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RESEARCH ARTICLE

INTEGRATION OF WIND TURBINE AND HYDROGEN FUEL I.C. ENGINE.

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Abstract

This study aims to examine the execution of hydrogen fuel Internal combustion engine, by separating into three subsystem (photovoltaic modules/wind turbine as the principle power source to electrolyser, internal combustion engine).Then a mathematical model of PV array is reproduced in MATLAB to get operational curves. The sizing of the PV modules and wind turbine to give required amount of energy of 39.41Kwh to produce 1kg of hydrogen, ifectrolyser is 100% efficient. At that point, assessing enough power of the PV modules for the nine months (January to may and September to December) and wind turbines for three months (June to August) when wind pace is moderately high and sun powered insolation is less in these three months at vellore area in Tamil Nadu. Then finally examine the performance of hydrogen fuel I.C. engine utilizing liquefied hydrogen fuel for entire year

Introduction:-

The world today is transcendentally controlled by fossil-based energizes including petroleum and refined derivates, for example, gasoline.Nuclear power plants are likewise conveyed in more created countries; a half and half of coal and atomic fueled plants bolster those national electric frameworks and drive the economies. Likewise, if the fuel comes from methods rely on upon fossil fuel, similar to common gas steam changing or coal gasification, then the framework is considered a greenhouse gasses GHGs emitter such like conventional sources, while if the fuel is created without GHGs, such as utilizing renewable sources to electrolyze water, then it is considered as a renewable energy unit framework. Be that as it may, the requirement for cleaner power is centering our drive and move towards non-fossil eco-friendly powers for what's to come. One driving answer for a greener future is hydrogen. Hydrogen inalienably postures less risk than traditional fills, for example, fuel or normal gas. Hydrogen is vapid, scentless, non-harmful and won't pollute groundwater. On the off chance that discharged into the air, it won't add to environmental contamination. Hydrogen is 14 times lighter than oxygen, which implies it diffuses quickly into a non-combustible focus when discharged into the air.Hybrid power frameworks comprise of two or more sources, controllers and gear for the capacity of vitality, utilized together to give expanded framework effectiveness. Utilizing the hybrid the framework the general effectiveness, the dependability and enhance the quality and accessibility is essentially expanded when contrasted and singular frameworks.Advantage of hybrid power frameworks is amplifying the utilization of renewable at the most minimal worthy expense.This renewable framework is broke down into four subsystems: renewable energy units, electrolysers, and lastly H_2 storage tank, and Internal combustion Engine.

Modelling of PV module:-

Solar cell, the building block of the PV array, is essentially a P-N junction semiconductor equipped for creating power because of photovoltaic impact.. PV cells are interconnected in arrangement parallel design to shape a PV exhibit Using perfect single diode as appeared for a cluster with Ns arrangement associated cells and Np parallel associated cells, the cluster current might be identified with the cluster voltage.It has a equivalent circuit as demonstrated below

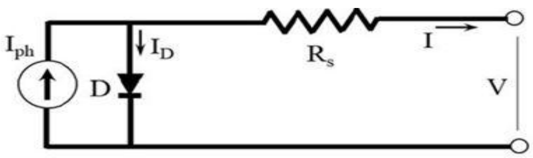

Figure 1: Equivalent circuit of PV cell

The PV mathematical model used to simplify above PV array is represented by the equation:

$$I = N_p I_{ph} - N_p I_{rs}\ [\exp(\frac{qv}{KTAN_s}) - 1] \qquad (1)$$

Where,
I=PV panel output current;
V = PV panel output voltage;
N_s= number of cells in series;
N_p= number of cells in parallel;
k = Boltzmann"s constant;
q = charge of an electron;
T = cell temperature (K);
A = p-n junction ideality factor;
Irs= cell reverse saturation current.

