,PID controller Simulink, solar energy, storage system.

I. INTRODUCTION

The sun as the originator of all living creatures needed many millions of years to create the fossil energy materials, but mankind has almost totally used up all this materials within a period of less than two hundred years. Now, the human intelligence has progressed to be capable of utilizing the sun energy directly. The reached sun energy to our global are exceed the world Energy consumption for approximately 6000 fold [2]. According to scientific studies the total of all oil resources of the world will be exhausted within 40 to 50 years [3]. Also the nuclear energy will not cover the world demand of the future in addition to the problems of its waste disposal hazards. The biggest energy source represents the sun which mainly emits its energy by electromagnetic waves onto the earth. Its solar constant amounts 1353W/m2 [4], [5]. The solar constants indicate the performance which reaches a surface of one-square meter, situated externally of the earth atmosphere, which shows vertical to the emission direction. Every day the sun radiates, or sends out an enormous amount of energy. As matter of fact the sun radiates more energy in one second than all the human have used since the beginning of time [1]-[5]. To convert sun energy into electrical energy solar cells have proved to be excellent. Their factor of expenses has considerable decreased through the mass production. Most economical are those cells which possess an efficiency of approximately 25%. Conversion of solar energy to chemical free energy in the form of molecular hydrogen and oxygen is attractive because the products are stable, versatile, and nonpolluting. Hydrogen gas is so much lighter than air that it rises fast and is quickly ejected from the atmosphere. This is why hydrogen as a gas (H_2) is not found by itself on Earth. It is found only in compound form with other elements. Hydrogen combined with oxygen, is water (H_2O). Hydrogen combined with carbon forms different compounds, including methane (CH_4), coal, and petroleum. Hydrogen is also found in all growing things for example, biomass. It is also an abundant element in the Earth's crust. Hydrogen has the highest energy content of any common fuel by weight (about three times more than gasoline), but the lowest energy content by volume (about four times less than gasoline) [6]. It is one of the most promising alternative fuels for the future because it has the capability of storing energy of high quality and it is in accordance with a sustainable development. Hydrogen has therefore been visualized to become the cornerstone of future energy systems based on solar energy and other renewable energy sources [7].

The concept of using hydrogen as an energy carrier in storage and transport of energy, i.e., the so-called hydrogen economy, has therefore been studies by many scientists. It is also this author's belief strongly that particular attention should be paid to hydrogen energy based systems. Hydrogen can be produced chemically from hydrocarbons (e.g., renewable fuels such as methane, ethanol, or methanol), but this will not be considered. A more attractive option is to produce hydrogen from water via water electrolysis, simply because of the abundance of water on earth. The basic chemical reaction for splitting water in hydrogen and oxygen is

$$H_2 + energy \rightarrow H_2 + \frac{1}{2}O_2 \qquad \ldots\ldots(1)$$

For this reaction to occur, an amount of energy must be added, while the opposite reaction releases energy. The oxygen in water electrolysis in last equation is usually release to the atmosphere, but may be stored in an artificial structure as well. Thus, in theory, if hydrogen is produced from natural energy resources the hydrogen cycle is 100% environmentally benign energy cycle, because solar energy for all practical purposes can be regarded as an infinite source of energy, the hydrogen cycle is one of the best options for a sustainable future. Since water is one of the most abundant resources on earth, covering three fourths of the earth's surface.

A. Solar Energy Storage System

Since electrical energy is capable of performing chemical work, it is possible to split the molecules of normal water into the two gases namely Hydrogen and Oxygen. Hydrogen can be produced from solar energy and water by water electrolysis. Although the photo electrochemical (PEC) methods for direct water splitting are being developed, the technically most viable path is by coupling a PV photovoltaic module or array to an electrolyze [8], [9]. Most of the industrial electrolyzes used today in capacities up to several thousand m3/hr are used on alkaline [koh] electrolyte. Electrolyzes using a polymer, proton-conducting membrane (PEM) as the electrolyte, are being developed, particularly for small-scale hydrogen generation [9]. In PV powered hydrogen generation systems performance is limited by the efficiency of PV's conversion of solar energy to electrical energy, which in commercial devices is about 15%. Conversion efficiencies of newly developed multi-junction PV cells reached up to 42% [8]. One of the important issues in photovoltaic/electrolysis (PV/EL) hydrogen generation systems is maximum power transfer problem between two devices at different irradiance conditions. A typical PV system, maximum power points MPP change with irradiance and temperature. Usually, in directly connected systems, there is a mismatch between input PEM electrolysis I-V characteristic and output PV's MMP characteristic. To overcome this problem, PV/EL systems are usually supported with additional MPP tracker power electronic control device. To operate at the MPP, the MMP tracker device sets optimum impedance harmony between PV and EL system in response to irradiance variations. However, this causes additional cost and complexity of a number of smaller units-cells, which can be connected in series and/or in parallel. With appropriate sizing optimization approaches of both PV and EL it is possible to directly connect these two systems.

