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USE OF SMALL-SCALE WIND TURBINES IN ROAD LIGHTING

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ABSTRACTS

In this research, it has been studied energy consumption by luminaires, used in road lighting, which is providing by small-scale wind turbines. As the application area, the Bitlis-Rahva region, which is the new settlement of the city centre of Bitlis, was chosen. For the study, the wind data at a height of 10 m representing the road lighting poles were recorded with a data logger every 10 minutes (for 1 year). In many studies in the literature, the Weibull distribution has been used in the analysis of wind data and determination of wind energy potential. It has been seen that the accuracy of this method is high and therefore the Weibull distribution is chosen for the power generation capacity of the small-scale wind turbine to be used in road lighting. The maximum likelihood method was used to determine the parameters of the Weibull density function. Considering the dimensions of the lighting poles and the loads they can carry, it was concluded that it would be appropriate to use small-scale vertical-axis wind turbines for energy generation on these poles. It has been determined that the amount of energy produced by the wind turbine on the road lighting pole is much more than the luminaire on a lighting pole will consume.

Keywords: road lighting, wind energy, wind turbine

1. INTRODUCTION

The energy needed for the continuation of human life must be provided in a continuous, high-quality, and safe manner. Fossil resources have a wide usage area both as heating and fuel throughout the world. The reserves of these fossil resources are not considered sufficient for the future. In addition, the fact that it requires a large amount of advanced technology and financial resources in terms of acquisition and storage has caused all countries in the world to urgently review their current energy programs and take the necessary measures. The measures to be taken at the beginning are the gradual reduction of the share of oil in the total energy demand, the tight conservation of energy and the efficient use of resources, and the rapid development and implementation of technologies to benefit from renewable energy sources [1–6]. One of the renewable energy sources is wind energy. Wind energy is one of humanity's oldest energy sources. Until recently, wind energy was used to pump water and generate electricity in rural areas. Today, it has taken its place in the energy sector as an alternative energy production source. The energy used in road lighting in the world is obtained from dams or thermal power plants. The production and continuity of this energy, which is required for thousands of tunnel luminaire and road lighting poles, is costly [7–9].

Today, the use of renewable energy sources at the highest possible level has become a necessity rather than a choice. Among the renewable energy sources, the most important sources other than water are solar and wind energy. The increase in the cost of solar panels reduces the advantages of solar electricity generation. In recent years, significant technological developments have been experienced in obtaining electrical energy from wind energy [1–4, 7]. The unit power of wind turbines has become competitive with other energy sources in terms of

Fig. 1. The wind farm set up at sea

establishment costs. The share of wind energy in total electricity production is increasing day by day by establishing wind farms in the seas. Fig. 1 shows a wind farm set up at sea.

Mankind cannot afford to give up any clean energy source, because they are not cheaper than fossil and nuclear fuel types, and the energy consumption resulting from lighting alone corresponds to 25 % of the whole consumption [10–16]. Wind energy, which was neglected with the developments in fossil fuel consumption and which was the most important energy source before the industrial revolution, has again become a hope for humanity today. The planning, establishment, and operation of large-powered wind farms should be the most important public policy in terms of utilizing wind energy.

In addition, the share of electricity generation in total electricity production should be increased thanks to small and medium-powered wind turbines for lighting, which is the subject of this study. For this purpose, it is aimed to reduce the consumption of road lighting, which causes a large consumption in the world [17–21]. Thanks to this research, the amount of energy produced by wind turbines that can be mounted on road lighting poles has been studied. Although horizontal axis turbine systems are generally used in small powerful wind turbines, they are also used in vertical axis small powerful turbines due to their unique advantages. In this study, the vertical axis wind turbine was preferred because of the energy efficiency it provides. Examples of horizontal and vertical-axis wind turbines are shown in Fig. 2.

