ВЕСТНИК
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МОРСКОГО И РЕЧНОГО ФЛОТА ИМЕНИ АДМИРАЛА С. О. МАКАРОВА

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THE IMPACT OF REGION NATURE ON WIND TURBINE POWER PRODUCTION

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In the context of climate change, the implementation of renewable energy sources is becoming not only a trend, but also a necessity. The expansion of human habitat especially along waterways leads to the installation of long power lines, often vulnerable to accidents and vandalism. Energy complexes based on renewable energy sources can serve as an alternative. The behavior and the cost of a renewable power system that includes wind turbine module can be affected by the nature of system establishment location. In particular the air flows along the rivers could greatly increase the power generation of wind turbines installed on the river banks. In addition to that navigable rivers should be equipped with navigation equipment (buoys, differential stations, etc.) which could be powered from the local renewable based power stations. This research work concentrates mainly on studying the impact of surface nature on the behavior and the cost of a hybrid power station of solar system and wind turbine module. However, the hybrid power station is dominated significantly by wind turbine module. Three different critical surfaces in Amarah city - Iraq with respect to their anemometer height variations are studied. The proposed surfaces that have natural impairments are chosen to be in few trees, forests (woodlands), and city center (tall building) regions. The simulation results based on Homer software have shown that the performance and the design cost of the system in city center (tall building) region is the best. Finally, the proposed hybrid system inspires future extension for more investment projects due to the awful excess power generated.

Keywords: Surfaces Roughness, Wind Power Stations, Hybrid Power System Evaluation, HOMER Software.

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ВЛИЯНИЕ ПРИРОДЫ РЕГИОНА НА ПРОИЗВОДИТЕЛЬНОСТЬ ВЕТРОЭНЕРГЕТИКИ

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Отмечается, что в условиях изменения климата внедрение возобновляемых источников энергии становится не только трендом, но и необходимостью. Расширение ареала человека особенно вдоль водных артерий приводит к установке протяженных линий электропередач, зачастую уязвимых для аварий и вандализма. Альтернативой могут служить энергокомплексы на основе возобновляемых источников энергии. Параметры и стоимость системы на основе возобновляемых источников энергии, включающей в себя ветроэнергетический модуль, могут быть в значительной степени обусловлены местными особенностями ландшафта. В частности, воздушные потоки вдоль пойм рек могут существенно повысить уровень генерации электроэнергии ветроэнергетическими установками, расположенными на берегу реки. Более того, судоходные реки должны быть оснащены навигационным оборудованием (буи, дифференциальные станции и т.д.), электроснабжение которых может осуществляться за счет электростанций на основе возобновляемых источников. Представленная исследовательская работа сосредоточена главным образом на изучении влияния природы поверхности на производительность и стоимость гибридной ветро-солнечной электростанции с преобладанием в структуре станции ветроэнергетического модуля. Изучены три различные критические поверхности в городе Амара (Ирак) с измерением скорости ветра на различных высотах. За основу исследований взяты поверхности, имеющие естественные препятствия и находящиеся в лесных массивах и в центре города с высотными зданиями. Результаты моделирования на основе *программного обеспечения Homer показывают, что производительность и стоимость проектирования системы в регионе с высотными зданиями являются наиболее оптимальными. Предлагаемая гибридная система имеет перспективы дальнейшего изучения и внедрения с целью организации инвестиционных проектов в связи с высоким прогнозируемым уровнем генерируемой энергии.*

Ключевые слова: шероховатость поверхностей, ветроэлектростанция, оценка гибридных энергосистем, программное обеспечение HOMER.

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Introduction

The impression of power production based on renewable energy systems has recently fascinated the world due to the great role that is played by such systems to struggle the ultimate change of the climate conditions and to decrease the endless risks of the modern machineries. Apparently, the influence of wind turbine models to produce sustainable power systems might be sensible and clear nowadays particularly in the highlands and mountain terrains. In addition to that due to the air flows along the rivers, the banks not suitable for living but with open terrain, could be used for installation of wind turbines, solar power stations and other electric supply equipment, which could power the local navigation equipment, etc. It is worth mentioning that the generated power based on wind turbine models can be increased eight times with doubled speed depending on the cubic function to measure wind effectiveness. To be more precise, the average wind speed of 8 m/s in some specific places can generate power around (75 – 100) % greater than other places with lesser wind speed average. The annual information of the wind speed was given based on Amarah city – Iraq in 2014 – 2015. Moreover, wind speed data is collected form Weather Underground Organization (WUO) [1, 2] at station elevation with respect to wind speed results that assigned as wind resource input in Homer based measured and Weibull monthly and annually estimation of wind speed average [3]. The Tigris river is crossing the city, represents the clear place without obstacles, could be used both for installation of wind turbines and solar power stations. Since the water transportation requires lots of electric powered navigation equipment, the generation level could be further increased and successfully used for the reduction of power consumption, at the same time improving the quality of water transport navigation. In particular the team of authors had invented the small 3 kW wind turbine based on the river buoy, presented in Fig. 1.

