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Potentiometry of wind power of the regions of northwest of Iran and generation of 10 kw/h electric power by the use of wind energy at the height of 3475m

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Abstract

Nowadays, in consideration of shortage of the sources of fossil energy on the one part, and non-generation of electric power at the far and arduous zones on the other part, the necessity of consumption of renewable energy is revealed more than past. In the present research, because the area is out of reach and as there is a high potential of wind, the wind turbines are used in order to generate power in this area. Thus, by the application of the hourly and daily wind statistics for a period of 5 years from the station of the   of northwest Iran, the Potentiometry researches of the zone is performed, and on this basis, the average of wind velocity is resulted as 11.1 m/s, the wind power density is resulted as 953.6 W/ m2, the wind change coefficient is resulted as 46.78% and the wind constancy coefficient is resulted as 16.54%. The direction of the dominant wind at the said station is south-western direction and its frequency percentage is 32.3%. Such a zone may be considered as one of the most appropriate zones to exploit wind energy. Furthermore, for the purpose of generation of electric power of 10 kW/ h, the wind turbines of 3Kw, 7.5Kw and 10Kw together with hybrid of diesel generator are studied as 3 different scenarios. The results of economic and technical analysis are stated by the application of Homer Software.

Keywords: Renewable energy, 10 kw/h power system, wind turbines, diesel generators, homer

1. Introduction

In consideration of ever-increasing need of the world for energy, and whereas, there are shortage in the sources of fossil energy, the necessity of consumption and usage of renewable energy beside the sources of fossil energy has emerged more than before. The necessity of consumption of the independent renewable sources exists in two general status; when connection of the load to the power network is impossible, and when procurement of fossil fuel required at the zone is much costly and expensive [1] .A suggestion for being dominant to alternativeness of the sources of renewable energy, such as solar energy and wind energy is to develop the system of hybrid energy, through which we may convert and store the extra electrical energy. Such sources, together with energy storage, may provide a system of better dependability and reliability, which may be appropriate for independent usage of the network. In this way, in the present study, in consideration of the climate conditions of the zone, the hybrid energy system of wind and diesel generator is used together with the battery storage system. Among the emerging energies, the wind energy is of special place because of high level of energy generation efficiency, easy access and compatibility with the environment. The purpose of this research is to present the results of technical and economic analysis of 10 Kw electric power generation in the northwest border strip of Iran, which is simulated and optimized by the application of HOMER Simulating Software.

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2. Geographical Conditions of Northwest of Iran

The area in question for generation of electric power is located on the northwestern border strip at the height of 3475 m from the sea level, at the latitude of 45°.00′ to 45°.70′ of the northern grade and the longitude of 36°.32′ to 36°.40′ of the eastern grade, and because this zone is hard to access, and there is no electric power facility for connection to the network, and as there is no appropriate solar radiation and intense weather coldness, the wind turbines are used for generation of electric power. In this research, the Potentiometry is conducted on the basis of the statistics of the hourly and daily 5-year winds from the station of the border zone of the northwest Iran. Direction and wind velocity, speed on the border strip of the northwest are classified according to the Table 1 and Table 2.

Table 1. Frequency percentage of wind velocity direction in northwest at the heights of 3475m

Wind direction	North	North West	West	South West	South	South East	East	North East
Frequency	364	34797	427	42597	204	19794	298	32991
Percentage	0.28	26.47	0.32	32.4	0.16	15.06	0.23	25.09

Table 2. Average of wind velocity in different months in the northwest on the heights of 3475 m

Month	Average Northwest velocity	Maximum Northwest velocity	Dominant Northwest velocity
January	15	39.6	12.4
February	14.9	33.3	11.4
March	13.4	31.8	11
April	10.9	23	9.7
May	9.9	19.2	8.3
June	9.4	19.2	7.3
July	7.8	18	7.1
August	7.8	16.4	7
September	9	21.8	7.4
October	11.6	27	10.2
November	11.1	29	9.6
December	12.8	30.1	11.8
January	11.1	25.7	9.4