The factor A in equation (1) deduces the cell deviation from the ideal p-n junction characteristics; it lies between 1-5 but in our case A=2.51. The cell reverse saturation current Irs changes with temperature according to the following equation:

$$I_{rs} = I_{rr}[\frac{T}{T_r}]^3 \exp(\frac{qE_G}{KA}[\frac{1}{T_r} - \frac{1}{T}])(2)$$

Where
Tr= cell reference temperature
Irr= cell reverse saturation temperature at Tr
EG = band gap of the semiconductor used in the cell.
The temperature reliance of the energy gap of the semi-conductor is represented by

$$E_G = E_G(0) - \frac{\alpha T^2}{T+\beta} \qquad (3)$$

The photo current Iph relies on the solar irradiance and cell temperature as follows:

$$I_{ph} = [I_{scr} + K_i(T - T_r)]\frac{S}{100} \qquad (4)$$

Where,
S = solar radiation in mW/cm2.
Iscr = cell short-circuit current at reference temperature and irradiance
Ki = short circuit current temperature coefficient
The power PV panel can be calculated using equation (1) as follows:

$$P = IV = N_p I_{ph} V[(\frac{qv}{KTAN_s}) - 1(5)$$

Table 1:Electrical parameter of 300 Watts (72 Cells YINGLI Solar Panel)

Parameters	Values
P_{MP} (W)	300
V_{mp} (V)	32.7
I_{scr} (A)	7.16
I_{mp} (A)	6.70
V_{oc} (V)	41.7
N_p	1
N_S	72
K_i (A/K)	0.00023
T_{r1} (Degree celcius)	40
I_{rr} (A)	0.00002
K (J/K)	1.38065*10^-23
q (c)	1.6022*10^-19
A	2.51
E_G0 (Ev)	1.66
α	0.473
β	636
T(ke;vin)	298

Table 2:Monthly averagesolar irradiance at vellore

Months	Irradiance (Kw/m^2/day)	Irradiance (mW/cm^2)
January	4.82	20.08
February	5.72	23.83
March	6.43	26.79
April	6.28	26.79
May	5.92	24.66
June	5.19	21.62
July	4.75	19.79
August	4.88	20.33
September	5.11	21.29
October	4.37	18.20
November	3.99	16.62
December	4.16	17.34

MATLAB code for PV panel

```
clearall
clc
T=298;
Tr1=40;
Tr=313;
S=[26.79 26.16 24.66 23.83 21.29 20.08 18.20 17.34 16.62];
ki=0.00023;
Iscr=7.16;
Irr=0.000021;
k=1.38065*10^(-23);
q=1.6022*10^(-19);
A=2.51;
Eg0=1.166;
```

```
alpha=0.473;
beta=636;
Eg=Eg0-(alpha*T*T)/(T+beta)*q;
Np=1;
Ns=72;
V0=[0:1:300];
c={'blue','red','yellow','green','black','cyan','magenta','red','green',};
for i=1:9
Iph=(Iscr+ki*(T-Tr))*((S(i))/100);
Irs=Irr*((T/Tr)^3)*exp(q*Eg/(k*A)*((1/Tr)-(1/T)));
I0=Np*Iph-Np*Irs*(exp(q/(k*T*A)*V0./Ns)-1);
P0 = V0.*I0;
figure(1)
plot(V0,I0,c{i});
hleg = legend('26.79 w','26.16 w','24.66 w','23.83 w','21.29 w','20.08 w','18.20 w','17.34 w','16.62 w');
axis([0 60 0 4]);
xlabel('Voltage in volt');
ylabel('Current in amp');
holdon;
figure(2)
plot(V0,P0,c{i});
hleg = legend('26.79 w','26.16 w','24.66 w','23.83 w','21.29 w','20.08 w','18.20 w','17.34 w','16.62 w');
axis([0 60 0 150]);
xlabel('Voltage in volt');
ylabel('Power in watt');
holdon;
figure(3)
plot(I0,P0,c{i});
hleg = legend('26.79 w','26.16 w','24.66 w','23.83 w','21.29 w','20.08 w','18.20 w','17.34 w','16.62 w');
axis([0 4 0 100]);
xlabel('Current in amp');
ylabel('Power in watt');
holdon;
end
```