Small strong wind systems can be realized more easily with national resources in terms of technological infrastructure, knowledge, and investment. High-energy magnet-excited synchronous generators are used in all small-powered wind systems, and the obtained alternating current of variable amplitude and frequency is rectified and fed to the batteries with a maximum power draw algorithm, or it can be connected to the grid in parallel with the help of suitable power electronic circuits. These turbines are specially optimized for low wind speeds and are the most suitable turbine type in terms of price performance. Turbines shift the propeller rotation axis towards the axis and change the tail angle when the wind speed increases. In this way, dangerous increases in turbine speed at high wind speeds can be prevented and the wind turbine continues to produce. In addition, this approach prevents the excessive increase of the mast peak force. The amount of energy that can be taken from the wind system depends on the current wind potential as well as the performance of the turbine controller. The turbine controller adjusts the power drawn according to the wind speed and tries to keep it at the maximum point of the turbine's power characteristic. Accordingly, the power transferred and the operating speed of the turbine is measured in each case. To bring the optimum turbine speed at this power to the optimum speed, the charging current is increased or decreased. In this way, the system is tried to be kept at the optimum operating point.

While continuous lighting is provided day and night in tunnel lighting, a battery system is needed in road lighting since energy consumption will be made at night. In this study, it is assumed that there will be a battery system in the poles used in road lighting, because road lighting does not con-

Fig. 2. Examples of horizontal and vertical-axis wind turbines

Fig. 3. Satellite photograph of the application area Bitlis-Rahva Street

sume energy during the day. The energy obtained from the battery during the night will be used for road lighting. When the batteries are fully charged in the wind turbine systems, the charge is automatically cut off as the tip voltage will increase. In this case, an auxiliary load is connected to the resistor so that the turbine does not accelerate to excessive idle speeds. The system stays in this position until the battery voltage drops below a specified value. In addition, a similar operation can be performed manually to lock the turbines. In turbine controllers, an energy measurement system that allows the measurement of the total and intermediate production amount and a power measurement system that can measure the maximum and average power amounts can be used.

2. MATERIAL AND METHOD

In this study, it has been investigated that the electrical energy consumed in luminaires used in street lighting is met by a small-scale wind turbine.

2.1. Mast Top Wind Turbine

In the study, the Bitlis-Rahva region, which is the new settlement of the city centre of Bitlis and has the longest street, was chosen as the application area. Bitlis-Rahva Street is a region that receives regular and intense winds. In the calculation of the electrical energy that can be produced from the wind turbine, the wind data measured in the field where the energy production will be made should be used. In this study, wind information was obtained from the Bitlis meteorological station of the Turkish Meteorology General Directorate, located between 38° 28’ N North latitude and 42° 9’ E East longitude. Wind data measured at a height of 10 meters were used to represent road lighting poles. Bitlis Meteorology Station, where wind data are obtained, is located on Bitlis-Rahva Street, which was chosen as the application area. In Fig. 3, the satellite photo of the application area Bitlis-Rahva Street is seen.

To determine the energy that can be produced in a wind turbine, statistical analysis of the wind data measured at the power generation site is required. One of the most important features in the evaluation of wind data is the average wind speed. Average wind speed is the average of the measured wind speed values. The variability of a wind dataset is also important. The mean velocity (v_m), the standard deviation (σ), and the average power density (P_m) of a wind series can be calculated in Equations 1, 2, and 3.

$$v_m = \frac{1}{n}\sum_{i=1}^{n} v_i. \quad (1)$$

$$\sigma = \left[\frac{1}{n-1}\sum_{i=1}^{n}\left(v_i - v_m\right)^2\right]^{1/2}. \quad (2)$$

$$P_m = \frac{1}{2\,\mathrm{n}}\rho\sum_{i=1}^{n} v_i^3. \quad (3)$$

In these equations, ρ represents the density of the air and n represents the number of measured wind speeds. The Weibull distribution has been used in most studies to analyse wind data and determine wind energy potential. In many studies on wind energy, it has been determined that the wind speed data show a two-parameter Weibull distribution feature [22–27]. It consists of the Weibull probability density function (*f(v)*), shape (*k*), and scale (*c*). This function expresses the number of blows at any wind speed. The probability density function of the Weibull distribution is shown in Equation 4.

