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Building Hybrid Energy System, PV/Wind Turbine Using Local Material

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Abstract: Many used materials are available around us which can be produced useful devices, especially in the field of electricity generation. Hybrid devices are one of these machines. Especially, that operate on renewable energy such as (solar, wind, water, etc.). Recently, there has been a lot of research that is particularly combining wind and solar energy as complementary to each other. Iraq has enough of this combined energy with natural potential of the astronomical location between the land and water and the climate factor which made it a region of the passage of wind through the year when the wind speed reached more than 5 m/sec in addition to solar energy. In is the study, it was built and developed Hybrid of Solar-Wind Turbine system (HSWT) with relying on simple and low-cost component.

Key words: Solar energy, wind energy, hybrid power system, wind turbine, useful devices, water

INTRODUCTION

The renewable energy sources are great importance for cleanness and low environmental impact. Increase demand for fossil fuels (coal, oil, natural gas and uranium) worldwide has exacerbated the problem of global warming and climate change. This was an important factor for investing renewable energy sources in power generation. Iraq is an appropriate area to invest this energy in terms of location and climate. The world already is responding to these imperatives. In 2002 the world's total investments in renewable energy sector was $17 billion with constant increase to the present (Deepchand, 2005; Lund and Mathiesen, 2009). One of the most important elements of investment success is reducing the cost of manufacturing. While in Iraq, the share of renewable resources accounts almost to be non-existent as compared to other fossil fuels type. Figure 1 explain the story of renewable energy growth (Bhattacharya *et al*., 2016; McCrone *et al*., 2012). The Iraqi government should accelerate the development of this sector and benefit from the abundance of renewable sources of available energy, especially, the sun and wind.

There are many problems by conventional energy such as oil supply insecurity, extreme pollution and climate change risks due to fossil fuel burning. Therefore, looking for alternative non-conventional energy resources has become an urgent matter. One of the most popular non-conventional power resources are solar energy power plants which convert the solar energy or solar heat

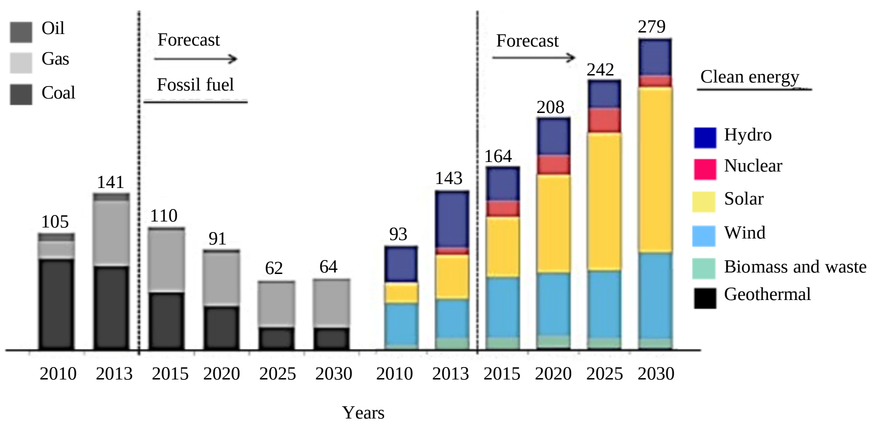

Fig. 1: Comparison of the quantities of energy sources within 30 years (McCrone *et al*., 2012)

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to electricity. Yet, the disadvantage is that it does not work when there is cloudy or rainy weather. This has created the need to combine solar energy with wind energy to obtain a solid power source known as a hybrid solar wind power generation system.This study looking for building hybrid system using very low-cost material to generate electricity.

Site selected information: Figure 2 shown the location area of the Aerodynamics Laboratory at Mechanical Engineering Department, Engineering College, Diyala University to power supply residential household located.

Experimental work: The model and dimensions for the wind turbine was modulated to agree the concept to evaluate the reliability of hybrid systems. This can be seen in Fig. 3 and 4.