Estimationfor no. of panels required:-

Max. power of pv panel after MATLAB coding is equal to 119 watts and Min. power is 101 watts.
To produce 1kg of hydrogen,39.41kwh energy is required .
Energy produced by one 300 W PV panel in a day
= Actual power output × 8 hours/day (peak equivalent)
= 119 × 8 = 952 watts-hour
Number of solar panels required to satisfy given estimated daily load :
= (Total watt-hour rating (daily load)/(Daily energy produced by a panel)
=315280/952 = 331.17 = 332 (round figure)

Wind turbine power calculations:-

The essential mathematical expression governing the mechanical power of the wind turbine is given by :

$$P_w = \frac{1}{2} C_p(\lambda, \beta)\rho A V^3 \qquad (6)$$

where ρ is air density (kg/m^2), Cp is power coefficient, A is swept area of the rotor blades (m^2), V is average wind speed (m/s), λ is tip speed ratio. The theoretical maximum value of the power coefficient Cp is 0.593, also known as Betz's coefficient. The Tip Speed Ratio (TSR) for wind turbine is defined as the ratio of rotational speed of the tip of a blade to the wind velocity.

$$\lambda = \frac{R\omega}{V} \quad (7)$$

where R is radius of turbine (m), ω is angular speed (rad/s), V is average wind speed (m/s).

The energy generated by wind can be obtained by

Q_W= Power*Time (Kwh) (8)

Table 3:Monthly averagesolar wind speed at vellore

Months	wind speed(m/s)
June	4.28
July	3.90
August	3.80

Table 4:Technical parameters of (QINGDAO RENERGY EQIPMENT) 10kw variable pitch Technical parameter Wind Turbineat vellore

Technical parameters

Wind rotor diameter (m)7.6
Blade material and quantity Fiber glass reinforced * 3
Rated power / max power (w)10k/12k
Rated wind speed (m/s)11
Rated rotating speed (rpm)170
Working wind speed (m/s)3-30
Startup wind speed (m/s)2
Survived wind speed (m/s)60
Working voltage (v)DC240V(off grid) /DC400V(on grid)AC240
Battery voltage / capcity (v, ah)12*20=240V/200Ah
Speed regulation methodVariable pitch regulation + electromagnet brake

Stop methodMechnical brake, aerodynamic brake
Generator typeThree phase, permanent magnet
Gear boxNo, direct drive
Tower height / weight (m/kg)12/1200
Max horizontal force (N)22670
Wind turbine dimension D*L (m)7.6*6.1
Noise level (dB)<65

Power estimation from equations (6),(7),(8) and taking data from speed from table 3and 4 using excel sheet.

	A	B	C	D
1	velocity in m/s	P(in watt)	P(in killo watt)	P in KWh
2	3.8	1523.89	1.523890369	12.19112
3	3.9	1647.391	1.647391252	13.17913
4	4.28	2177.38	2.17738006	17.41904

Xaxis-wind speed in m/s

Yaxis-output power in kwh

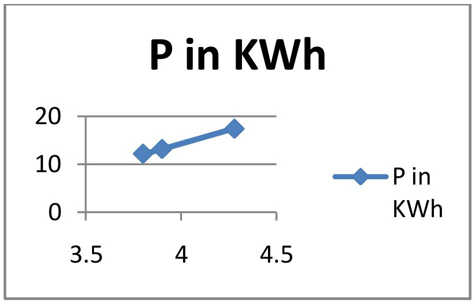

Figure 2 curve between power and wind speed

So maximum Av. power output from the estimation is 14.25kwh and requirement for electrolysis input is 39.41kwh energy. Thus three these type of wind turbine is required to fulfill the energy requirement for electrolysis.

Estimation the performance of hydrogen fuel i.c. engine:-

This engine is the FIAT licensed 124 engine produced by TOFAŞ. The engine and subsystem parameters are:

Torque: 89 Nm at 3400 rpm
Valve: 8 valves (OHV)
Bore: 73.0 mm
Stroke: 71.5 mm
Compression Ratio: 8.8:1
Swept Volume: 1197 cc
Torque: 89 Nm at 3400 rpm
Power: 60 HP (DIN) at 5600 rpm

CALCULATIONS:
T = 89 Nm
P_{MAX} (kW) = 2π ω (rev/s) × T(Nm) × 10^-3
P = 2 π × (3400 × 1 / 60) × 89 × 10^-3 P = 31.7 kW

Simulations and experimental results:-

The desired power is approximately calculated for electrolysis input from wind and solar cell.Then finally performance analysis is done for hydrogen fuel i.c. engine. Max power of a PV Module and wind turbine is 119W and 14.25Kwh respectively.Then finally the performance of I.C. engine is done which gives 31.7 Kw.