A more effective, optimum sizing strategy of both devices is proposed for MPP natural tracking at a wide irradiance interval in directly connected PV/EL hydrogen generation systems. By this way we achieve a stored solar energy which is even transportable Fig. 1 shows the proposed system. The main components of the system include a PV-generator, an electrolyzer, and a hydrogen storage (compressed gas).

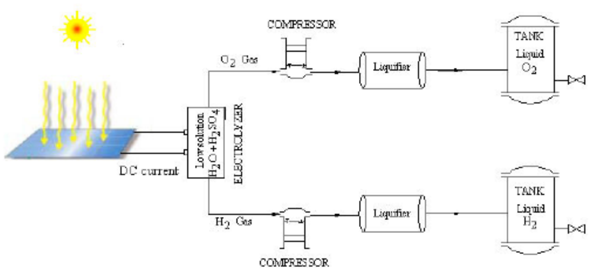

Figure 1:- Schematic of solar-energy storage system

This type of energy storage provides significant advantages when compared to conventional batteries in terms of energy density and long-term storage. By using an electrolyzer, hydrogen conversion allows both storage and transportation of large amounts of power at much higher energy densities. Thus, hydrogen generation can lead a pathway for solar-based energy generation to contribute directly to reducing the dependence on fossil fuel.

B. Hydrogen Economy

Hydrogen is ecologically beneficial. Its combustion doesn't release carbon dioxides and sulfur dioxides are also not created. The only by-product is simple vapor. As well there is no radioactivity produced. Hydrogen is absolutely nonpoisonous. One kilogram of hydrogen releases at its combustion 33kW/h electrical energy. This is the threefold of energy of benzene. In principle, then one can an envision an energy economy in which hydrogen is produced from water and electrical energy, is stored until it is needed, is transmitted to its point of use and there is burned as a fuel to produce electricity, heat or mechanical energy. Hydrogen can be transmitted and distributed by pipeline in much the same way that natural gas is handled today. The movement of fuel by pipeline is one of the cheapest methods of energy transmission; hydrogen pipeline would be no exception. A gas-delivery system is usually located underground and is therefore inconspicuous. It also occupies less land area than an electric-power line. Hydrogen can also be stored in a huge quantities by the very same techniques used for natural gas today.

C. Simulink Modeling Solar Energy Storage System

Each physical component of the proposed system is modeled as a separate component subroutine and Simulink block for a modular system simulation program. All of the developed models are based on physical and chemical principles, as well as empirical parameters. The models have been designed to be as general as possible and all the blocks take both design parameters, (such as number of cells in series and/or parallel) and specific component characteristics obtained from manufacturers (such us current-voltage curve) into account. Simulink offers the advantage of buildings hierarchical models, namely to have the possibility to view the system at different levels. Thus each block can contain other blocks, other levels.

D. Modeling of PV Panel

The mathematical model of the photovoltaic (PV) generator is based on the one-diode equivalent circuit [9] as shown in Fig. 2.

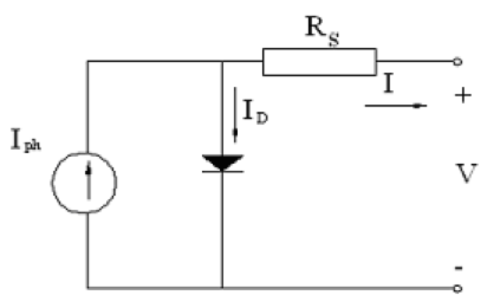

Figure 2:- Model for a single solar cell

The relationship between the current I and the voltage V of the equivalent circuit can be found by equating the light current I_{ph}, diode current I_D, to the operation current I as follows:

$$I = I_{ph} - I_D = I_{ph} - I_{sat}\left[e^{\frac{q(V+IRs)}{nkT}} - 1\right] \quad \ldots\ldots(2)$$

where I_{ph} the light current [A], I_{sat} the diode reverse saturation current [A], Rs, the series resistance [M], V the operation voltage [V], and I the operation current [A].

q = charge of one electron(1.602 $* 10^{-19}$ C),
η = Diode idealizing factor , and
ƙ= Boltzman's Constant (1.38 $* 10^{-23}$ J/K),
T = Junction temperature in Kelvin.