The project is designed in two steps, the first step is to design and manufacture while the second step is to connect the solar cell with the wind turbine and the production and storage to generate electric power. In general, the sectional shape of the Horizontal-Axis Wind Turbine (HAWT) blade consists of the airfoil which result the lift and drag forces by virtue of pressure differences across theblade surface. Because of this, the Blade Element Momentum (BEM) theory is widely used to outline the procedure for the aerodynamic design of a (HAWT) blade. The optimum distributions of the chord length and the pitch angle in each study can be acquired according to the design parameters which include the rated wind speed, number of blades, design tip speed ratio and design angle of attack (Diaf *et al*., 2007). The specification of photovoltaic, HAWT and battery parameter are clearly shown in Table 1-3.

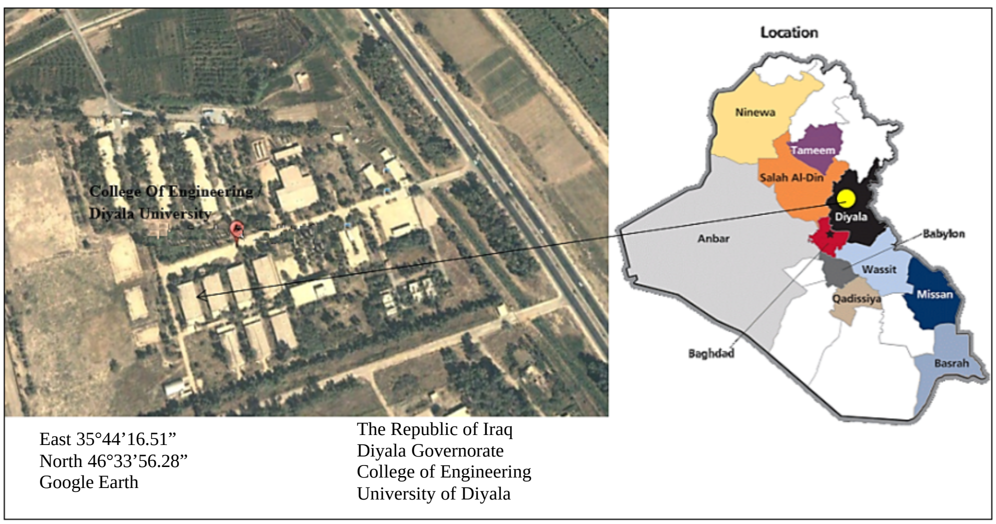

Fig. 2: Geographical location to conduct the experiment

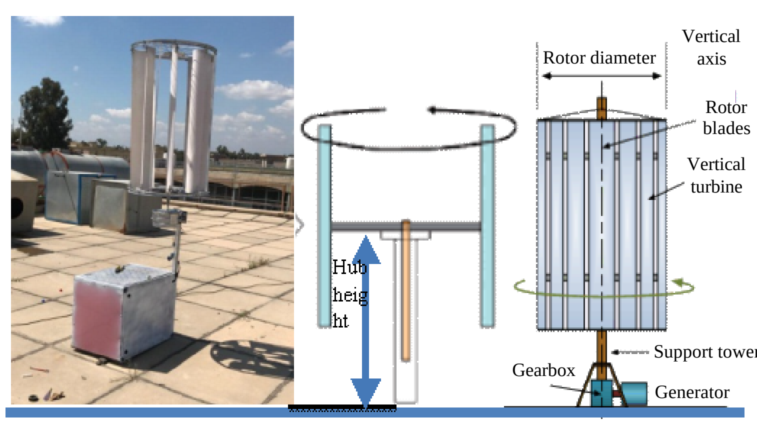

Fig. 3: Horizontal-Axis Wind Turbine (HAWT) blade section

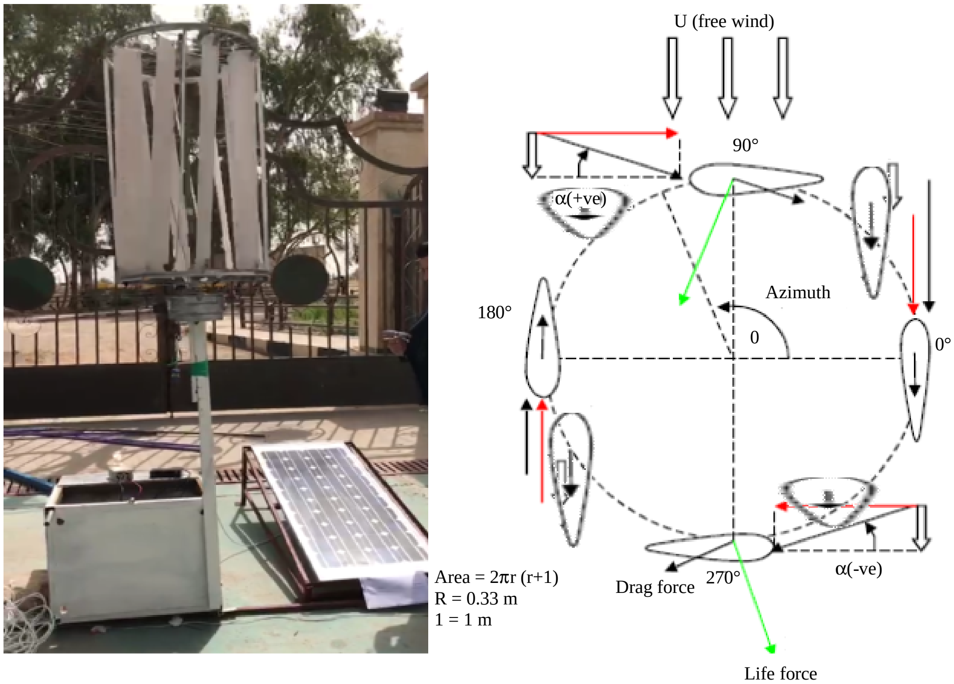

Fig. 4: The Blade Element Momentum (BEM) design of a (HAWT)

Table 1: Wind Turbine (HAWT) modules parameters

Wind turbine (HAWT)		Blade	
Diameter	40 cm	Diameter	10 cm
Length	1.7 m	Number of wheels	2 bicycle wheelsused to fix the blade in booth side with diameter (0.66 m)
Cost of Pipe	8$		The end of the blade is converted to by fit to the required design
Number of sections	4		

Table 2: Photovoltaic and wind turbine modules parameters

Variables	Values	Variables	Values
PV		**Wind turbine**	