Table 3. Classification of wind velocity in the station of the northwest at the height of 3475 m, in the statistical years 2009 to 2014, taking into consideration the mild and gentle wind

Wind groups	V/ms	Vi	Fi	vi^3	p(vi)	Fivi	Pvi	$(vi-v)^2$	$Fi(vi-v)^2$	$p(vi)vi^3$
Gentle wind	0.6-1.9	1.25	1684	1.95	1.28	2105	0.01	98.98	166682.32	2.5
	2-3	2.5	3379	15.62	2.57	8447.5	0.04	75.67	255688.93	40.16
	3.1-5	4.05	11291	66.43	8.59	45728.5	0.13	51.11	577083.01	570.63
Average wind	5.1-8	6.55	21591	281.01	16.42	141421	0.29	21.61	466581.51	4614.2
Wind storm	8.1-10.5	9.3	24157	804.35	18.37	224660.1	0.47	3.61	87206.77	14776.04
Intense wind	10.6-13.5	12.05	29915	1749.69	22.75	360475.7	0.7	0.72	21538.8	39805.45
Storm	13.6-16.5	15.05	21789	3408.86	16.57	327924.4	0.87	14.83	323130.87	56484.86
	16.6-20	18.3	10557	6128.48	8.03	193193.1	0.95	50.42	532283.94	49211.75
Typhoon	20.1-23.5	21.8	4431	10360.23	3.37	96595.8	0.98	112.38	497955.78	34913.98
	23.6-27.5	25.55	2164	16679.10	1.65	55290.2	1	205.95	445675.8	27520.52
	27.6-31.5	29.55	272	25803.13	0.21	8037.6	1	336.76	91598.72	5418.66
	31.6-35.5	33.55	161	37763.96	0.12	5401.55	1	499.57	80430.77	4531.68
	35.6-39.5	37.55	49	52945.59	0.04	1839.95	1	694.38	34024.62	2117.82
	39.6-43.3	41.45	32	71215.34	0.02	1326.4	1	915.12	29283.84	1424.31

In the Table 3, V/ms stands for classification of velocity (speed) from the point of view of the international standard, vi stands for the average of velocity in each class, Fi stands for the frequency of the wind velocity of each class and p(vi) stands for the percentage of frequency of wind velocity of each class.

Calculation of the wind density in a geographical zone is the first and most essential matter to use the wind energy and to estimate the potential and the other characteristics of wind [2]. Therefore being aware of the annual average velocity and wind power density will be of special importance in selecting a place to establish a wind power plant [4], [5].

$$p = \frac{1}{2}\rho A \sum_{i=1}^{n} p(v_i)v_i^3 / 100 \quad (1)$$

In this zone in question, on the basis of the height from sea level, the density is selected as 0.79 kg/m^3.

Coefficient of Variations of Wind C.V: This coefficient is expressed on a percentage basis and is also called Confusion Coefficient, and is resulted form dividing Standard Deviation to Velocity Average [3].

$$c.v = \frac{s}{v} \times 100 \quad (2)$$

In which v and s, are respectively, the target speed and standard deviation.

$$V = \frac{1}{n}\sum_{i=1}^{n} F_i V_i ... S = \left[\frac{1}{n-1}\sum_{i=1}^{n} F_i (v_i - v)^2\right]^{\frac{1}{2}} \quad (3)$$

Coefficient of Permanence of Wind C.P is also called Perseverance Coefficient of Wind . The size of the resulted wind and the angle of the direction of wind blowing in the station in question inclduing tan, is equal to the amount resulted from the formula 4:

$$\begin{aligned} U_x &= \frac{\sum W - \sum E + 0.707(\sum NW + \sum SW) - 0.707(\sum NE + \sum SE)}{n} ... R = \sqrt{U_x^2 + U_y^2} \\ U_y &= \frac{\sum S - \sum N + 0.707(\sum SW + \sum SE) - 0.707(\sum NE + \sum NW)}{n} ... \tan\beta = \frac{U_x}{U_y} \end{aligned} \quad (4)$$

n is the number of watching turns of wind, which has been applied in the calculation, N ،NE ،E ،SE ،S ،SW ،W and NW stand for the lone velocities of the wind from different directions. The constancy coefficient of wind is resulted from the formula 5 taking into account the amounts of U_x, U_Y, R and V.