When the PV module operates at its maximum power point, the produced power is given by,

$$P_{max} = V_{max} * I_{max} = \gamma * V_{o.c} * I_{s.c} \quad \ldots\ldots(3)$$

where V_{max} and I_{max} are terminal voltage and output current of PV module at maximum, power point (MPP), and γ is the cell fill factor which is a measure of cell quality.

The energy output in the form of current is directly proportional to the energy input in the form of solar irradiation. There is a small temperature coefficient, α_{sct} on the order of a few milliamps per degree Celsius to account for temperature differences recognized empirically.

$$I_{ph}\,(G,T) = I_{scs} * \frac{G_a}{G_{as}} + \propto_{scT}\,(T - T_s) \qquad \ldots\ldots(4)$$

where:
I_{scs} = Short circuit current at standard test condition
G_α = Solar irradiance (w/m^3)
$G_{\alpha s}$ = Solar irradiance at standard test Condition (1000 W/m^3)
T = Cell Temperature (^{0}C)
T_s = Cell Temperature at standard test condition (25^{0}C)

The open circuit voltage under given environmental conditions is calculated as follows:

$$V_{OC}\,(G,T) = V_{OCs} + \beta_{o.c.T}\,(T - T_s) + \frac{kT}{q}\,In\left(\frac{I_{mpp}}{I_{scs}}\right) \qquad \ldots\ldots(5)$$

V_{ocs} = Open-circuit voltage at standard test condition
β_{oct} = Temperature coefficient of open - circuit voltage
I_{mpp} = Current at MPP

Under open Circuit condition :

$$I_{ph}(G,T) = I_D(G,T) \qquad \ldots\ldots(6)$$

But

$$I_D\,(G,T) = I_{sat}(G,T) * [[e^{\frac{V_{o.c}}{v_t}} - 1\,] \qquad \ldots\ldots(7)$$

$$I_{saT}(G,T) = \frac{I_{ph}(G,T)}{e^{\frac{V_{o.c}(T)}{V(T)}} - 1} \qquad \ldots(8)$$

$$V_t(T) = \frac{AkT}{q} \qquad \ldots\ldots(9)$$

The previous equations have been translated into the Simulink diagram shown in Fig. 3 and the masked model shown in Fig. 4

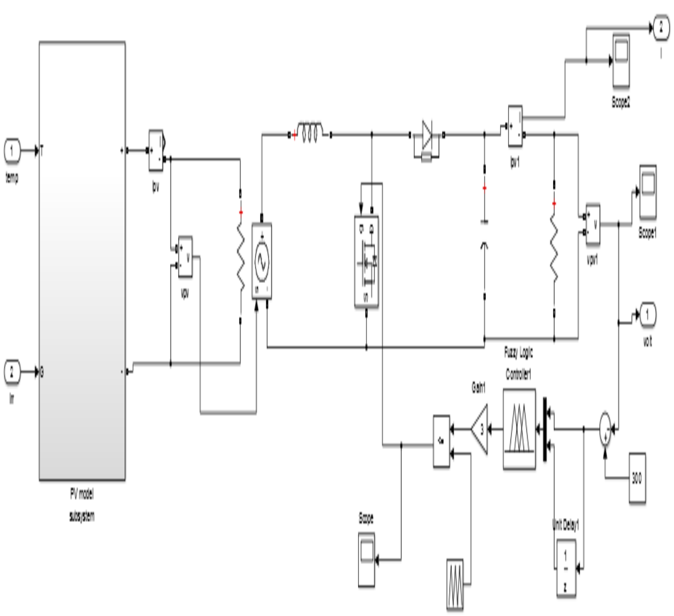

Figure 3:- Subsystem implementation of generalized PV model

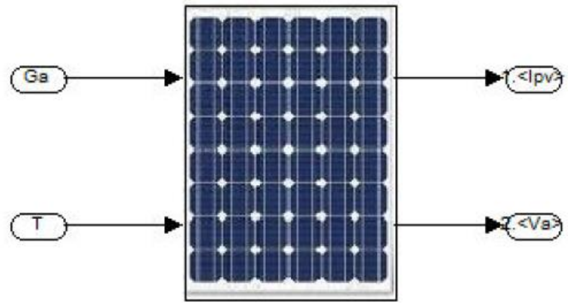

Figure 4:- Masked implementation of generalized PV model

The Simulink implementation of the PV module, illustrated in Fig. 3, is used to perform a simulation of the PV module for different values of irradiation and cell temperature.