Rated maximum	90 W	Start wind speed	0.75 m/sec
Operating voltage	12 V	Rated voltage	12 V
Current at pmax	5.17 A	Rated power	10-120 W
Voltage at pmax	17.4 V	Wind turbine material	Plastic+Aluminum
Short circuit voltage	5.9 A	No. of wings	8
Open circuit voltage	12.4 V	Fan diameter	0.66 m
Nominal operation cell temp	50°C	Total weight	8 kg
Angle of inclination	45°		

As for the solar cell, it is used at a price of 110$ with accessories at a total price (165$)

Table 3: Battery parameters

Type	Nominal capacity (Ah)	Voltage (V)	Minimum charge	Cost ($)
ATRX-80d26l 70 Ah 256*175*200 222 mm	80	12	18%	45$

The design stages of wind turbine including the battery, controller and inverter are shown in Fig. 5.

Figure 4 clearly showed how the parts were connected to each other with the power storage.

Theoretical methods: In this study, the power law is applied for the vertical wind speed profile applicable to turbine type Horizontal-Axisto find the velocity of wind turbine (Diaf *et al*., 2007):

$$V = V_0 \left[\frac{H}{H_0}\right]^{\alpha 1} \quad (1)$$

Where:

V = The wind speed at hub Height (H)
α_1 = The power law exponent which varies with elevation
V_0 = The wind speed measured at the reference height H_0

To calculate the amount of electrical energy generated by the system, possible follow these steps. Total power generated an hour (t) is calculated by combine between the wind turbine and PV generator power as follows (Diaf *et al*., 2008):

$$P_{tot}(t) = P_{PV}(t) + P_{WG}(t) \quad (2)$$

$P_{PV}(t)$ = 90 w form specifications of PV that using in the model. The power generator of wind turbine can be defined as:

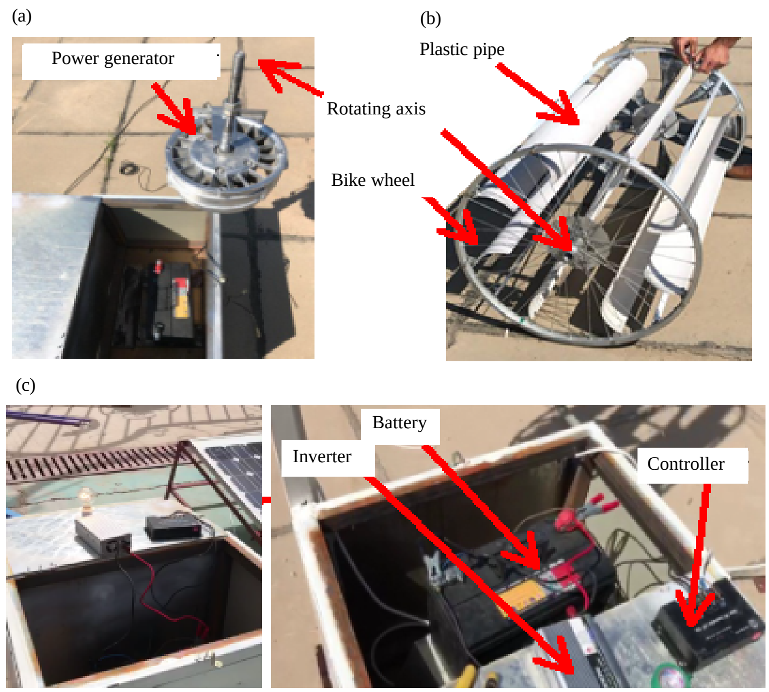

Fig. 5: Design stage of (HAWT) used in the experiment: a) Power generator; b) Wend turbine design and c) Solar controller 24 V LSA and storage battery

$$P_{WG}(t) = \frac{1}{2} \times \rho \times A \times V_o^3 \quad (3)$$

Also, to calculate the inverter input power by using Eq. 4:

$$P_{inv}(t) = \frac{P_{load}(t)}{\eta_{inv}} \quad (4)$$

Where:

P_{inv} = The Power consumed by the load at hour t

η_{inv} = The inverter efficiency will be fixed at 85%

There is relationship between turbine type, wind speed with engineering requirements of a wind turbine that named of power Coefficient (C_p). The theoretical C_{pmax} of any design equal 59% (Manyonge *et al*., 2012) of the turbine includes gearbox, bearings and generator that effects on thepower of the wind, so, C_p is very important. Accordingly, C_p needs to extractable power from the wind through Eq. 3:

$$P_{avail} = \frac{1}{2} \rho A v^3 C_p \quad (5)$$

The process of transfer power output from PV and wind generators to the battery can be described by state-of-charge process, consumption situation of the system during the time from (t-1-t) during the charging process:

$$C_{bat}(t) = C_{bat}(t-1).(1-\sigma) + \left(E_{PV}(t) + E_{WG}(t) - \frac{E_L(t)}{\eta_{inv}}\right)\eta_{bat} \quad (6)$$

Where:

$C_{bat}(t)$ = Capacity of battery available

$C_{bat}(t-1)$ = Bank Capacity (Wh)

$E_{PV}(t)$ = Energy generated by PV = 90 (W)t

$E_{WG}(t) = P_{WG}$ (W)t = Power fromwind generators can be taken from Table 3

$E_L(t)$ = The load demand at hour t

η_{bat} = The battery efficiency = 0.65-0.85 take 77.3% in this type (Li *et al*., 2012)

η_{inv} = The inverter efficiency = 85%

σ = Self-discharge rate of the battery bank = 20% per month (McEvoy *et al*., 2003)

Table 4 and 5 contains the details of the storage capacity of the battery. To calculate the time required to store the battery, the following equation can be used (Ai *et al*., 2003; Guo and Sharma, 2016; Li *et al*., 2012):

$$C_T = C_{battery}(t)/P_{tot}(t) \quad (7)$$

Where:

C_T = Equal Charging time (h)

$C_{battery}$ = Battery capacity (Ah)

P_{tot} = The amount of power fitted to the battery measured (A)

Table 4: Values obtained from the experiment work for HPWS at level (7.5 m)