$$C.P = \frac{R}{V} \quad (5)$$

From among the total of 131472 cases of views of wind, taking into consideration the wind blowing direction, the most blowing was related to the southwestern side at 32.4% and the less was related to the northern direction at 0.28%. The northwestern direction, after the southwestern direction has had the most percentage of wind blowing 26.47% in the statistical period.

Aside from the percentage of gentle wind, the velocity classes of 2-3 m/ s and 3.1-5 m/ s, respectively, allocated 2.57% and 8.59% of the number of wind blowing in the statistical period. The storms, windstorms and violent and destructive winds during the statistical period, have possessed about 5.41%, 24.6% and 22.75% of the entire blows. The average of the wind velocity in winter, spring, summer and fall, are, respectively, 15.1 m/s, 10.4 m/s, 7.8 m/s and 11.4 m/s. The average velocity of wind in the warm and cold biannual of the year, is, respectively, reported as 13.2 m/s and 9.1 m/s. The gentle wind appropriates a trifling percentage of the statistics in question. The average of the wind velocity in this region is resulted as 11.1 m/s. The wind power density which is of special importance in consumption of wind energy and estimate of its potential in geographical regions, is estimated at 953.6 W/m^2. Therefore, in consideration of the wind density resulted in this region, the increase in power is of high importance in this station. The coefficient of variations or wind confusion intensity is 46.78%. The coefficient of permanence which is very significant in feasibility of consumption of wind energy in a region, is resulted as 16.74% for the station in question. The amounts of U_x, U_y, R and tanB for the region in question, are, respectively, 1.82, -0.42, 1.87 and -4.27.

The coefficients of variation and permanence of wind, both, determine the variations of wind velocity. But we should consider that, the coefficient of variations is only a criteria of variations of numerical velocity of wind, but the permanence coefficient, is a relative comparison between the numerical and vector means and averages of wind, and if the permanence coefficient is equal to 0, indeed, the resulted velocity R should be 0, and such a matter indicates that the wind is blowing from the opposite direction and is distributed in all directions. Therefore, the most desirable region from the point of view of wind energy, is a region in which all the variations coefficients of the wind are the least amounts and the permanence coefficient is relatively the maximum amount. The wind flow in the said region is almost constant, and the wind energy in this region may be consumed in the best manner. On the northwest border strip of Iran, the average velocity of wind is in desirable limit, but the coefficient of variations of wind is relatively high and the constancy coefficient is relatively medium and in an acceptable level.

3. Simulation and Site Systems of Northwest Region

3.1. Specifications and needs of consumer

In order to conduct more careful studies in the site, the simulation of the system, Fig. 1 (a), is performed in three states, and such states, has, respectively, applied the wind turbines of 3 Kw, 7.5 Kw and 10 Kw, together with diesel generator. In Fig. 1 (b), the amount of need of the consumer within the hours of night and day is shown, and on this basis, the amount of need of the consumer is 240 kWh/ day.