Fig. 1. Small 3 kW buoy based vertical axis wind turbine developed by the author team

Undoubtedly, the wind energy is one of the cleanest forms of producing power from a renewable source. However, such systems are not that easy to be installed without effecting on the efficiency of the module. Hereby, there exist four major factors effect considerably on the efficiency of wind turbine units. These factors are identified as follows:

A. Wind Power

The power of the wind blowing in specific location effects considerably on the amount of realized power such that faster wind speed and stronger wind force generate greater amount of power produced by a wind turbine [4, 5].

As an equation, the whole mater can be expressed as follows:

$$P = kVF$$

Where P — represents the power of the wind; V — is the wind speed; F — is the wind force, and k i — s constant.

It is worth mentioning that each region has its own wind speed. Hence, it is necessary to understand the relationship between wind speed and the amount of the realized power correspondingly.

B. Altitudes and Obstacles

The wind speed in the higher locations is considered considerably faster due to the numerous atmospheric factors [5]. In addition, these locations have fewer obstacles from the adjacent hills, trees, and higher buildings. It can be stated that around 12 % wind speed elevation will be realized as the distance between the ground level and the turbine extended to be doubled [1].

The speed of the wind is slowed by trees, buildings, hills, and mountains, which all create a certain form of friction that limits the blowing of the air. In order to ensure the continuity of a project, a wise decision is measuring the speed of the wind in the proposed site minimally for one year.

C. Air Temperature

The temperature of the wind plays a prominent role in dominating the efficiency of the generated power from wind turbine module [6]. It can be stated that the power from a wind turbine can be increased about 16% as the temperature decreased around the range (+20^{o}C) – (-20^{o}C) for any given wind speed.

D. Blade Aerodynamics

The maximum power efficiency based on wind turbine modules, depends mainly on the shape of the blades chosen to establish a wind power source. Hereby, the nature of the blades should be accurately taken into consideration. In addition, the amount of the lift for a specific airfoil depends considerably on the direction of the wind that generates the angle of the wind blowing up. This means, that as long as the angle is chosen to be larger, the intensity of the disturbance increases leading the lift to be vanished.

As a final point, a comparison based on standalone vs grid extension system was done using HOMER software [7] in this paper to reveal the cheapest design with respect to break-even distance as the example illustrated in [8].

Homer Software

Homer is one of the best power optimization programs due to wide usability and demand all around the universe. The program is identified and developed through Mistaya engineering specialized for the employ and implementation of national renewable energy laboratory (NREL) in USA. This organization fascinates the difficulties regarding appreciation issues for the design of grid connected and renewable solar systems based on different components [9]. The decision simplifications of HOMER fascinated the designer due to the harsh conditions that energy and solar system were known due to the variation of the cost and the high technological prosperity nowadays appeared [10].

The Aim of Work

This research work concentrates only on the factor in section (B). The paper aims to demonstrate the impact of wind turbine height variation difficulties based on surface roughness lengths on the performance and cost of renewable power systems in HOMER software with respect to certain location and anemometer height.

Surface roughness is the term given to the critical locations that suffer from natural impairments such as blown sea, lawn grass areas, snow surface, heavy trees areas, city center that contains tall buildings [7], etc. which all dominate the power production of wind turbine units. It is worth mentioning that three surfaces natures are taken into account to prove the offered challenge, identified as shown in Table 1.

Table 1

The Chosen Surface Roughness

Surface Roughness	Lengths, m
Few trees	0,1
Forests and woodlands	0,5
City center and Tall buildings	3,0

The information shown in Table 1 is given by Homer software such that each surface roughness is linked with wind turbine hub height is suitable for the nature of the region.