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} exp\left[-\left(\frac{v}{c}\right)^{k}\right]. \quad (4)$$

Various methods have been developed in the literature for the determination of Weibull parameters. Graph, moment, maximum likelihood, and simplified maximum likelihood estimation methods are among these methods. In this study, the maximum likelihood method was used to determine the parameters of the Weibull density function. The *k* and

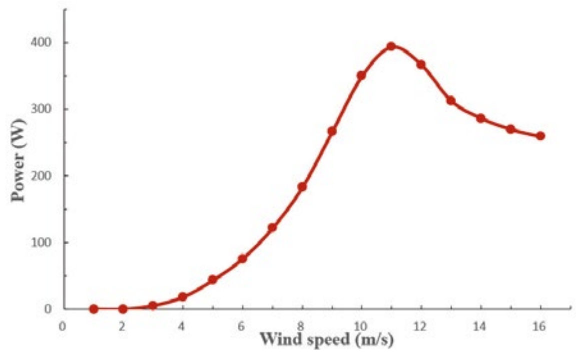

Fig. 4. Aeolos-V 0.3 kW power curve [27, 28]

c values that make this function the highest are considered as the maximum likelihood estimates [26, 27]. According to the Weibull distribution, the average wind speed and power density are expressed by Equations 5 and 6 [27, 28].

$$v_m = \int_0^\infty v f(v)\,dv = c\Gamma\left(1+\frac{1}{k}\right). \quad (5)$$

$$P_m = \int_0^\infty \frac{1}{2}\rho v^3 f(v)\,dv = \frac{1}{2}\rho c^3 \Gamma\left(1+\frac{3}{k}\right). \quad (6)$$

Here, Γ is expressed as a gamma function. The electrical power to be produced from the wind turbine, P_{Ge}, is calculated using the power generation curve of the wind turbine. The electrical power generation for this wind turbine model is shown in Equation 7 [29, 30].

$$P_{Ge} = \begin{cases} 0, & v < v_1 \\ a + bv^k, & v_1 \le v \le v_R \\ P_R, & v_R < v \le v_0 \\ 0, & v > v_R \end{cases}. \quad (7)$$

Here, v_1 shows the speed at which the turbine starts to produce power (cut in wind speed), v_R shows the speed at which it starts to produce nominal power (rated wind speed), v_0 shows the speed at which the turbine exits the power generation (cut out wind speed) and P_R shows the nominal power (rated power) of the turbine [27]. According to this model, the amount of energy that can be produced from a wind turbine is calculated according to E_{Ge}, Equation 8.

$$E_{Ge} = T\left(\int_{v_1}^{v_R}\left(a + bv^k\right) f(v)\,dv + P_R\int_{v_R}^{v_0} f(v)\,dv\right). \quad (8)$$

As a result, if the Weibull density function is substituted in Equation 11 to express T time, the amount of energy that can be produced from a wind turbine is calculated by Equation 9 [27, 28].

$$E_{Ge} = TP_{Ge}\left[\frac{exp\left[-\left(\frac{v_1}{c}\right)^k\right] - exp\left[-\left(\frac{v_R}{c}\right)^k\right]}{\left(\frac{v_R}{c}\right)^k - \left(\frac{v_1}{c}\right)^k} - exp\left[-\left(\frac{v_0}{c}\right)^k\right]\right]. \quad (9)$$

It is symbolized as the capacity factor (C_F) of a wind turbine. C_F expresses the turbine's power generation performance and is expressed as the ratio of the actual power generation amount to the turbine's power generation rate at nominal power [31].

Today, lighting poles used in streets and streets are preferred at a height of about 8–10 meters. Considering the dimensions of the lighting poles and the load they can carry, it was concluded that it would be more appropriate to use small-scale vertical-axis wind turbines for power generation on these poles. For this reason in this study, the wind turbine, which characteristics are given in Table 1, was used to meet the electrical energy consumed in road lighting. The power generation graph of the selected turbine is given in Fig. 4.