E. Electrolyzer Model

An electrolyzer is a well known electrochemical device utilizing electrical current to decompose water into hydrogen and oxygen. It consists of several electrolyzer cells connected in series. The current in comparison to voltage feature of an electrolyzer depends on its working temperature [10] according to Faraday's law, the production rate of hydrogen in an electrolyzer cell is directly proportional to the transfer rate of electrons at the electrodes, which in turn is equivalent to the electrical current in the circuit expressed in the following equation,

$$\eta_{H_2} = \frac{\eta_F . n_n . i_e}{2F} \qquad \ldots(10)$$

η_{H2} = Hydrogen Production rate , mol s^{-1}
η_F = Faraday's Efficient
η_c = the number of electrolyzer cell in series
i_e = Electrolyzer current [A]

The ratio between the actual and the theoretical maximum amount of hydrogen produced in the electrolyzer is known as Faraday efficiency. Assuming that the working temperature of the electrolyzer is 40 °C, Faraday efficiency is expressed by:

$$\eta_F = 96.5 * \left[e^{\frac{0.09}{i_e} - \frac{75.5}{i_e^2}}\right] \qquad \ldots(11)$$

According to (8) and (9), a simple electrolyzer model is developed using Simulink, which is shown in Fig. 12.

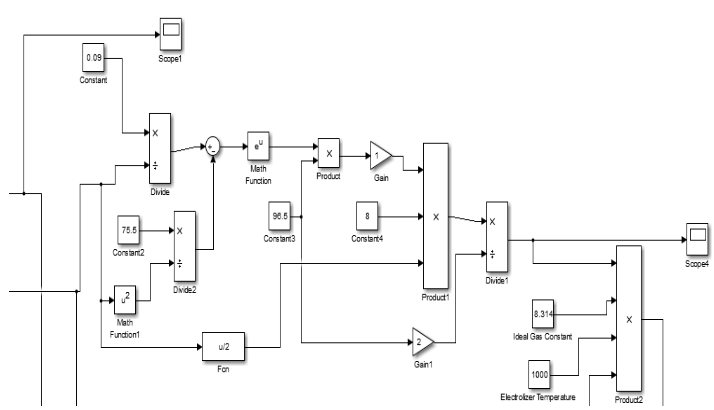

Figure 5 The Simulink diagram of the electrolyzer model

F. Hydrogen Storage Model

One of the hydrogen storage techniques is physical hydrogen storage, which include using tanks to store either compressed hydrogen gas or liquid hydrogen. The produced hydrogen storage is stored in the tank whose system dynamics can be expressed as follows:

$$P_b - P_{bi} = z * \frac{NH_2RT_b}{MH_2V_b} \quad \ldots\ldots(11)$$

P_b = Pressure of tank (pascal)
P_{bi} = Initial pressure of the storage tank(pascal)
R = universal (rydberg) gas constant(J/kmol K)
T_b = Operating temperature (K)
V_b = Volume of the tank _w5$
Z = Compressibility factor as a function of the pressure,
$Z = \frac{PV_m}{RT}$, P = Pressure , V_m= Molar Volume
T = Temperature

This model directly calculates the tank pressure using the ratio of hydrogen flow to the tank. All auxiliary power requirements such as pumps, valves, fan and compression motor were ignored in the dynamic model, the simulink model of the hydrogen storage is depicted in Fig. 6.

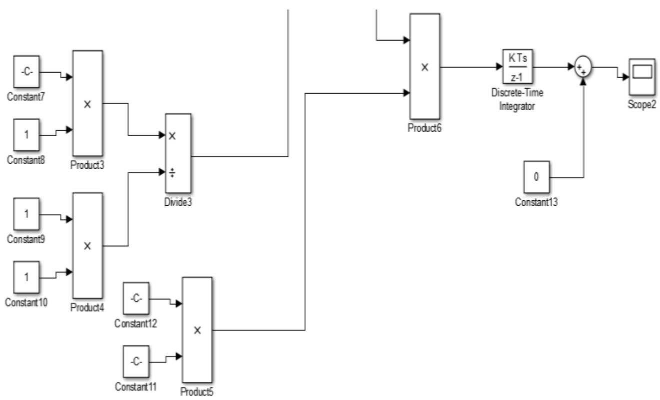

Figure 6 :- Simulink model of the hydrogen storage system

II. PROBLEM STATEMENT

The previous paper investigates the energy storage technologies that can potentially enhance the use of solar energy. Water electrolysis systems are seen as the principal means of producing a large amount of hydrogen in the future. Starting from the analysis of the models of the system components, a complete simulation model was realized in the Matlab-Simulink environment. In the previous paper , they show the solar output current and power which is using in electrolyzer for electrolyze the H2 and O2 molecule. They show the hydrogen tank storage pressure . In this thesis we have to increase the hydrogen tank pressure . So we find below mention problem

A. Problem 1:- Increase Hydrogen storage tank pressure

In the previous paper , as we can see the hydrogen storage tank pressure is low . As per gas and liquid theory as the pressure get increase of the Gas then it will be convert into liquid form. So liquid hydrogen is easy to transport it from one place to another place. So in this thesis, we have to improve the hydrogen storage tank pressure so that maximum hydrogen gas can be change into liquid . Solar is using for given spark to electrolyzer. In the previous paper model, battery is replace by solar model.