Proposed System Argument

In this paper, the tendency is to feed a certain load input specified by 1.1 kW by sufficient power. Most of power units generate higher energy depending on hybrid or individual modules such as PVs, hydro turbines, wind turbines, and the other subcomponents identified by batteries, converters, and generators. In this work, it is proposed to generate electricity using hybrid module constructed of PV panel and Wind turbine in order to provide the identified load by the required energy. The power system is established at Amarah city with respect to anemometer heights above ground level. It is worth mentioning that the data of the proposed location is given based on measured and Weibull estimated parameters. To be more specific, the coordination of the proposed location is given with respect to the attitude and longitude as 31.83^o N, 47.17^o E [1].

Wind Resources Based Amarah City

The geographical impairments of Amarah city lead the anemometer height to be risen up to specific meters above ground level [1], [2] with respect to measured and Weibull estimated parameters in order to reach the desired wind resources that shown in Fig.2. The information bar confirms that the maximum wind speed can be realized in June and hence the maximum power production will be assigned in the same period accordingly. Measurements of wind speed on the banks of Tigris river are appr. 18 % higher than on the other terrains due to the extra air flows generated by the difference of pressures. However it should be analysed as a separate topic for locally installed power based on renewables.

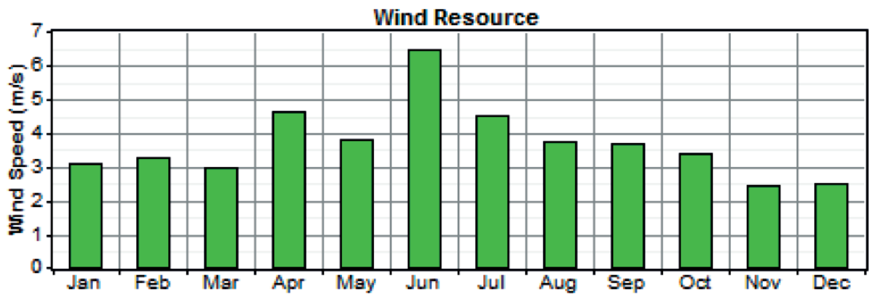

Fig. 2. Wind speed information of Amarah city

Load Setup Process

The load input is chosen to be specified by 1.1 kW – 11 kWh/d and assigned as a virtual residential load type with power consumption of 24 hours as shown in Table 2.

Table 2

Primary load power requirements

Hour	Load, kW	Hour	Load, kW
00:00 – 01:00	0.200	12:00 – 13:00	0.600
01:00 – 02:00	0.200	13:00 – 14:00	0.600
02:00 – 03:00	0.200	14:00 – 15:00	0.600
03:00 – 04:00	0.200	15:00 – 16:00	0.600
04:00 – 05:00	0.300	16:00 – 17:00	0.550
05:00 – 06:00	0.300	17:00 – 18:00	0.550
06:00 – 07:00	0.400	18:00 – 19:00	0.550
07:00 – 08:00	0.500	19:00 – 20:00	0.550
08:00 – 09:00	0.500	20:00 – 21:00	0.500
09:00 – 10:00	0.500	21:00 – 22:00	0.450
10:00 – 11:00	0.550	22:00 – 23:00	0.400
11:00 – 12:00	0.550	23:00 – 00:00	0.300

Power System Establishment

The hybrid system module that is employed to confirm the aim and the challenge of this work is constructed of several components specified by:

1) photovoltaic panel (PV);
2) converter;
3) hoppecke H300 Battery;
4) PGE 20/25 Wind turbine module.

For more clarity, it is intended to unveil the connection scheme of the proposed power system modules in Homer software as shown in Fig. 3.

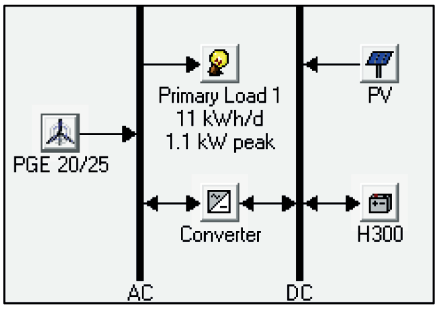

Fig. 3. Hybrid system module

1. Pv Module

Photovoltaic panel PV is the module that is employed to convert the incident sun light falling over the panel into electricity depending on the semiconductor materials that exist in the panel. In this research work, the size of the panel is specified by 2 kW since the load input is chosen to be around 1.1 kW peak. This means, the chosen PV size is extremely sufficient to provide the load by the required power. The cost items of the proposed PV panel are given as shown in Table 3, for lifetime of 25 years.