As can be seen from Table 1 when Fig. 4 is examined the turbine starts to produce energy when the cut in wind speed (v_1) is 2.5 m/s. When the rated wind speed (v_R) is 10 m/s the turbine produces energy at nominal power. In this way, the energy pro-

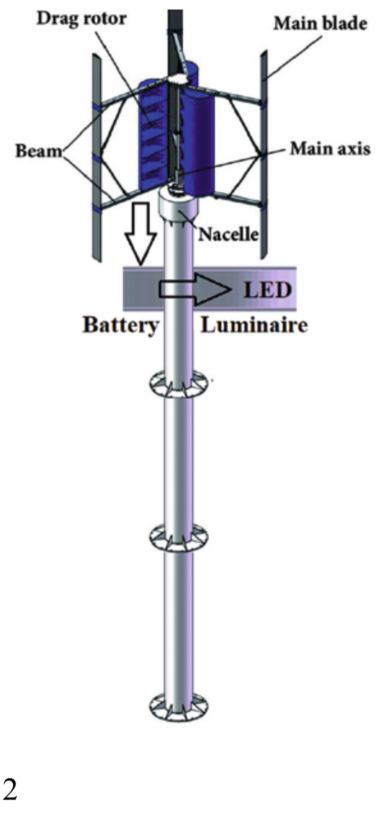

Fig. 5. A vertical wind turbine road lighting pole [34]

Table 1. Wind Turbine Specification [32, 33]

Manufacturer & Model	Aeolos-V 0.3 kW Vertical Axis
Rated power (P_R)	0.3 kW
Maximum output power	0.4 kW
Hub height	1.6 m
Rotor diameter	1.2 m
Rated power (P_R)	0.3 kW
Start-up wind speed	1.5 m/s
Cut in wind speed (v_1)	2.5 m/s
Rated wind speed (v_R)	10 m/s
Cut-out wind speed (v_0)	42 m/s
Survival wind speed	50 m/s
Swept area	1.1 m^2
Number of blades	3
Generator	Permanent magnetic
Generator efficiency	> 0.96
Turbine weight	10 kg
Noise level	< 45 dB(A)

duced is sent to the battery system in the road lighting pole.

The energy produced from the turbine is stored in the pole-mounted battery system under the wind turbine at the top of the pole. The high-efficiency LED lighting fixture right next to the battery, on the other hand, activates at night and illuminates the road. In Fig. 5, a vertical wind turbine road lighting pole is shown.

2.2. Road Lighting Parameters

One of the most important parameters in the perception of objects is the visual comfort of the eye. Lighting evokes different physiological and psychological effects in each individual. Accordingly, these effects can have positive or negative consequences. The lighting quality should always provide adequate visual performance for road lighting. Visual comfort on the road can be impaired by inadequate lighting, inappropriate lighting levels, glare, and unwanted shadows. Insufficient lighting prevents the correct perception of the environment, objects, and colours. Therefore, the optimum light balance should be set according to international lighting standards (CIE). The road used in this study is in the M2 class according to CIE standards. Required conditions for the M2 class according to CIE standards are shown in Table 2.

Table 2. Road Lighting CIE Standards

Lighting class	$L_{average}$, cd/m^2	U_O	U_1	TI,%
M2	>1.5	>0.4	>0.7	<10

For the Bitlis-Rahva Street, features such as the distance between luminaires, the distance of the luminaire to the surface, IP protection class, pollution rate, luminaire cleaning frequency, and maintenance factor were selected as lighting parameters [35–40]. For the luminaire parameters, variables such as the angle of the luminaire relative to the surface, the power of the luminaire, its lifetime, and the luminous flux were taken into account in the calculation. LED luminaires with a luminous flux value of 12000 lm are used in road lighting. Luminaire angles were chosen as 0 degrees, road surface reflectance 0.10, and maintenance factor 0.86 (for moderately polluted environments cleaned every two years). Lighting parameters for Bitlis-Rahva Street are shown in Table 3.

The point Lighting Calculation Method was used in road lighting calculation. In this method, the area to be calculated for point lighting is selected first. The area between the two poles is determined as the calculation area. Starting from the first luminaire in

Table 3. Lighting Parameters for Bitlis-Rahva Street

Road lighting parameters			
Lighting pole type	Galvanized	Lighting class	M2
Number of road lanes	2	Console length, m	1.5
Lane width, m	3.5	Console angle, degree	–
Road width, m	7	Armature angle, degree	0°
Road surface class	R1	Luminaire type	LED
Q_o	0.1	Luminaire power, W	60
Distance between poles/luminaires, m	33	Luminaire luminous flux, lm	12000
Illumination height from ground, m	10	Maintenance factor (every 2 years)	0.86

the calculation area, the point standing in the middle of each strip is selected according to the observer [41, 42]. When calculating the luminance level in a point on the road surface the luminance level in a point is equal to the sum of the luminance created by the all luminaires.