Test information (time)						
No. of test	Start	End	Data	Wind observation (V_0) (m/sec)	Voltage (V)	PPV (V)
1	10:00 am	10:15 am	14/2/2017	3.1	18	12
	10:15 am	10:30 am		3.6	20	12
	10:30 am	10:45 am		2.6	15	12
	10:45 am	11:00 am		4.2	23	12
2	8:00 am	8:10 am	20/3/2017	2.2	11	12
	8:10 am	8:20 am		3.0	18	12
	8:20 am	8:30 am		3.5	19	12
	8:30 am	8:40 am		2.0	10	12
	8:40 am	9:00 am		3.0	18	12
3	12:00 pm	12:15 pm	6/4/2017	4.0	21	12
	12:15 pm	12:30 pm		2.6	15	12
4	2:00 pm	2:15 pm	20/5/2017	2.8	16	12
	2:15 pm	2:30 pm		3.4	19	12

Table 5: Calculate the wind speed V (m/sec) at hub (1 m)

Speed	V_0 (m/sec)	H (m)	H_0 (m)	α_1	V (m/sec)
Low	2	1	1.5	0.5	1.633
Medium	3.6	1	1.5	0.5	2.939
High	4.2	1	1.5	0.5	3.429
Low	2	1	1.5	0.4	1.701
Medium	3.6	1	1.5	0.4	3.061
High	4.2	1	1.5	0.4	3.571
Low	2	1	1.5	0.3	1.771
Medium	3.6	1	1.5	0.3	3.188
High	4.2	1	1.5	0.3	3.719
Low	2	1	1.5	0.27	1.793
Medium	3.6	1	1.5	0.27	3.227
High	4.2	1	1.5	0.27	3.764

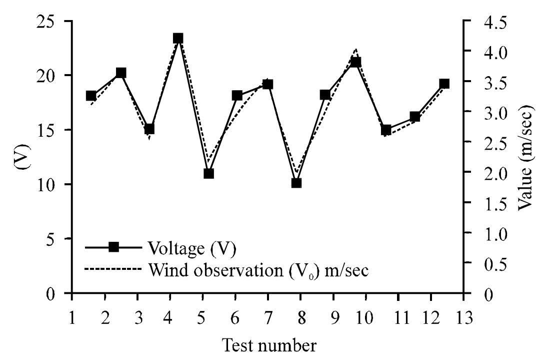

Fig. 6: Relation ship between wind speed and voltage of (HAWT)

RESULTS AND DISCUSSION

From Table 4, the Hybrid PV/Wind System (HPWS) result was collected experimentally using digital manometer (AR836) which has accuracy of ±3% ±0.1dgt (Table 4).

Figure 6 explains the wind power, it was taken from (McEvoy *et al*., 2003) readings at period between 02/14/2017-05/20/2017 about four months. Measurements were made at a specified height (7.5) m including (6 m height of the building +1.5 m hub high). The air speed was changed depending on the surrounding weather conditions resulting in different voltages increasing with increasing air velocity and vice versa.

Table 6: Calculate the total power generated an hour (t) with power consumed by the load at hour t

V_0 (m/sec)	Inv100%	(W) t	(W) t rated power	(W) t	Pinv (W) t
3.1	0.85	90	47.0850	137.085	161.276
3.6	0.85	90	73.7400	163.740	192.635
2.6	0.85	90	27.7790	117.779	138.563
4.2	0.85	90	117.097	207.097	243.643
2.2	0.85	90	16.8290	106.829	125.681
3	0.85	90	42.6740	132.674	156.087
3.5	0.85	90	67.7640	157.764	185.605
2	0.85	90	12.6440	102.644	120.758
3	0.85	90	42.6740	132.674	156.087
4	0.85	90	101.152	191.152	224.885
2.6	0.85	90	27.7790	117.779	138.563
2.8	0.85	90	34.6950	124.695	146.700

According to the measured wind velocity, the result were divided into three sections (low, medium and high) depending the mathematical statistics work between (2,3.6 and 4.2) m/sec. According to Eq. 1, the velocity of wind turbine was calculated and clearly showed in Table 5.

Power law exponent (α_1), arias between (0.6) for stable air and (0.27) for unstable air above human inhabited areas, however, in case neutral air above human inhabited areas take (0.34) (Kaltschmitt *et al*., 2006). Figure 7 explain how the wind speed increase when the power law exponent (α_1) reduced. To calculate the power consumed by the load at hour, Eq. 2-4 were used and Table 6 also shown that.