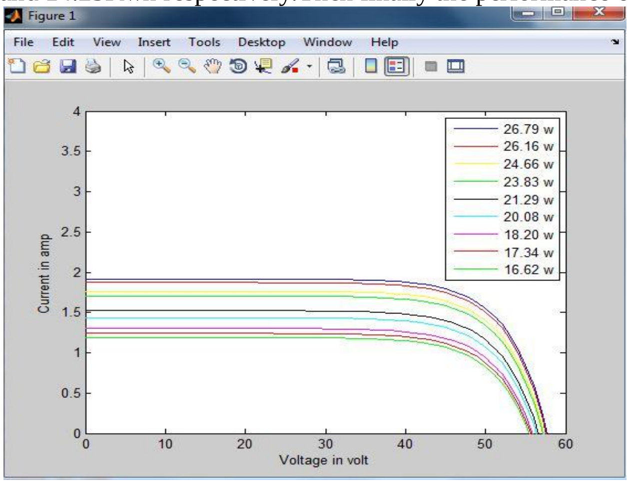

Figure 3: Simulated Results

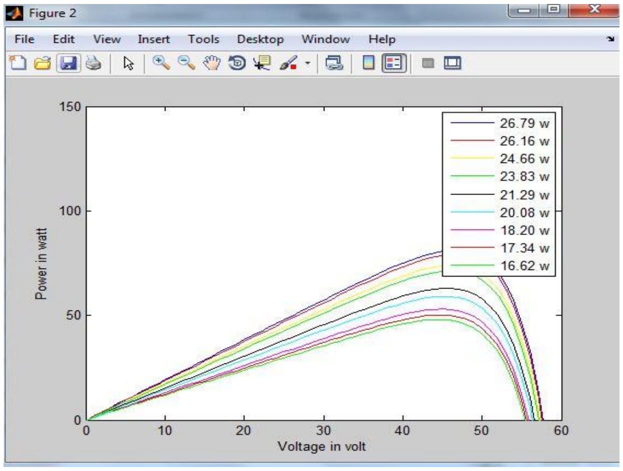

Figure 4: Simulated Results

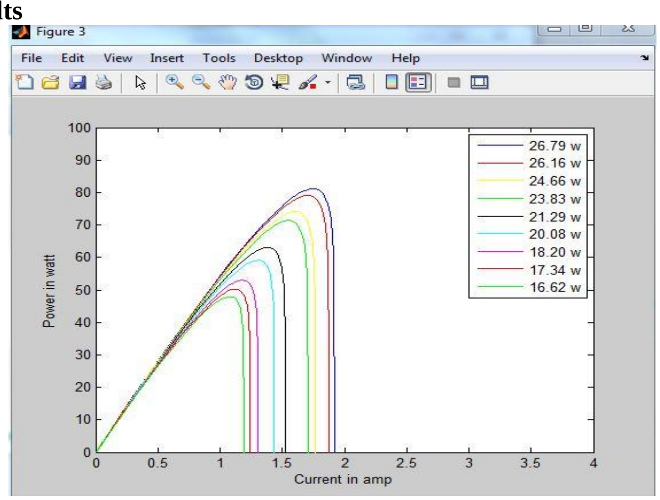

Figure 5: Simulated Results

Figure 6: Simulated Results

Conclusion:-

The paper presents an improved mathematical model for photovoltaic modules that employs only parameters provided by manufacturers datasheets .

Wind turbine system analysis is carried out by excel sheet to get max. power. Internal combustion engine is taken from fiat engine to carry out the performance analysis of the engine using hydrogen fuel.Further hydrogen can be used in variety of application such in fuel cell,stored hydrogen can work as stand alone system in remote areas and also for backup energy source when there is scarce of energy when demand is high.

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