In this study, calculations were made at 66 points selected in horizontal and vertical positions along the 2-lane road on the road and the illumination values of the selected points were recorded in Table 4 [35–40]. The comparison of the minimum values calculated for Bitlis-Rahva Street and given in the CIE standards is shown in Table 4. When Table 4 is examined it is seen that the lighting conditions are provided for Bitlis-Rahva Street, which is the subject of the study.

3. RECOMMENDATIONS AND DISCUSSIONS

In this study, the annual variation of wind characteristics of a wind turbine to be mounted on lighting poles for Bitlis-Rahva Street was investigated, using Weibull distribution. Average wind speed and energy density calculations were made and the parameters of the Weibull distribution for Bitlis-Rahva Street were determined. The standard deviation of the wind speed data was between the expected values [33, 34, 43–46]. This is an indication of suitability for the generation of electrical energy using wind energy.

Table 4. Comparison of the Minimum Values Calculated for Bitlis-Rahva Street and Given in CIE Standards

	Calculated road lighting parameters	CIE Standards M2 Lighting Class
$L_{average,}$ cd/m^2	1.52	>1.5
U_o	0.79	>0.4
U_1	0.88	>0.7
TI, %	6.9	<10

The statistical analysis results of the wind data for the lighting poles of a wind turbine to be installed on the lighting poles for Bitlis-Rahva Street are given in Table 5. Observed values of annual average wind speed and power density were found as 3.13 m/s and 50.01 W/m^2, respectively. The k and c values of the Weibull distribution were estimated as 1.49 m/s and 3.61 m/s, respectively. Weibull values of annual average wind speed and power density were found as 3.26 m/s and 49.77 W/m^2. Weibull results were found to be very close to the observed results.

The sectoral frequency change of the wind-blowing direction is shown in Fig. 6. The highest fre-

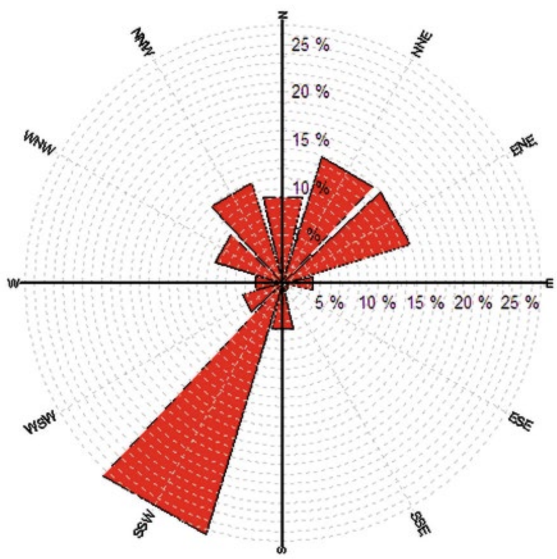

Fig. 6. Sectoral frequency changing of wind direction

Table 5. Statistical Analysis Results of Wind Data for the Lighting Poles of the Wind Turbine

	V_m, m/s	k	c, m/s	σ	P_m, W/m^2
Observed	3.13	–	–	2.2449	50.01
Weibull distribution	3.26	1.49	3.61	2.1789	49.77

Table 6. Results for the Aeolos-V 300W Wind Turbine

Annual power energy output (E_{GE})	**245.554 kW·h/year**
Annual energy consumption for 60 W LED luminaire	240.90 kW·h/year
Capacity factor (C_F)	9.34 %
Operational time	5927 hour/year
Operational time at rated power	899 hour/year

quency of the wind speed was found to be 27.5 % in the South-Southwest direction, the average wind speed in this direction was 5.0 m/s, the Weibull shape parameter was 1.97 and the scale parameter was 5.63 m/s. Therefore, it was observed that the dominant wind direction in the region is the South-Southwest direction.