III. PROPOSED METHODOLOGY

For improve the performance of the system, we have to increase the hydrogen storage tank pressure. So that gas form can be convert in liquid form. For increase the pressure we are using Fuzzy logic controller. As we can see from the results section hydrogen storage tank pressure get increase as we apply fuzzy logic controller.

Fuzzy logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1, considered to be "fuzzy". By contrast, in Boolean logic, the truth values of variables may only be 0 or 1, often called "crisp" values. Fuzzy logic has been employed to handle the concept of partial truth, where the truth value may range between completely true and completely false.[1] Furthermore, when linguistic variables are used, these degrees may be managed by specific (membership) functions.[2]

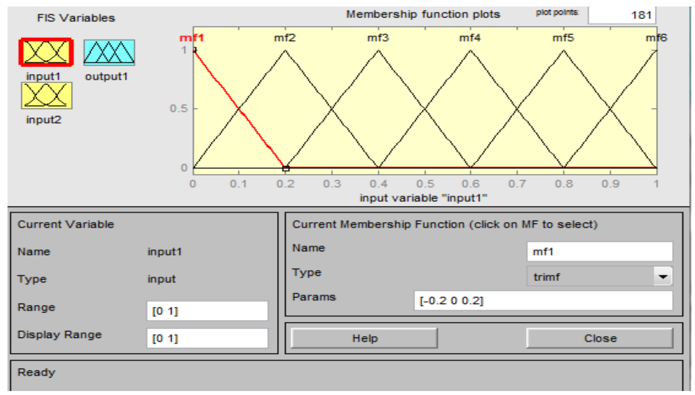

Figure 7:- Fuzzy logic Input1 Member ship Function

Figure 7 is showing the membership function for the input one . The range of the input is [0 1].In this we take 6 membership function. The functions are MF1,MF2,MF3,MF4,MF5,MF6.

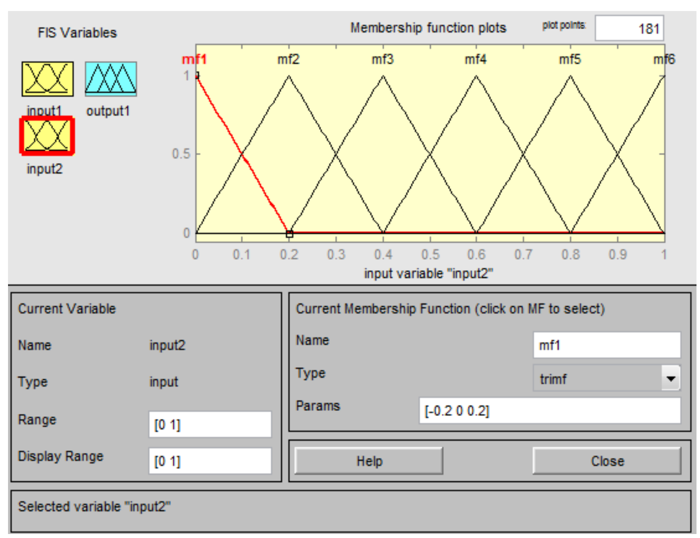

Figure 8:- Fuzzy logic Input 2 Member ship Function

Figure 8 is showing the membership function for the input one . The range of the input is [0 1].In this we take 6 membership function . The functions are MF1,MF2,MF3,MF4,MF5,MF6.

