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DESIGN OF HYDROGEN BASED ELECTRICITY GENERATOR

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ABSTRACT

The paper presents a methodology for determining the efficiency of a hydrogen generator taking the power requirements Hydrogen can be produced from different feedstock, starting from coal and hydrocarbons and going through biomass and water The method used by us in the Hydrogen production process is steam methane reforming process which is continent with greater efficiency than electrolysis. The known energy conversion devices, fuel cells (FCs) offer the highest energy density, with an optional theoretical energy density of 150 times higher than batteries. Before fuel cell and steam reforming parameters were calculated including efficiency, energy consumption and hydrogen flow rate. Suggested technology represents combination of FC and SRM and thus overall efficiency of such technology should be calculated. Therefore the performance evaluation and the development procedure of SMR based Hydrogen generator that was designed taking user convenience for commercialization were described in this paper.

Keywords: Feedstock CH_4, SMR, H2 Generation, Fuel Cell.

I. INTRODUCTION

The incumbent technologies that support power needs in data centers are primarily diesel generators and electricity from the grid. The hydrogen supplies currently available would support this level of usage. In the long term, prime power is seen as the ultimate goal and where more benefits could be realized. Potential benefits include carbon-free power with full micro grid capabilities, thermal integration for increased total efficiency, and cost savings from elimination of some of the backup systems or design simplification An important consideration about hydrogen is that, since it is energy carrier and not an energy source, it must be first produced, and then it can be used In brief, hydrogen and Fuel cell together represent one of the most promising ways to realize sustainable energy, whilst fuel cells provide the most efficient conversion device for converting hydrogen, and possibly other fuels, into electricity. The Solid oxide Fuel Cells (SOFC) are electrochemical devices that convert chemical energy to electric energy with low operation noise and no gas emissions.

II. METHODOLOGY

- Selection of generator –Hydrogen Generator.
- Choose the best method of hydrogen production and fuel cell technology to produce electricity.
- Selection of Hydrogen Production process – Steam Methane Reforming.
- Choose the most appropriate energy carrier and calculate its efficiency.

Generation of Hydrogen

There are many process of hydrogen generation like SMR, electrolysis, POx, ESR, ATR and Coal Gasification. From all the study we get that SMR is feasible, economical and comparatively efficient than others.

What is SMR (Steam Methane Reforming)?

- Steam and hydrocarbon enter as feedstock in the reactor and at end of this process hydrogen and carbon dioxide are obtained the natural gas consist of methane molecule and water gets added in form of steam and it is produced from waste heat recovered from exhaust of the system Steam and methane mixture reaches a high heat flux .
- The catalyst causes the main reaction in this reaction causes hydrogen and carbon monoxide carbon monoxide reacts with carbon di oxide. Ni based Catalyst added and reaction occurs in 500-900°C, Pressure absorber absorbs all gaseous gases released except hydrogen, Pressure absorber absorbs all gaseous gases released except hydrogen pressure swing absorber full saturated with undesired species pressure is decreased in carbon monoxide and carbon di oxide led into the burner generate heat for new hydrogen production.

- Now in WGS reaction as a 2ndry Catalyst Max production occurs at 1000°C i.e. 42.89 mol (50-60% efficient). Increase of 9.5 to 10 % occurs. When CO/CO2 at 250-800°C and hydrogen above 200°C.