The result of the wind power plant analysis for the selected wind turbine is given in Table 6. It is mounted on the road lighting pole of the wind turbine. Since the approximate wind data of the hub height is at the measurement height, the variation of the wind data according to the height was not calculated. The annual energy production of the wind turbine was found to be 245.554 kW·h and the capacity factor was 9.34 %. The working time of the turbine in annual energy production was found to be 5927 hours, and the production time at nominal power was found to be 899 hours.

If the wind turbine lighting poles are used for road lighting, great cost savings will be achieved as there will be no connection cable between the poles. In this study, since the price of the wind turbine mounted on the pole is lower than the price of the cable between the poles, the wind turbine will not cause an additional cost. Therefore, it is obvious that small-scale wind turbines will not create additional costs.

4. RESULTS

The state, non-governmental organizations, industrial organizations, and universities have great responsibilities for the more widespread use of wind and solar energy systems and the evaluation of the existing potential. In this context, wind turbines mounted on small-scale road lighting poles can be used as the government gives more importance to renewable energy systems such as wind in the creation and implementation of energy policies.

The most important obstacle to the widespread use of wind energy conversion systems is the high initial establishment costs. Electricity generation from wind energy will be increased by providing public support for the initial establishment cost and production of these systems with national technologies.

For this study, wind parameters at 10 m height for road lighting were recorded at 10-minute intervals and for 1 year. Since it is known that wind speed data show a two-parameter Weibull distribution in many studies on wind energy, the Weibull distribution has been used. As a result of the study, the working time of the wind turbine in annual energy production is 5927 hours. The production time at rated power was found to be 899 hours. The annual energy production of the wind turbine was measured as 245.554 kW·h.

Considering that the lighting poles illuminate the road for an average of 11 hours per day, the consumption to be made in lighting for 1 year is equivalent to a 61.16 W luminaire. For this reason, 60 W LED luminaire was used in road lighting. The annual consumption of the 60 W luminaire is 240.90 W, and the 0.3 kW vertical wind turbine can meet this consumption throughout the year. Considering that the annual energy consumption of a 60 W LED luminaire is below 245.554 kW·h, it can be seen from Table 6 that the wind turbine selected for road lighting meets the energy consumption. The fact that the electricity production of the small-scale wind turbine selected for the lighting pole is close to the annual consumption of the lighting luminaire indicates that the optimum wind turbine has been selected.

This value corresponds to much more than the energy consumed by a lighting pole. In this direction, wind turbines should be installed on the road lighting poles on Bitlis-Rahva Street.

REFERENCES

1. Gil-Martín, L.M., Peña-García, A, Jiménez. A, Hernández-Montes, E. Study of light-pipes for the use of sunlight in road tunnels: From a scale model to real tunnels // Tunnelling and Underground Space Technology 2014, Vol. 41, pp, 82–87.

2. Kaynaklı, M., Palta, O., Cengiz Ç. Solar radiation and temperature effects on agricultural irrigation systems // Bitlis Eren University Journal of Science and Technology, 2018, Vol. 6, #1, pp. 53–58.

3. Parlakyildiz, S. The Effects of Luminaire Glass Type on Road Parameters in Road Lighting // Light and Engineering, 2023, Vol. 31, #1, pp. 100–104.

4. Özenc, S., Uzunoglu, M., Güler, Ö., Experimental evaluation of the impacts of considering inherent response characteristics for lighting technologies in building energy modeling // Energy and Buildings, 2014, Vol. 77, pp. 432–439.

5. Duman, CA., Güler, O. Techno-economic analysis of off-grid PV/wind/fuel cell hybrid system combinations with a comparison of regular and seasonally occupied households // Sustainable Cities and Society, 2018, Vol. 42, pp. 107–126.

6. Yurci, Y., Kaynaklı, M., Palta, O., Efe, SB., Cengiz, Ç. The performance-cost effect of the SCADA system on distribution networks // Journal of Electrical and Electronics Engineering, 2016, Vol. 11, #6, Ver.III, pp. 32–38.