Figure 8 indicates the relationship between wind turbine andpower generator with higher wind speed a maxing power generating can be reduced. Such that higher the wind speed increases the power generation.

Thus, increasing total energy and thus, increasing the storage capacity added to the energy generated by the solar cells. This is confirmed by theoretical and practical calculations. From Eq. 5 by taken:

- *ρ equal 1.146 kg/m^3@ temperature 35°C (Cengel and Boles, 2002)
- **C_p values limited between (0.35-0.45) represent the best engineering design of wind turbines, it a variable with the tip speed ratio of the turbine (Manyonge *et al*., 2012)

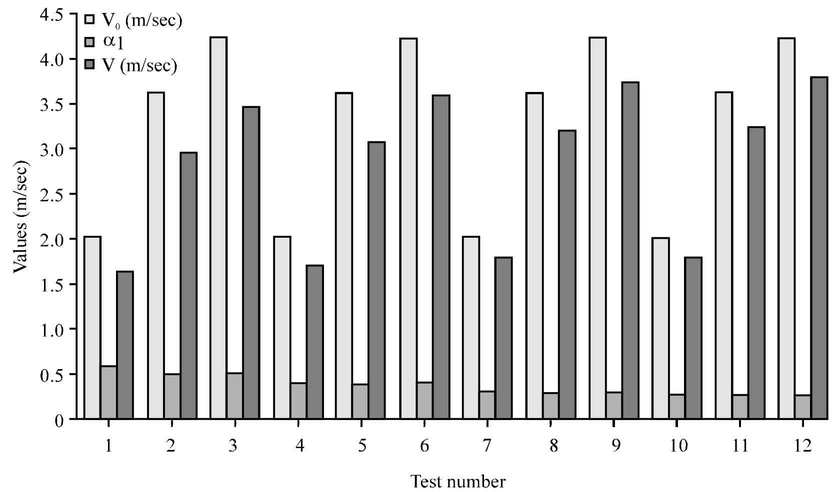

Fig. 7: Relationship between wind speed and wind turbine of HAWT

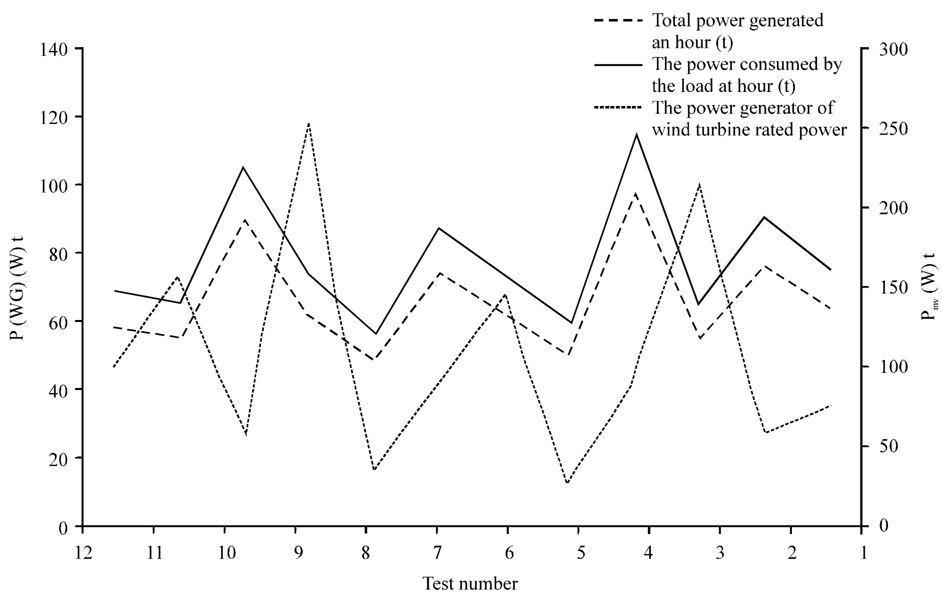

Fig. 8: Power generator of wind turbine with the power consumed for the samewind observation

Table 7: Calculate the avail power from wind generator depend on power coefficient