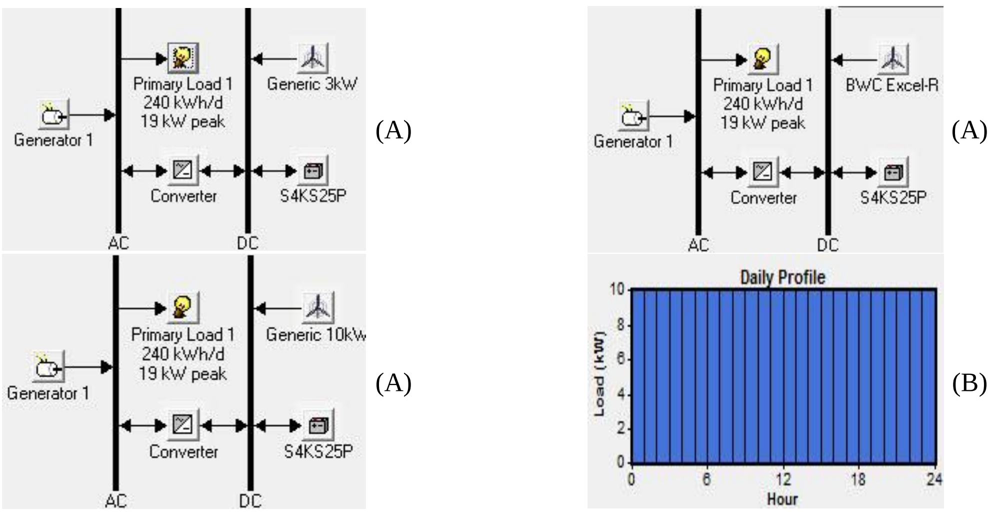

Fig. 1. (a) Diagram of hybrid of wind turbine and diesel tenerator (b) estimate of daily consumption .

3.2. Wind turbine

In order to simulate the system, the wind turbines of 3 Kw, 7.5 Kw and 10 Kw are applied, and the Table 4, describes the expenses of wind turbine. As you observe in Table 4, O&M are estimated as the expenses of maintenance and repair for the various turbines in the year.

Table 4. Expenses of investment of wind turbine [4]

Quantity	Quantity	Capital($)	Replacement($)	O&M ($/yr)
Generic 3Kw	1	5216	4173	200
BWC Excel-R 7.5Kw	1	9354	7483	200
Generic 10Kw	1	11408	9126	200

3.3. Battery

The battery selected for simulation in this site is of kind LEAD-ACID. The privilege of this kind of battery in comparison with the similar cases is the high efficiency, low expenses and low level of self-discharge [5]. In this project, the batteries of each row are connected to each other on series basis. In this site, the SURRETTE 4KS25P battery is used The specifications of the battery is 1900 Ah and 4V, and taking into consideration this matter that the system voltage is 24 V, therefore, 6 batteries will be put together on series basis to supply the system voltage [6]. The price of battery is given in Table 5.

Table 5. Expenses of surrette 4KS25P battery

Quantity	Capital($)	Replacement($)	O&M ($/yr)
1	1230	738	0

3.4. Transformer

A transformer with the capacity of 20 Kw, which converts the voltage 24 V, Dc to Ac, is applied in Table 6.

Table 6. Expenses of Transformer [7]

Size(Kw)	Capital($)	Replacement($)	O&M ($/yr)
20	4830	4830	0

3.5. Diesel

In order to supply a part of electrical energy of the hybrid system, a diesel generator may be used, and such a matter may decrease the site expenses. The price of diesel generator is given in Table 7. The limitation of fuel which is taken into consideration for this site is 547.5 L/ye (liter per year) of diesel oil, and taking into account the diesel oil price at 0.2 dollars per liter.

Table 7. Expenses of diesel generator [8]

Size(Kw)	Capital($)	Replacement($)	O&M ($/hr)
3	2990	2400	0.05
5	4984	4000	0.05
10	9000	7890	0.05

In order to prevent the diesel generator to be turnoff, when intense wind is blowing, it is suggested to apply the invented plan of Fig. 2 inside the exhaust of diesel generator, so as to decrease the pressure of entry air to the exhaust.