7. Almasri, R.A., Narayan, S. A recent review of energy efficiency and renewable energy in the Gulf Cooperation Council (GCC) region // International Journal Green Energy, 2021, Vol. 18, #14, pp. 1441–1468.

8. Cengiz, M.S., Mamis, M.S., Akdag, M., Cengiz, C. A review of prices for photovoltaic systems // International Journal of Technolgy Physical Problems of Engineering, 2015, Vol. 7, #3, pp. 8–13.

9. Guk, E., Venkatesan, V., Sayan, Y., L., Kim, JS. Spring Based Connection of External Wires to a Thin Film Temperature Sensor Integrated Inside a Solid Oxide Fuel Cell // Scientific Reports, 2019, Vol. 9, pp. 2161.

10. Sayan, Y., Venkatesan, V., Guk, E., Kim, JS., Wu, H. Single-step fabrication of an anode supported planar single-chamber solid oxide fuel cell // International Journal of Applied Ceramic Technology, 2018, Vol. 15, #6, pp. 1375–1387.

11. Kaynaklı, M., Palta, O., Yurci, Y., Cengiz, Ç. Cooperation of conventional electric power grids and smart power grids // Journal of Electrical and Electronics Engineering, Vol. 11, #6, Ver.IV, pp. 23–27.

12. Cengiz M.S., Cengiz, C. Numerical analysis of tunnel lighting maintenance factor // International Islamic University Malaysia IIUM Engineering Journal, 2018, Vol. 19, #2, pp. 154–163.

13. Efe, S.B., Varhan, D. Interior lighting of a historical building by using led luminaires a case study of Fatih Paşa Mosque // Light and Engineering, 2020, Vol. 28, #4, pp. 77–83.

14. Qin, X, Zhang, X, Qi, S., Han, H. Design of solar optical fiber lighting system for enhanced lighting in highway tunnel threshold zone: A case study of Huashuyan tunnel in China // International Journal of Photoenergy 2015, Vol. 2015, pp. 1–10.

15. Cengiz, M, S. The relationship between maintenance factor and lighting level in tunnel lighting // Light and Engineering, 2019, Vol. 27, #3, pp. 75–88.

16. Parlakyildiz, S. Visual Comfort at the Road Lighting on the Border Line // Light and Engineering, 2023, Vol. 31, #1, pp. 94–99.

17. Cengiz, M.S. Effects of luminaire angle and illumination topology on illumination parameters in road lighting // Light & Engineering, 2020, Vol. 28, #4, pp. 47–56.

18. Cengiz, M.S. Using electric lighting to support daylighting in architectural building designs // Light & Engineering, 2022, Vol. 30, #1, pp. 113–123.

19. Aboneama, W.A. Achieving energy efficiency performance and urban connectivity development in Saudi Arabia through renewable energy Resources and sustainable transportation-case study asir province // Resilient and Responsible Smart Cities, Springer 2021, pp. 195–205.

20. Cengiz, MS. Lighting master plan application in living areas // Light & Engineering, 2022, Vol. 30, #6, pp. 124–132.

21. Cengiz, MS. Role of functional illumınation urban beautification: Qatar-Doha road illumination case // Light & Engineering, 2022, Vol. 30, #3, pp. 34–42.

22. Talama, F., Kutty, S.S., Kumar, A., Khan, M., Ahmed, M.R. Assessment of wind energy potential for Tuvalu with accurate estimation of Weibull parameters // Energy Exploration & Exploitation, 2020, Vol. 38, pp. 1742–1773.

23. Idris, A.I., Ahmed, R.A., Omar, A.I., Said, R.K. Akinci, T.C. Wind energy potential and micro-turbine performance analysis in Djibouti-city, Djibouti // Engineering Science and Technology and International Journal, 2020, Vol. 23, pp. 65–70.

24. Teimorian, A., Bahrami, A., Teimourian, H., Vala, M., Huseyniklioglu, A.O. Assessment of wind energy potential in the southeastern province of Iran // Energy Sources, Part A: Recovery Utilization, And Environmental Effects, 2020, Vol. 42, #3, pp. 329–343.