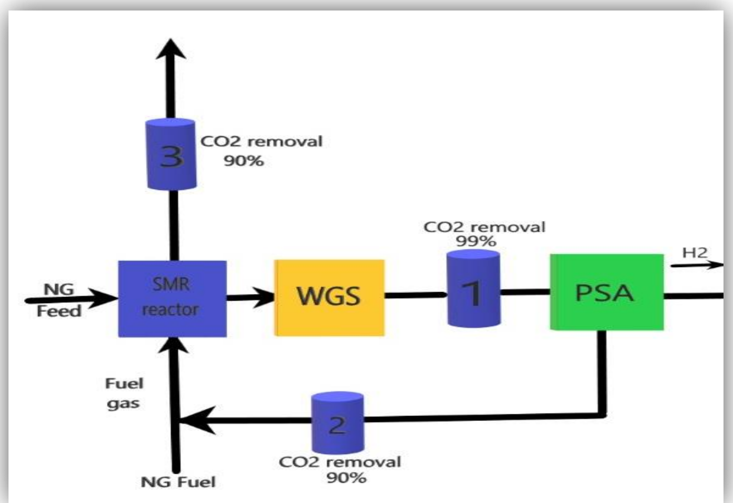

Fig. (a) SMR and Hydrogen Generation Process

- While we have the CH_4 feed in market its.[1]
- We can use zinc oxide beds and other filters for its purification if wanted.
- Sulfur is Harmful for the system so it should be removed in filter.
- Now CH4 from filter after reacted with water (water temp increased before process using burners and exhaust gases) in SMR Membrane Reactor
- Ratio of CH4 and H2O (steam) is 1:3 when their temp reaches at high heat flux the "**Ni based Catalyst**"[2] added and reaction occurs in 500-900°C.[3][4]
- CH4 + H2O → CO + 3H2

  DH 298 = 206 kJ/mol (1)
- The temp of Syngas(CO + H2), we get from reaction is 720°Cor above.[5]
- More the temp more the production.
- **Max production occurs at 1000°C i.e. 42.89 mol (50-60% efficient).**[1]
- Now, cooling down the syngas from 300 to 500°C.
- Syngas mixture has to be separated for pure H2 by using PSA.(Pressure swing absorber)
- Than for increasing production 2nd Catalyst is also included i.e. Water Gas Shift.[6]
- In this WGS, Carbon monoxide(from PSA) reacted with steam.(by exhaust gas and burners)
- CO + H2O → CO2 + H2

  DH 298 = 41 kJ/mol (2)
- This CO2 and H2 mixture has to be separated for pure H2. [7]
- Co2 got sucked here in PSA.
- We use PSA for that, it has multiple vessels when one vessel is fully saturated with undesired species than pressure decreases in CO and CO2.
- **Using Vacuum PSA at 0.1 bar pressure it give 50-60% efficiency i.e. 99.99% purity of H2**
- Than they (CO/CO2) led off into Burner to generate heat for new H2 Production.
- When CO/CO2 at 250-800°C and hydrogen above 200°C.
- Steam Reforming process have Maximum efficiency compared to others like ATR, Pox etc.
- ***[In a report Calculated from LHV, SR has 52% efficiency at 12bar and ATR has 28% efficiency at 18 bar.]*** [8]

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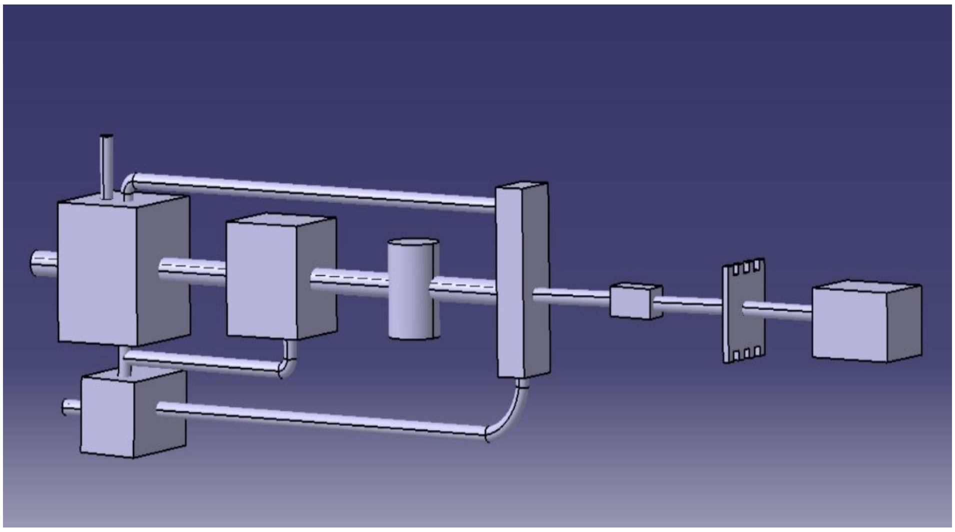