No. of test	Speed	V (m/sec)	ρ* (kg/m^3)	A (m^2)	C_p	P_{avail} (W)
1	Low	1.633	1.146	2.758	0.300	2.0650
	Medium	2.939	1.146	2.758	0.300	12.036
	High	3.429	1.146	2.758	0.300	19.115
2	Low	1.701	1.146	2.758	0.350	2.7220
	Medium	3.061	1.146	2.758	0.350	15.864
	High	3.571	1.146	2.758	0.350	25.188
3	Low	1.771	1.146	2.758	0.400	3.5110
	Medium	3.188	1.146	2.758	0.400	20.482
	High	3.719	1.146	2.758	0.400	32.515
4	Low	1.793	1.146	2.758	0.450	4.0990
	Medium	3.227	1.146	2.758	0.450	23.898
	High	3.764	1.146	2.758	0.450	37.924

Figure 9 explain how much the deference between the effect of C_p with wind speed generator to produce power coefficient that collected in Table 7.

The life span of this hybrid system can be considered 10 years according to the manufacturer of the solar cells. The storage battery needs to be changed several times during this period. Table 8-11 and Fig. 10 and 11 explain the capacity of battery with deferent time of charge.

From Table 4 and 7 when the capacity ofbattery generated by the PV and wind generators is negative that is mean the power needed by the load more than storage

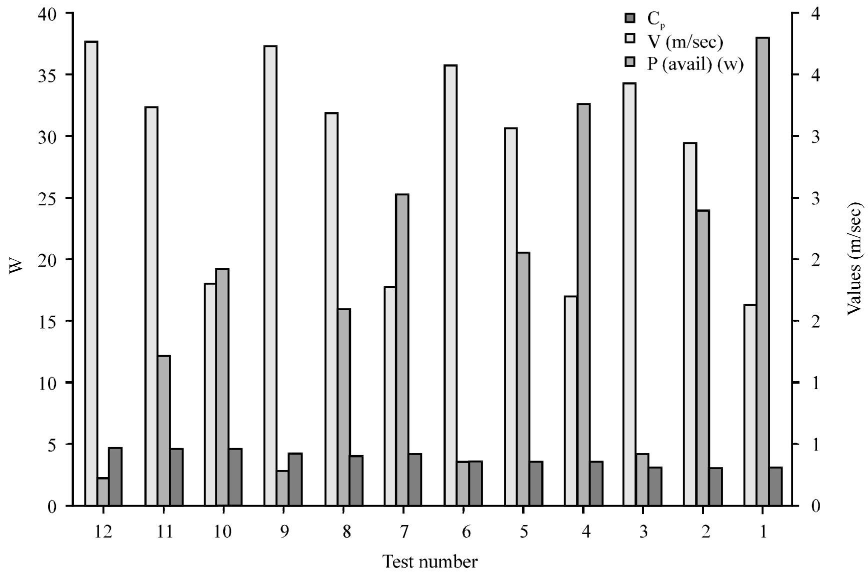

Fig. 9: Deference in avail l power from wind generator depend on power coefficient and C_p