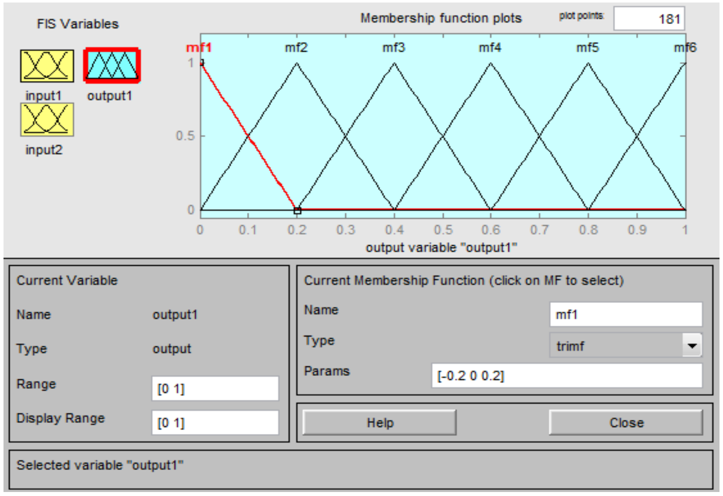

Figure 9:- Fuzzy logic output Member ship Function

Figure 9 is showing the membership function for the output one . The range of the input is [0 1].In this we take 6 membership function . The functions are MF1,MF2,MF3,MF4,MF5,MF6.

Input 1	Input 2	Output
MF1	MF1	MF1
MF2	MF2	MF2
MF3	MF3	MF3
MF4	MF4	MF4
MF5	MF5	MF5
MF6	MF6	MF6

Table 1:- Fuzzy logic Rules

IV. RESULTS

In this research, we are improving the hydrogen storage tank pressure. For improve the performance, we are applying the Fuzzy Logic controller. We show the results for the without any controller, with PID controller, with Fuzzy Logic controller.

A. Without Controller

As we can see from the figure 10, hydrogen storage tank pressure is $7*10^9$ Pa . As we can see from the results session the value of $7*10^9$ Pa is achieve at 10 sec.

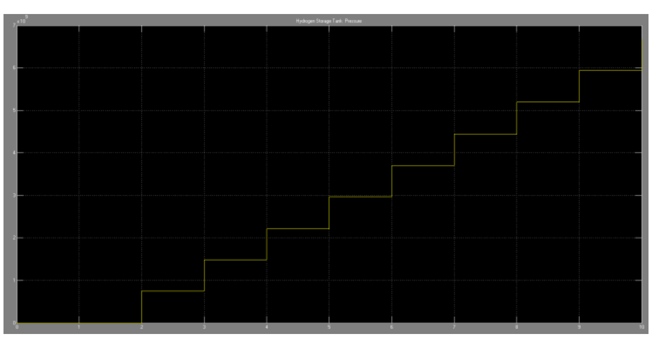

Figure 10 :- Hydrogen storage tank pressure

B. With PID Controller

As we can see from the figure 11, the hydrogen storage Tank pressure is same $7*10^9$ Pa and it is also achieving at10 sec.