Fig. (b) CAD Model

III. CALCULATIONS

1) Hydrogen Plant Efficiency from Input CH_4 to H_2 Production

- **Basic Efficiency Formula** $H2\%\ \eta = \frac{Output\ mass\ Hydrogen}{Input\ mass\ CH4} \times 100$
- $\eta = \frac{4M_{SBH} * \frac{MH_2}{M_{SBH}} * 100}{M_{SBH} + (M_{H_2o})Sto\,ch + (M_{H_2O})_{Sol}}$
- Where,
- M_{H2}, Are The Hydrogen And
- M_{SBH} - SBH Molar Mass,
- M_{h2}, M_{sbh}, M_{fuel} Are The Hydrogen, SBH And Total Fuel (SBH Þ H2O)
- $(M_{H_2o})StoCh$ - Water Mass Required For Reaction (From The Stoichiometric Formula)
- $(M_{H_2o})sol$ – CH_4 Solubility
- To heat feed mixture from 25 °C till 900 °C one should adjust Q1 amount of heat which is sensible heat of the process. Heat balance of fuel heating process.[9]

Enthalpy Calculations

- **Q1=(NCH4*ΔHCH4 + NH20*ΔHH20)OUT - (NCH4*ΔHCH4 + NH20*ΔHH20)IN**
- ΔHCH4IN = ΔH0CH4 + CP(T2-T1) = ΔH0CH4
- ΔHH20IN = ΔH0H20 + CP(T2-T1) = ΔH0H20
- ΔHCH4OUT = ΔH0CH4 + CP(T2-T1)
- ΔHH20OUT = ΔH0H20 + CP(T2-T1*) T1=25 °C T2=900°C*

All values from heat balance Sheet

Q1 = NCH4* CP (T2-T1) + NCH4* ΔH0CH4 + NH20* ΔH0H20 (GAS) + NH20* CP (T2-T1) - NCH4*ΔH0CH4 - NH20*ΔH0H20 (LIQ) [9]

Q1 = 0,25*56,4*875+0,5*(-241,8*10^3+37,49*875)-0,5*(-285,84*10^3)=12337,5-104515+142920=50742,5 =50.74 kj/mole =25.37 MJ/kg

Similarly

Q2= (NCO2*ΔHCO2 + NH2*ΔHH2) OUT - (NCH4*ΔHCH4 + NH20*ΔHH20) in

Q2=25,795 -87.83 +6,375 +104,513 =48,853 kj/mole

In total to perform steam reforming of methane with 100% efficiency we need 99.59 kj/mole.

Q=q1+q2=50.74 + 48,853=99.59 kj/mole=49,785 MJ/kg

To produce 1 kg of hydrogen 49,795 MJ is needed.

Combustion heat of methane = **50 mj/kg** Combustion heat of hydrogen =**121 mj/kg**[9]