Table 3

Photovoltaic panel cost items

Size (kW)	Capital ($)	Replacement ($)	O&M ($ / year)
2.00	1400	1350	50

The average sun radiation in the proposed town [11], [12] is assigned as Homer input and specified as given in Table 4.

Table 4

Average sun radiation in the proposed city

Month	Clearness index	Daily radiation (kWh/m^2/d)
January	0.546	2.78
February	0.572	3.66
March	0.597	4.90
April	0.622	6.19
May	0.654	7.26
June	0.664	7.66
July	0.667	7.53
August	0.670	6.93
September	0.698	6.13
October	0.637	4.41
November	0.593	3.18
December	0.531	2.48

2. The Convertor

The convertor is the module that converts the generated DC voltage by the PV into stable AC voltage in order to feed the primary load with the required power. Similarly, the size of the convertor is specified in Homer by 2 kW to be compatible with the proposed load input. Moreover, the cost items of the proposed convertor for lifetime of 15 years are given as shown in Table 5.

Table 5

Convertor cost items

Size, kW	Capital, $	Replacement, $	O&M, $ / year
2.00	1000	950	50

1. Hoppecke H300 Battery.

These kinds of batteries are made of lead acid compound that are suitable for such energetic systems. The nominal specification of H300 battery module is specified by 2V, 300 Ah, 0.6 kWh [7]. Besides, the cost items of the battery for lifetime of 4 years are given as shown in Table 6.

Table 6

H300 battery cost items

Quantity	Capital, $	Replacement, $	O&M, $ / year
1	181	160	8

It is worth mentioning that Ampere hour term(Ah) that is usually appeared on the batteries is the amount of energy charges in a battery that allow one ampere of current to flow in one hour [10]. Hereby, Fig.4 satisfies this fact based on H300 battery module.

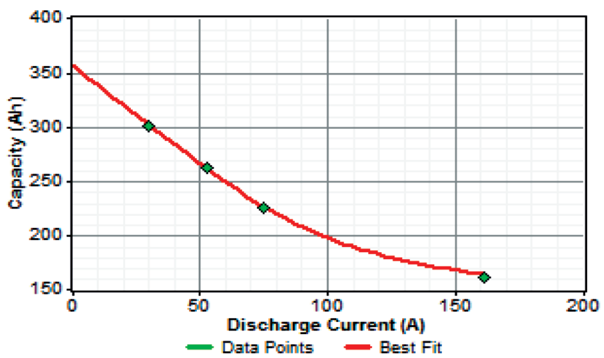

Fig. 4. Discharge curve of H300 battery module

2. PGE 20/25 Wind Turbine.

The proposed wind turbine is denoted as PGE 20/25, and specified by rotor diameter of 20m, 305 swept, 32 rpm, hub height of 25m and rated power of 25kW at 9m/s [7]. PGE 25, yields power around 25kW, this means that the generated power is extremely sufficient to feed the load input with the required power. The power curve regarding PGE 25 is unveiled intentionally as shown in Fig.5.

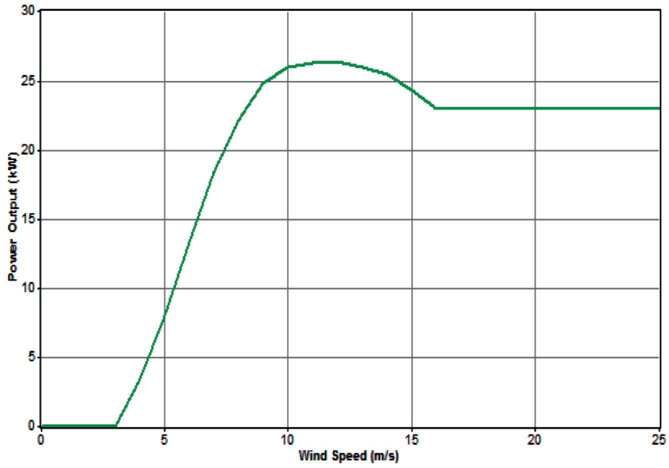

Fig. 5. Power curve of PGE 25

The quantity and cost items for PGE25 turbine are chosen for lifetime of 25 years [13] as shown in Table 7.

Table 7

PGE 20-25 wind turbine costs items

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	20000	16000	1000

Performance And Cost Evaluation

The proposed hybrid power station produces sufficient power required to feed the load effectively depending on both PV and wind turbine module in percentage. As mentioned before, that the aim of this work is to study the effect of the difficulties that might be encountered where the wind turbine is equipped in certain surfaces. Hereby, THREE surface impairments at Amarah city were studied in order to show the impact of the roughness on the performance and the cost of a power system as exposed in Table 8 & 9.