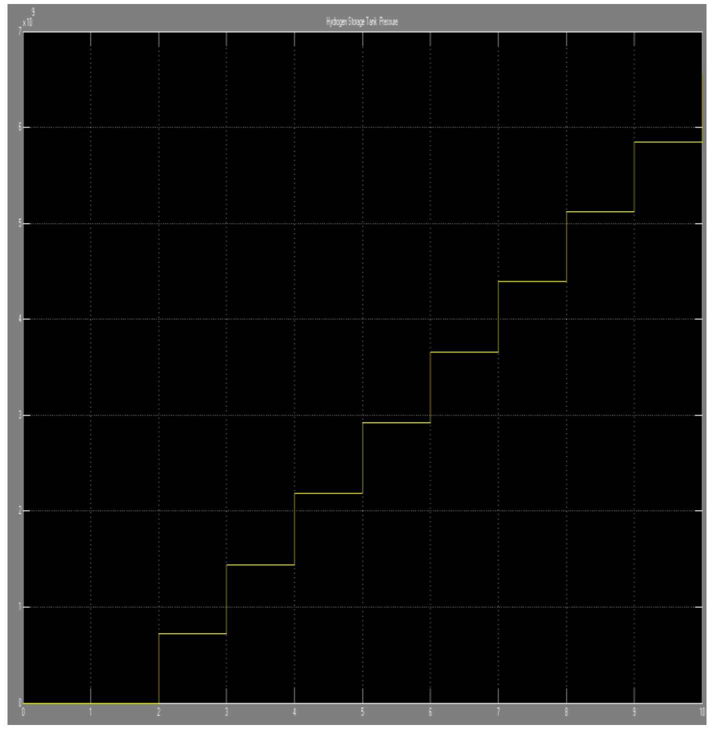

Figure 11:- Hydrogen storage tank pressure by PID controller

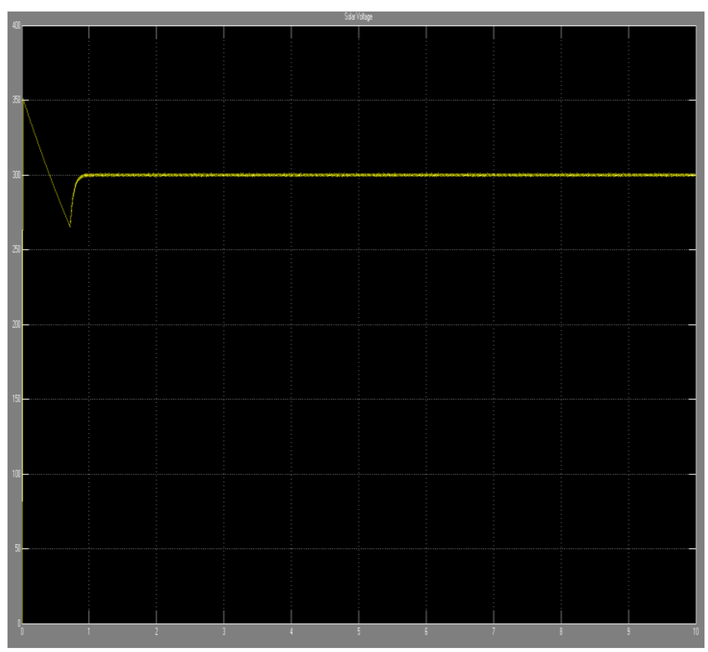

Figure 12 :- Output Solar voltage

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As we can see from the figure 12, the output voltage of the solar is 300 V . But it is not stable . It is getting unstable at 0.8 sec . we have to remove the un stability of the output voltage .

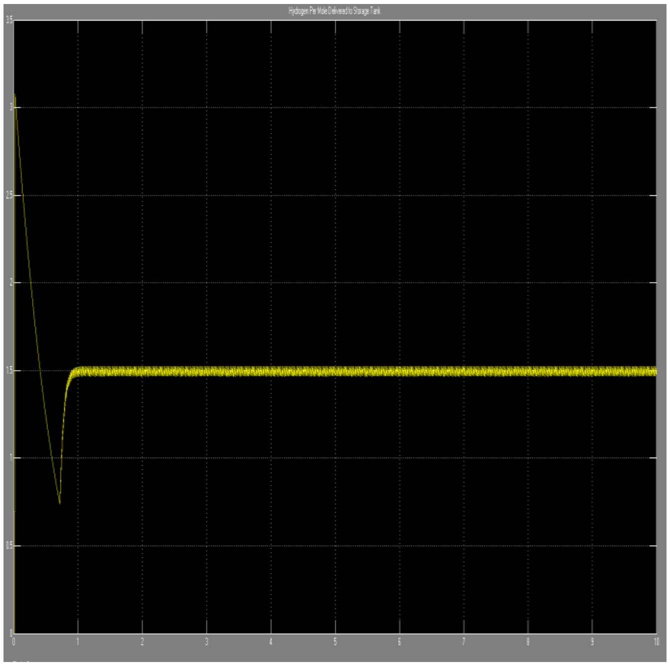

Figure 13:- Hydrogen per mole delivered to storage tank

Figure 13 is showing the hydrogen per mole delivered to storage tank. As we can see from the figure the system get un stable at 0.8 sec. We have to stable it so that in a constant form molecule can be transfer.

C. With Fuzzy Logic

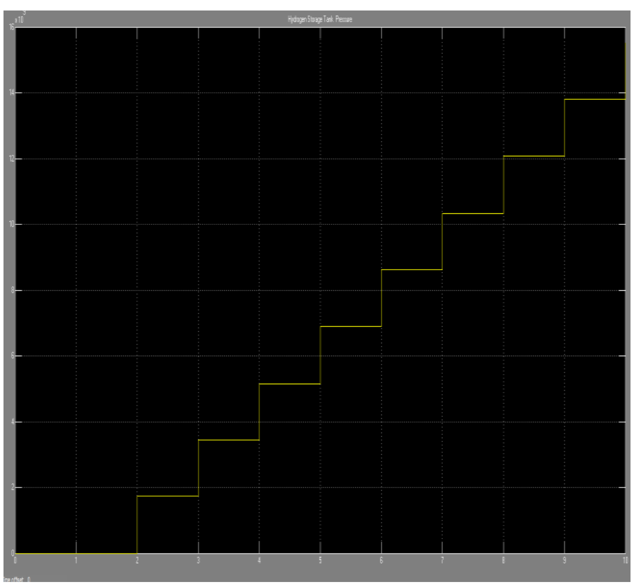

Figure 14:- Hydrogen storage Tank pressure by Fuzzy Logic

As we can see from the figure 14, the hydrogen storage tank pressure is 16 * 10^9 Pa . Hydrogen storage tank pressure gets increase as we apply fuzzy logic. By fuzzy logic we can increase the pressure of the hydrogen storage tank which will be able to convert the gas molecule of hydrogen in liquid molecule.