Working of Hydrogen Electricity Generator

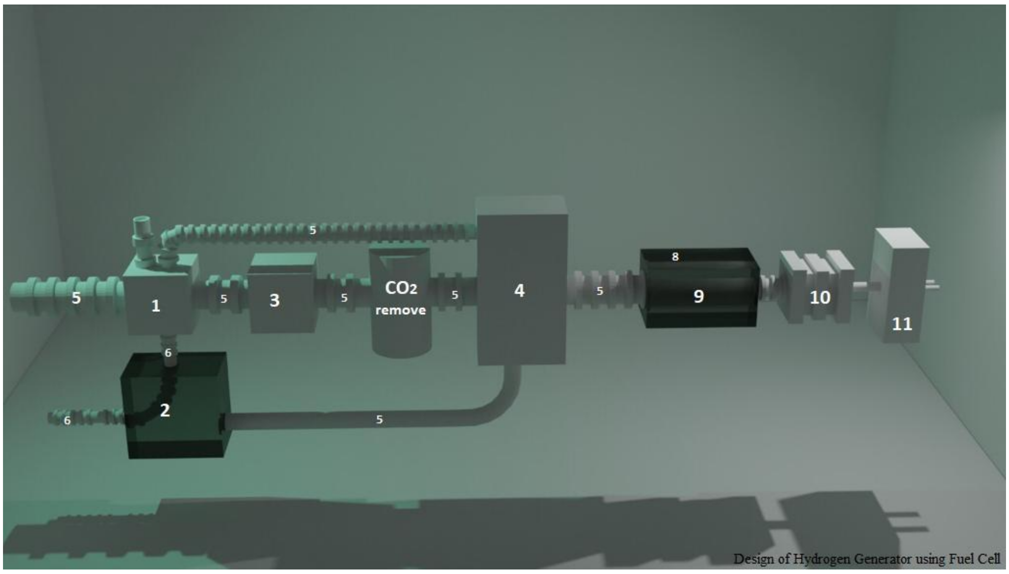

Fig. (c) Working Model of Hydrogen Based Electricity Generator

1.	*SMR Reactor*	*6.*	*Water Tubes*
2.	*Chamber of Gas Burners*	*8.*	*K-type Thermocouple*
3.	*WGS Reactor*	*9.*	*PID Controller*
4.	*PSA Unit*	*10.*	*SOFC*
5.	*Reformer Tubes & CH4 Feed*	*11*	*Inverter*

- Steam and hydrocarbon enter as feedstock in the reactor and at end of this process hydrogen and carbon dioxide are obtained the natural gas consist of methane molecule and water gets added in form of steam and it is produced from waste heat recovered from exhaust of the system Steam and methane mixture reaches a high heat flux .
- The catalyst causes the main reaction in this reaction causes hydrogen and carbon monoxide carbon monoxide reacts with carbon di oxide. Ni based Catalyst added and reaction occurs in 500-900°C.[3][6]Pressure absorber absorbs all gaseous gases released except hydrogen, Pressure absorber absorbs all gaseous gases released except hydrogen pressure swing absorber full saturated with undesired species pressure is decreased in carbon monoxide and carbon di oxide led into the burner generate heat for new hydrogen production.
- Now in WGS reaction as a 2ndry Catalyst Max production occurs at 1000°C i.e. 42.89 mol (50-60% efficient).[10] Increase of 9.5 to 10 % occurs. When CO/CO2 at 250-800°C and hydrogen above 200°C. [2]
- The hydrogen produced in steam methane reforming process is goes to the control module which helps to sense the temperature of the hydrogen ad display it into the PID controller the Hydrogen then passes to the fuel cell where the hydrogen is the basic fuel used that generates electricity with very little pollution and the By Single-cell stack we get 23.56 W from above info in 100 moles of H2. So by Using 4 cells we get 94 W of Electricity. [11]
- The DC current produced by fuel cell is sent to the inverter where the DC current is converted into AC current and is ready to use for further application.

Fuel Cell Calculations

Using Nernst's Equation

$$E = E^0 + \frac{RT}{zF} ln \frac{p(A) \times p(B)}{p(C) \times p(D)}$$

Where:

P (a), p (в) – partial pressure of products considering stoichiometric coefficients

P (c), p (d) – partial pressure of reactants considering stoichiometric coefficients

F=96485.3 kl/mole – faraday number

By entering input hydrogen of

Z –number of electrons in the reaction

T-temperature of reaction, к

R-universal gas constant, 8,314 kj/kg*mole

Get an output of 94 w from 4 cells.[9]

- By single-cell stack we get 23.56 W from above info 100 moles of h2.

IV. CONCLUSION

The hydrogen produced from methane steam reforming process is one of the finest method to extract hydrogen and it is a clean and green source of energy. From above calculation we find ΔH and While 100% of conversion we get 40.33% efficiency from SMR + SOFC reaction and after that if SMR + WGS + SOFC we get increase of 9.55-10% i.e., we get 50%-60% as overall efficiency.

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