Table 8

Performance results

Surface Type	Wind Power	Solar Power	Total Power	Excess Electricity
	kWh / year			
Few trees	63.186	6.610	69.796	65.621
Forests	76.452	4.957	81.409	77.267
City center	127.441	3.305	130.746	126.718

Table 9

Cost results

Surface Type	Initial capital ($)	Operating Cost ($/year)	Total NPC ($)	COE ($/kWh)
Few trees	26.558	1.766	49.140	0.984
Forests	25.858	1.734	48.028	0.962
City center	24.072	1.664	45.084	0.903

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For more confirmation, it is intended to demonstrate the monthly average electric production with respect to the proposed surface types as shown in Fig. 6–8.

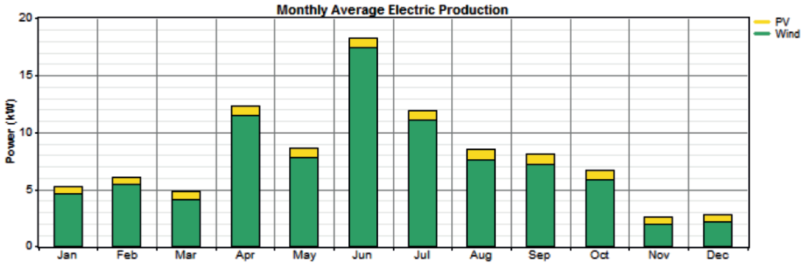

Fig. 6. Electric production in (Few trees) site

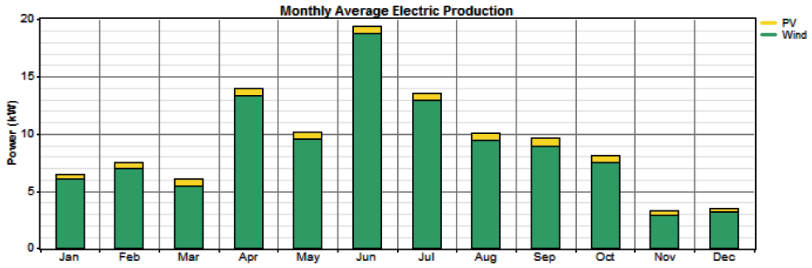

Fig. 7. Electric production in (Forests) site

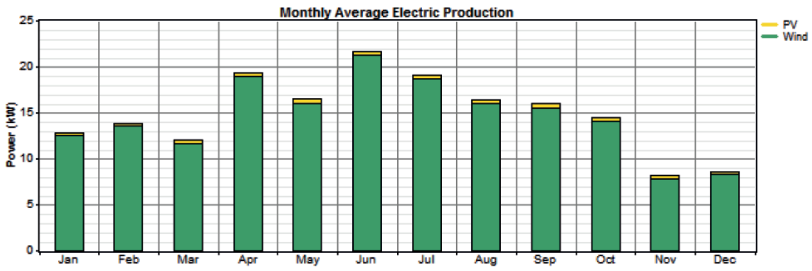

Fig. 8. Electric production in (City center) site

The three Figures 6–8 obey the performance results given in Table 8, and show the electric production of hybrid power station based on both solar and wind turbine systems in different percentages, with respect to wind turbine height variations identified in Table 1.

Moreover, the part that should pay attention is Table 10, which exhibits the excess electricity produced in each case study with respect to the height variations of the chosen surface roughness. The excess electricity results inspire future extensions for more investment projects.

Table 10

Excess electricity production

Surface Type	Lengths (m)	Excess Electricity (%)
Few trees	0.1	94
Forests	0.5	94.9
City center	3.0	96.6

Comparison With Grid Extension

The result of the comparison that was performed based on stand-alone vs grid extension demonstrates the minimum break-even distance with respect to extension inputs specified by the capital cost of 8000 $/km, operating and maintenance O&M of 160 $/year, and grid power price of 0.4 $/kWh . For more clarity, the result of the comparison over height variations is listed and demonstrated in Table 11.

Table 11

Stand-alone Vs Grid extension results

Surface Type	Lengths (m)	Grid extension distance (Km)
Few trees	0.1	2.90
Forests	0.5	2.79
City center	3.0	2.50

The breakeven grid extension distance means the minimum realized distance that makes the stand-alone system considered always economically inexpensive comparing with grid extension.