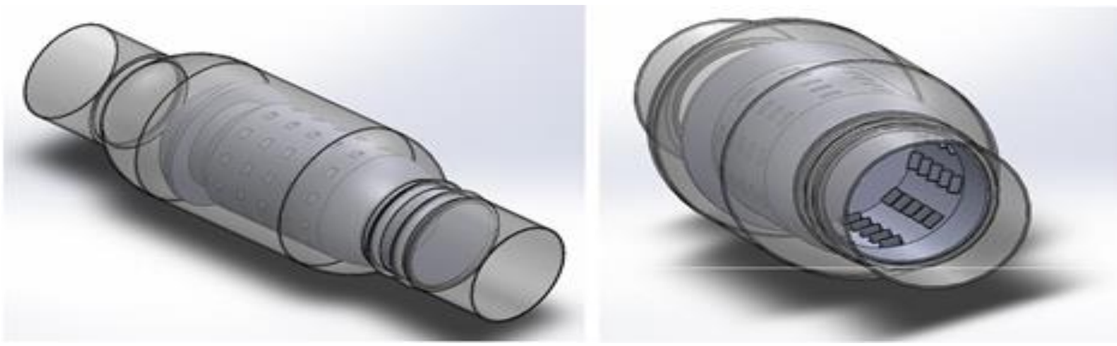

Fig. 2. Plan of prevention of the diesel generator to be Turned-off.

4. Results

Table 8 indicates the system dimensions, expenses and the extra power generated. Table 9 shows the amount of energy generated in both states, first for the single wind turbine, and second for the hybrid of diesel generator and wind turbine; Fig. 3A and 3B show the battery charging and discharging in various scenarios, at the time of application of hybrid of diesel generator and wind turbine, and when the wind turbine is the only system of power generation.

Table 8. Results of simulation of hybrid of wind and diesel generator

Wind Turbine	Numb Turbine	Diesel Power	Numb S4KS25P	Conv (kw)	Initial Capital($)	Operating Cost($/yr)	COE ($/kwh)	Diesel Full(lit)	Label Hours	Excess electricity (%)
3Kw	6	3kw	2400	18	2,990,583	75,598	3.534	547	553	0.203
	6	-	3000	18	3,725,593	93,835	4.398	-	-	0.206
7.5Kw	3	10kw	180	20	263,292	6,804	0.313	336	340	22.3
	3	-	420	20	549,492	14,185	0.653	-	-	21.4
10Kw	2	3kw	1200	20	1,506,636	37,889	1.778	547	553	2.46
	2	-	1800	20	2,241,646	56,127	2.643	-	-	2.49

Table 9. Power generated and share of each system detail in simulated systems

Wind energy and hybrid diesel	Production (%)	Production (Kwh/ye)	Total Production	wind energy	Total Production
Wind Turbine 3Kw	98	96,735	98,394	Turbine 3Kw	96,735
Generator	2	1,659			
Wind Turbine 7.5Kw	99	137,247	138,420	Turbine 7.5Kw	137,247
Generator	1	1,173			
Wind Turbine 10Kw	98	107,422	109,081	Turbine 10Kw	107,422
Generator	2	1,659			