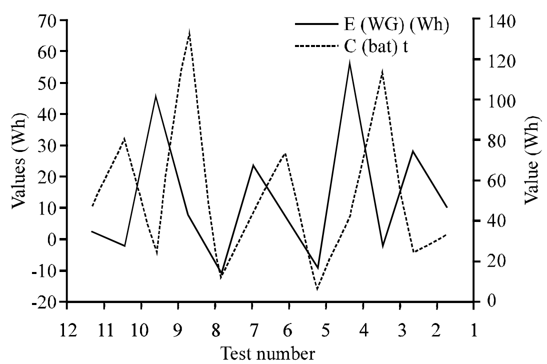

Fig. 10: The deferent in time required to charge the battery

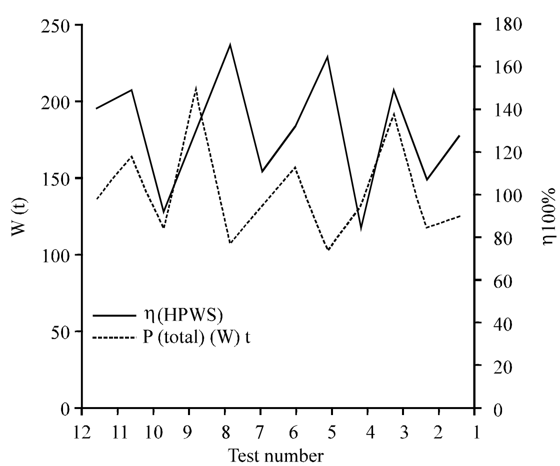

Fig. 11: HPWS efficiency

Table 8: Calculatecapacity of battery

C_{ab}* (t-1)	σ (%)	E_{PV} (Wh)	E_{WG} (Wh)**	E_L (Wh)	ζ_{inv}	ζ_{bat}	C_{bat} (t) (Wh)
80	0.2	90	47.085	175	0.85	0.773	10.820
80	0.2	90	73.740	175	0.85	0.773	31.424
80	0.2	90	27.779	175	0.85	0.773	-4.1040
80	0.2	90	117.097	175	0.85	0.773	64.939
80	0.2	90	16.829	175	0.85	0.773	-12.568
80	0.2	90	42.674	175	0.85	0.773	7.4100
80	0.2	90	67.764	175	0.85	0.773	26.805
80	0.2	90	12.644	175	0.85	0.773	-15.803
80	0.2	90	42.674	175	0.85	0.773	7.4100
80	0.2	90	101.152	175	0.85	0.773	52.613
80	0.2	90	27.779	175	0.85	0.773	-4.1040
80	0.2	90	34.695	175	0.85	0.773	1.24200

*From battery properties Table 3; **Hours of use: 1 h (from Eq. 5-6) pm by using ceiling fan andenergy saving lighting with 1 piece each

Table 9: The amount of time allocated to charge the battery by the hybrid system

C_{bat}(t) (Ah)	P_{tot}(A)	C_T(h)
80	10.116	7.908
80	11.187	7.151
80	9.3520	8.554
80	12.591	6.354
80	9.0300	8.859
80	9.8710	8.105
80	11.067	7.229
80	8.7640	9.128
80	9.8710	8.105
80	12.317	6.495
80	9.3520	8.554
80	9.6680	8.274

capacity. But in the positive state, the desired load is less than the amount of stored energy and this is required to provide excess storage energy.

In order to ensure the validity and integrity of the hybrid system. Be sure to check it out or check the amount of error that accompanies the research. For this reason, we can follow the number of Eq. 8 and 9:

Table 10: Find out how error in the HPWS

Hybrid system			
Practical		Theoretical	
Voltage	23 V for wind	Voltage	12 V for wind
I	R = 2.2 R, I = V/RI = 23/220 = 0.105 A	I	5 A
Power	P= V * I = 23* 0.105 = 2.405 W	Power (total)	P = V*I = 12*5 = 60 W

Error = 2.405/60 = 0.04 = 4%

Table 11: The efficient in the HPWS

Pload W(h)	P_{total} (W) t	ζHPWS
175	137.085	127.658
175	163.740	106.877
175	117.779	148.583
175	207.097	84.5010
175	106.829	163.813
175	132.674	131.902
175	157.764	110.925
175	102.644	170.492
175	132.674	131.902
175	191.152	91.5500
175	117.779	148.583
175	124.695	140.342

$$\text{Error} = \text{Practical/Theoretical} \quad (8)$$

$$\zeta_{HPWS} = \frac{\text{Useful energy output}}{\text{Energy input}} = \frac{P_{load}}{P_{total}} \quad (9)$$

CONCLUSION

The province of Diyala needs electricity (1120 MW) daily while currently processing (520 MW) from only four sources. The current research is characterized by low cost design and if it is matched with other engineering designs, this cangive the advantage of spreading over the houses in the study area. For example, this proposed design has not been prepared for 2000 homes. Table 5 was calculated the outcome of the system generated by the system. Despite the simple energy it generates, the total generated by this model will be (166 Wh). If it takes the hours of operation 6 h a day, it will generate a single home (995.24 Wh). The total will be around (1990483 Wh = 1.9 MW). A value that is not negligible because it comes from a free and renewable source. This is what aspired to in this research. This is a preliminary study that can be improved with further modifications to the initial design. Thus, it is possible to reduce the consumption of fossil fuels of all kinds and reduce the emissions resulting from the generation of electricity.

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