The results shown in curve Figures (9, 10 and 11) confirm that the stand-alone module proposed in each surface types in this work are considered better and cheaper than extending the grid, since the distance from the proposed location to the main power station at Amarah city is greater than the maximum distance in Table 11.

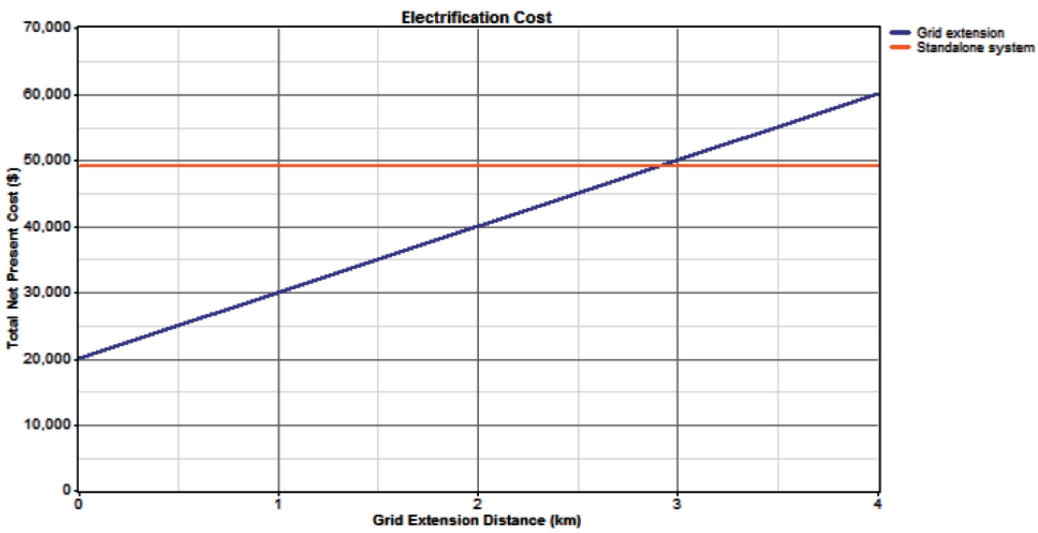

Fig. 9. Breakeven grid extension (Few trees)

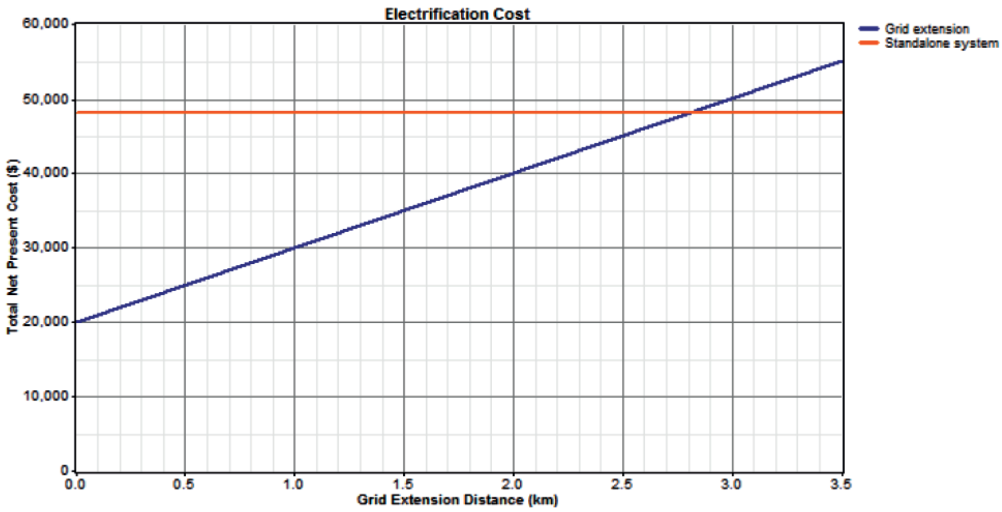

Fig. 10. Breakeven grid extension (Forests)