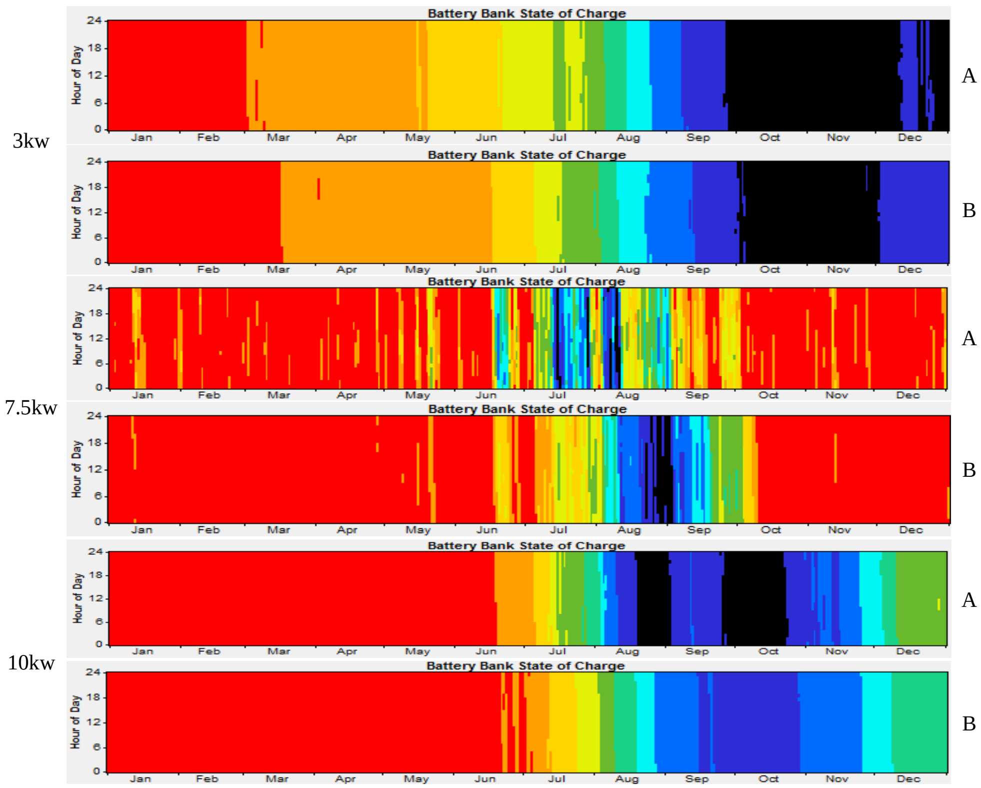

Fig. 3. Charge and discharge rate of battery (A) hybrid system and (B) wind turbine system.

5. Conclusion

1- Application of diesel generator with the burnable volume of 1 to 1.5 liter per day may cause economic thriftiness up to 30%.

2- Application of the diesel generator and its hybrid with wind turbine may decrease the number of times of battery charge and discharge and may increase the battery life, because the resulted power is directly entered into the circuit.

3- In the 2nd scenario, i.e. wind turbine of 7.5 Kw, because the battery is fully charged, it has benefited from the smaller storing system during a longer time, and therefore, in this scenario the amount of power generated is more than the other scenarios, according to the Table 9.

4- The best scenario selected for northwest site of Iran is to apply 7.5-Kw wind turbine, because this scenario is of the most compatible nominal power in comparison with the other scenarios from the point of view of generation of 10 Kw/H power, therefore, power generation in this state is more profitable than the other states from the point of view of economic aspects.

5- Whereas the consumers are of large volume and occupy larger spaces, it would be better to use the batteries with higher level of ampere/hour power so as to occupy less space.

References

[1] Mahmoudi H, Abdul-Wahab SA, Goosen MFA, Sablani SS, Perret J, Ouagued A, Spahis N. Weather data and analysis of hybrid photovoltaic-wind power generation system adapted to a seawater greenhouse desalination unit designed for arid coastal countries. *Desalination*, 2008; 222(1):119-127.

[2] Abdel-Qader M. Simulation of a hybrid power system consisting of wind turbine, PV, storage battery and diesel generator with compensation network: design, optimization and economical evaluation. MS thesis. Clean Energy and Energy Conservation Department, An-Najah National University. Nablus, Palestine; 2008.

[3] Zahedi M, Jamil M, Salahi B. Calculate the energy density and wind power in order to use it in Ardabil, Iran. *Journal of Geographic Iranians*, 2006; 53(1):1-17.

[4] Kanase-Patil A, Saini R. Integrated renewable energy system for off grid rural electrification of remote area. *Renewable Energy*, 2010; 35(6):1342–1349

[5] Larsen K. Smart grids-a smart idea. *Renewable Energy Focus*, 2009; 10(5):62-67.

[6] Purohit I, Purohit P. Wind energy in India: Status and future prospects. *Journal of Renewable and Sustainable Energy*, 2009; 1(4):1-20.

[7] Rajoriya A, Fernandez E. Sustainable energy generation using hybrid energy system for remote hilly rural area in India. *International Journal of Sustainable Engineering*, 2010; 3(3):219-227.

[8] Attala A, Taha A, Ahmed R. Evaluation of different hybrid energy potential in AL-Arish, *International Journal of Computer Applications*, 2014; 88(17):0975–8887.