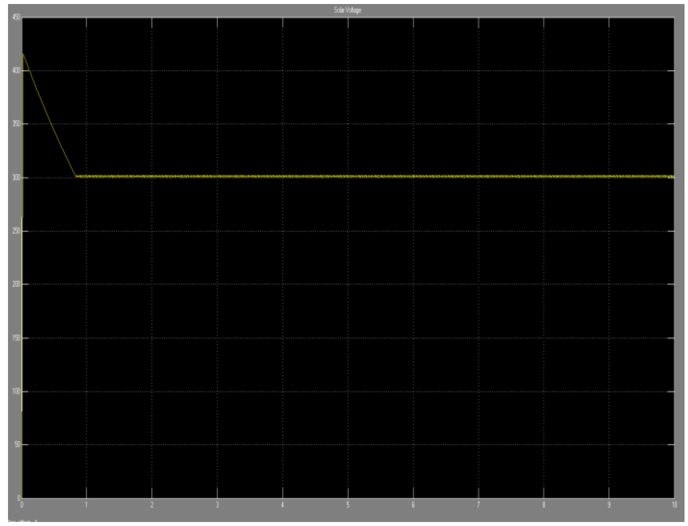

Figure 15:- Output Solar Voltage by Fuzzy Logic

As fig 15, is showing the output solar voltage for the fuzzy logic controller. By use Fuzzy logic controller the unstability of the output voltage get reduce and now system is able to give constant voltage of 300V. Constant voltage is good for the electrolyzing.

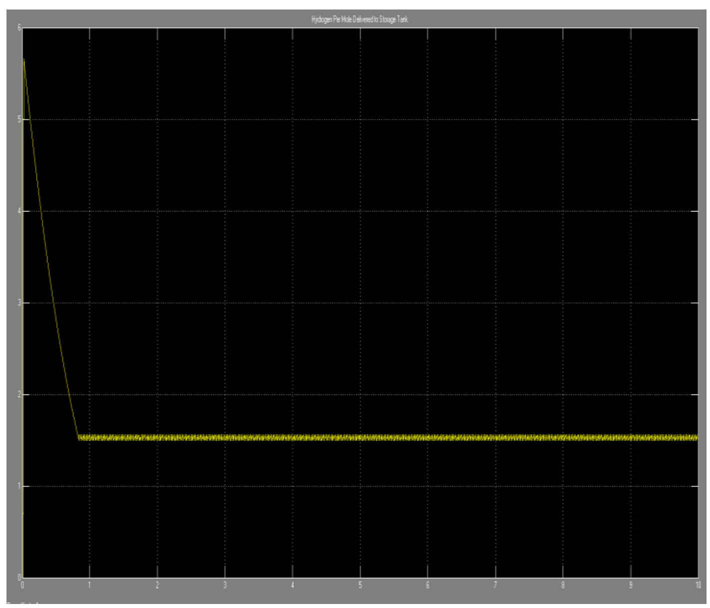

Figure 16 :- Hydrogen Per mole deliver to storage tank by Fuzzy logic

As we can see from the figure 16 hydrogen per mole deliver to storage tank by fuzzy logic get stable . Now there is not any un stability for transfer the molecule in the storage tank.

	Hydrogen storage tank pressure (Pa)	Solar output voltage(V)
With Out any controller	7* 10^9 Pa	300 V(Unstable)
With PID controller	7 * 10^9 Pa	300 V(Unstable)
With Fuzzy Logic	16 * 10^9 Pa	300 V (Stable)

Table 2:- Comparison Table

V. CONCLUSION

In this paper, the components of Fuzzy logic based solar energy storage system modeled and tested using solar radiation and temperature as primary input and hydrogen as seasonal energy storage. The components were modeled in the MATLAB Simulink. Renewable energy sources are highly dependent on environmental conditions such as season's weather. This storage energy system exhibits excellent performance under variable different radiant and temperature changes. We conclude that energy storage systems have the potential to improve the attractiveness of solar energy in India both technically and economically, especially in the future with greater development of solar power resources. Energy storage can help to mitigate technical issues associated with solar, wind and other intermittent generator integration with utility grids. More importantly, energy storage can mitigate the intermittent nature of renewable energy, its significant unpredictability, and its off peak availability, making solar power better able to integrate with electricity markets and match typical electricity demand profiles.

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