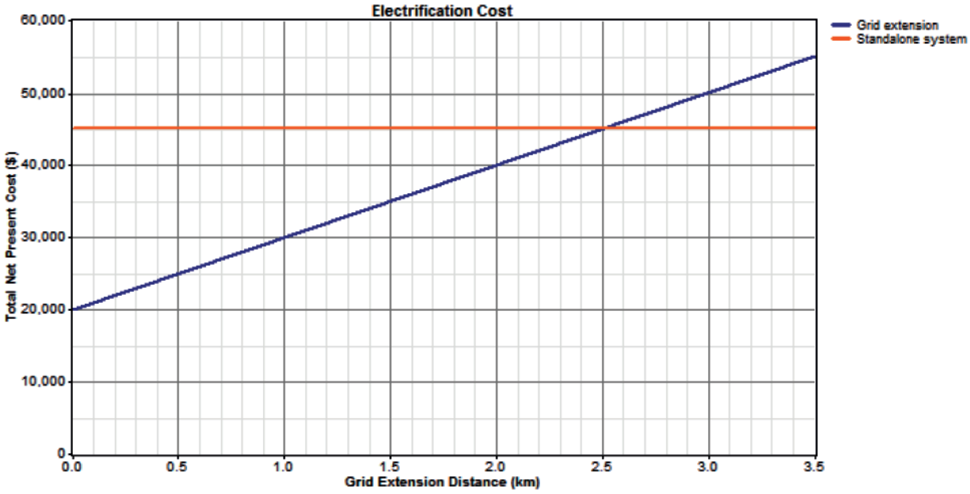

Fig. 11. Breakeven grid extension (City center)

Finally, it is intended to uniform the optimum results of the performance and cost with respect to height variations of the surface roughness in Table 12, in order to simplify the direct awareness while reviewing the results.

Table 12

Optimum performance and cost results

Surface Type	Performance results			
City Center & Tall Buildings	Wind Power	Solar Power	Total Power	Excess Electricity
	kWh / year			
	127.441	3.305	130.746	126.718
	Cost results			
	Initial capital, $	Operating Cost, $/year	Total NPC, $	COE , $/kWh
	24.072	1.664	45.084	0.903

Conclusions

The paper shows the impact of certain regions on the power systems that basically depend on the wind turbines to generate electric energy. In this work, three different wind turbine height variations based on surface roughness lengths were studied in Homer software to show the impact of these difficulties on the performance and the cost of hybrid power systems. For more clarity, it is intended to list the realized results as follows:

1. A unique hybrid power station is designed to provide a virtual residential load with required power.

2. The comparison operation based on stand-alone vs grid extension proved that the proposed stand-alone system is always better and cheaper than extending power from the grid.

3. The wind turbine located on the river bank, may increase power generation at least 18%.

4. The best performance and cost results were realized in city center case study, since the produced power is higher and the cost is lower.

5. The hub altitude of the wind turbine in the city center is chosen to be higher than other proposed locations in order to get rid of the obstacles that might be encountered. Hereby, the best power produced is obtained in city center case study.

6. As an investment, the established module achieves excess power production, which can be used to cover and feed larger rural or civil areas. Special attention should be paid to the clear water pools such as rivers, sea shores, etc.

7. Finally, it can be stated that the behavior of a power system in various specific locations regarding the performance and the design cost is significantly illustrious and different than each other.

СПИСОК ЛИТЕРАТУРЫ

1. *Rasham A.M.* Analysis of wind speed data and annual energy potential at three locations in Iraq / A.M. Rasham // Int J comp appl. — 2016. — Vol. 137. — No. 11. — Pp. 5–16.

2. Weather Underground Organization [Электронный ресурс]. — Режим доступа: https://www.wunderground.com/global/stations/40680.html (дата обращения: 15.09.2019).

3. *Fyrippis I.* Wind energy potential assessment in Naxos Island, Greece / I. Fyrippis, P. J. Axaopoulos, G. Panayiotou // Applied Energy. — 2010. — Vol. 87. — Is. 2. — Pp. 577–586. DOI: 10.1016/j.apenergy.2009.05.031

4. *Mathew S.* Wind energy: fundamentals, resource analysis and economics / S. Mathew. — Berlin: Springer, 2006. — 246 p. DOI: 10.1007/3-540-30906-3.

5. *Patel M.R.* Wind and solar power systems: design, analysis, and operation / M.R. Patel. — 2nd Edition. — CRC press, 2005. — 472 p.

6. *Nelson V.* Wind energy: renewable energy and the environment / V. Nelson. — 1st Edition. — CRC press, 2009. — 324 p.

7. *Lambert T.* HOMER® Energy Modeling Software. Computer software. December 27, 2007.