25. Mohammadi, K., Mostafaeipour, A. Economic feasibility of developing wind turbines in Aligoodarz, Iran // Energy Conversion and Management, 2013, Vol. 76, pp. 645–653.

26. Seo, S., Oh, S.D., Kwak, H.Y. Wind turbine power curve modeling using maximum likelihood estimation method // Renewable Energy, 2019, Vol. 136, pp. 1164–1169.

27. Stevens, M.J.M., Smulders, P.T., The Estimation of the Parameters of the Weibull Wind Speed Distribution for Wind Energy Utilization Purposes // Wind Engineering, 1979, Vol. 3, pp. 132–145.

28. Celik, A.N. A statistical analysis of wind power density based on the Weibull and Rayleigh models at the southern region of Turkey // Renewable Energy, 2003, Vol. 29, pp. 593–604.

29. Johnson, G.L. Wind Energy Systems // Electronic Edition. 2006. KS, Manhattan.

30. Bilir, L., Imir, M., Devrim, Y., Albostan, A. An investigation on wind energy potential and small scale wind turbine performance at Incek region–Ankara, Turkey // Energy Conversion and Management, 2015, Vol. 103, pp. 910–923.

31. Jaramillo, O.A., Borja M.A. Wind speed analysis in La Ventosa, Mexico: a bimodal probability distribution case // Renewable Energy, 2004, Vol. 29, pp. 1613–1630.

32. http://www.windturbinestar.com/300w-vertical-wind-turbine.html. (Accessed 19 March 2022).

33. https://en.wind-turbine-models.com/turbines/1849-aeolos-aeolos-v-300w. (Accessed 19 March 2022).

34. Feng, F., Qu, C., Zhao, S., Bai, Y., Guo, W., Li, Y. Static Mechanical Properties and Modal Analysis of a Kind of Lift-Drag Combined-Type Vertical Axis Wind Turbine // International Journal of Rotating Machinery, 2018, Vol. 2018, pp. 1–13.

35. CIE-194–2011 On site measurement of the photometric properties of road and tunnel lighting, 2011.

36. Güler, Ö., Onaygil, S. The effect of luminance uniformity on visibility level in road lighting, Lighting Research Technology, 2002. V35, pp. 199–215.

37. CIE-115–2010, International Commission on Illumination, Recommendations far the Lighting of Roads for Motor and Pedestrian Traffic, Vienna-Austria, 1995. p. 25.

38. Onaygil, S., Yol aydınlatma projelerinde yol sınıfının belirlemesinin önemi, Kaynak Elektrik Dergisi, 1998. #12, pp. 125–132.

39. CIE-136–2000, Guide to the lighting of urban areas, 3 August 2000.

40. Tetri, E., Chenani, S.B., Rasanen R.S. Advancement in Road Lighting, Light & Engineering, 2018. Vol. 26, #1, pp. 99–109.

41. Cengiz, M.S. Simulation and design study for interior zone luminance in tunnel lighting // Light and Engineering, 2019, Vol. 27, #2, pp. 42–51.

42. Parlakyildiz, S. Gencoglu, M.T., Cengiz, M.S. Analysis of failure detection and visibility criteria in pantograph-catenary interaction // Light & Engineering, 2020, Vol. 28, #6, pp. 127–135.

43. Kavak Akpınar, E., Akpınar, S. Statistical Analysis of Wind Energy Potential on the basis of the Weibull and Rayleigh Distribution for Ağın-Elazığ, Turkey // J. Power Energy, 2004, Vol. 218, pp. 557–565.

44. Oral, F. Statistical analysis of the wind energy potential of Bitlis province // Dicle University Journal of Engineering, 2020, Vol. 11, pp. 671–678.

45. Fırtın, E., Güler, Ö, Akdağ, S.A. Investigation of wind shear coefficients and their effect on electrical energy generation // Applied Energy, 2011, Vol. 88, #11, pp. 4097–4105.

46. Güler, Ö., Wind energy status in electrical energy production of Turkey //Renewable and sustainable energy reviews, Vol. 13 #2, pp. 473–478.

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