8. *Algburi S. S.* Design Hybrid Micropower System In Mistah Village Using Homer Model / S. S. Algburi // International Journal of Advanced Research in Engineering and Technology (IJARET). — 2013. — Vol. 4. — Is. 5. — Pp. 218–230.

9. *Nurunnabi M.* Grid connected hybrid power system design using HOMER / M. Nurunnabi, N.K. Roy // 2015 International Conference on Advances in Electrical Engineering (ICAEE). — IEEE, 2015. — Pp. 18–21. DOI: 10.1109/ICAEE.2015.7506786.

10. *Mahmood S. N.* The battery characteristics impact on solar systems: Performance and cost / S. N. Mahmood, A. Abdulabbas, H. Easa, S. S. Algburi // 2017 International Conference on Current Research in Computer Science and Information Technology (ICCIT). — IEEE, 2017. — Pp. 151–156. DOI: 10.1109/CRCSIT.2017.7965551.

11. *Kasaeian A.* Simulation and Economic Optimization of Wind Turbines and Photovoltaic hybrid System with Storage Battery and Hydrogen Tank (case study the city of Yazd) / A. Kasaeian, A. Shamel, R. Alayi // Journal of current research in science. — 2015. — Vol. 3. — No. 5. — Pp. 105–113.

12. *Devine M.* Wind-diesel hybrid options for remote villages in Alaska / M. Devine, J. Manwell, E. I. Baring-Gould, B. Petrie // Proceedings of the AWEA Annual Conference. — 2004.

13. *Al-Juboori S.* Optimization investigation of a stand-alone hybrid energy system design in Kirkuk technical college / S. Al-Juboori, A. Mejbel, A. Mutlag // Recent Advances in Educational Technologies. — 2015. — Pp. 119–126.

REFERENCES

1. Rasham, Ali M. “Analysis of wind speed data and annual energy potential at three locations in Iraq.” *Int J comp appl* 137.11 (2016): 5–16.

2. Weather Underground Organization. Web. 15 Sept. 2019 <https://www.wunderground.com/global/stations/40680.html>.

3. Fyrippis, Ioannis, Petros J. Axaopoulos, and Gregoris Panayiotou. “Wind energy potential assessment in Naxos Island, Greece.” *Applied Energy* 87.2 (2010): 577–586. DOI: 10.1016/j.apenergy.2009.05.031

4. Mathew, Sathyajith. *Wind energy: fundamentals, resource analysis and economics*. Berlin: Springer, 2006. DOI: 10.1007/3-540-30906-3

5. Patel, Mukund R. *Wind and solar power systems: design, analysis, and operation.* 2nd edition. CRC press, 2005.

6. Nelson, Vaughn. *Wind Energy Renewable Energy and the Environment.* 1st Edition. CRC press, 2009.

7. Lambert, Tom. HOMER® Energy Modeling Software. Computer software. Last Modified: December 27, 2007.

8. Algburi, Sameer Saadoon. “Design Hybrid Micropower System In Mistah Village Using Homer Model.” *International Journal of Advanced Research in Engineering and Technology (IJARET)* 4.5 (2013): 218–230.

9. Nurunnabi, Md, and N. K. Roy. “Grid connected hybrid power system design using HOMER.” *2015 International Conference on Advances in Electrical Engineering (ICAEE)*. IEEE, 2015. 18–21. DOI: 10.1109/ICAEE.2015.7506786.

10. Mahmood, Sarmad Nozad, Ali Abdulabbas, Haider Easa, and Sameer Saadoon Algburi. “The battery characteristics impact on solar systems: Performance and cost.” *2017 International Conference on Current Research in Computer Science and Information Technology (ICCIT)*. IEEE, 2017. 151–156. DOI: 10.1109/CRCSIT.2017.7965551.

11. Kasaeian, Alibakhsh, Ali Shamel, and Reza Alayi. “Simulation and Economic Optimization of Wind Turbines and Photovoltaic hybrid System with Storage Battery and Hydrogen Tank (case study the city of Yazd).” *Journal of current research in science* 3.5 (2015):105–113.

12. Devine, Mia, E. Ian Baring-Gould, and Brent Petrie. “Wind-diesel hybrid options for remote villages in Alaska.” *Proceedings of the AWEA Annual Conference*. 2004.

13. Al-Juboori, Sameer, Amer Mejbel, and Ali Mutlag. “Optimization investigation of a stand-alone hybrid energy system design in Kirkuk technical college.” *Recent Advances in Educational Technologies* (2015): 119–126.

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