FOREX Publication
Open Access | Rapid and quality publishing

International Journal of
Electrical and Electronics Research (IJEER)
Research Article | Volume 12, Issue 1 | Pages 126-133 | e-ISSN: 2347-470X

Benefit Through Vehicles Passing on Highways in Electrical Power Generation

Firas Saaduldeen Ahmed [1] **and Zozan Saadallah Hussain** [2]

[1]*Department of Electrical Techniques, Technical Institute of Mosul, Northern Technical University, Iraq, firas_saad@ntu.edu.iq*
[2]*Department of Electrical Techniques, Technical Institute of Mosul, Northern Technical University, Iraq, zozan.technic@ntu.edu.iq*

***Correspondence:** Zozan Saadallah Hussain, zozan.technic@ntu.edu.iq

ABSTRACT- The turbulent airflow caused by vehicular movement on highways is a source of kinetic energy for wind energy (WE) that can be utilized to power highway lighting and communications. The purpose of the current work is to design, install and measure the extent of benefit from small wind turbines along a Highway (HW) in one of the governorates of Iraq - Dohuk. In this investigation, wind speed measurements are close to a significant HW on the Dohuk-Zakho-Iraq (DZI) Road. The three positional characteristics are examined for the wind turbines' optimal position. These factors are heights above ground level, lateral distances from the road shoulder, and the wind turbines' highway-facing orientation. It is possible to supply electrical power for side lighting of external roads via vertical axis wind turbines (VAWT), which are produced from disturbances in air movement. In addition, a battery pack has been used to store energy to sustain fluctuations caused by stopped vehicle traffic and to ensure load operation in the event of a wind turbine stop. A 500W capacity vertical axis windmill is being worked on. The suggested landscaping technique has generated exceptional and long-lasting effects for a price of under 350 US dollars.

Keywords: Dohuk-Zakho-Iraq, Wind Energy, Highway, Blades, Vertical Axis Wind Turbines.

ARTICLE INFORMATION
Author(s): Firas Saaduldeen Ahmed and Zozan Saadallah Hussain;
Received: 10/10/23; **Accepted**: 31/01/24; **Published**: 26/02/24;
E- ISSN: 2347-470X;
Paper Id: IJEER231006;
Citation: 10.37391/IJEER.120118
Webpage-link:
https://ijeer.forexjournal.co.in/archive/volume-12/ijeer-120118.html

crossref member
CROSSREF.ORG THE CITATION LINKING BACKBONE

Publisher's Note: FOREX Publication stays neutral about jurisdictional claims in published maps and institutional affiliations.

1. INTRODUCTION

The global energy demand is increasing rapidly, and there is a growing need to explore alternative power generation sources [1]. One promising avenue is using vehicles passing on highways as a source of electrical energy [2]. This concept involves capturing the kinetic energy generated by moving vehicles and converting it into usable electricity [3]. By integrating this technology into our existing transportation infrastructure, we can potentially reduce our reliance on traditional power sources and contribute to a more sustainable future. The need for energy in modern life is significantly greater than the cost of producing it. Since people first understood that natural resources would eventually run out and a substitute would need to be found, this has been one of the largest problems. In addition, fossil fuels significantly contribute to pollution, global warming, and greenhouse gas emissions [4]. In the twenty-first century, it is imperative to include additional renewable energy sources, such as solar, wind, and biomass, to address these issues. The growth of every country depends largely on its access to energy [5]. Due to a rapid increase in population and industrialization, as well as the quick depletion of energy resources, the world's energy consumption is accelerating. Currently, thermal power stations that use fossil fuels like coal, diesel, etc. provide more than 68 percent of the world's electrical energy [6].

Other researchers used a similar method through the movement of trains, where the air moves quickly when the train passes, so the movement of the wind was used to generate electrical energy [7]. Also, other researchers used the compression method for land transportation to generate and produce direct current electricity [8]. Some of them used the Harvesting Technologies method to generate electrical energy in public and highways [9]. Others used the method (vibrations in the roads through the movement of wheels on the roads) to generate electrical energy on public roads and highways [10].

The fastest-growing source of sustainable energy is thought to be wind energy. However, due to its erratic nature, it is constrained. Due to heavy traffic, HW may generate a sizable quantity of wind to power a turbine. Wind will be produced due to the pressure differential in the air next to the vehicle. The most effective way to obtain this energy is the goal of this project [11] VAWT; Perpendicular to the revolving center are the mounting surface and the wind direction. The Basic feature is that since the engine is on the earth, accessing them is simpler and a yaw system is unnecessary. Due to its proximity to the Earth, the possible wind speeds are decreased [12]. It is a vertical axis machine, which is physically and practically rather simple. In addition to being simple, it has the benefit of being fairly robust and having a robust initial torque, making it simple to start even with moderate wind. The turbine operates well in mild winds, but its yield declines in severe gusts and even becomes brittle, limiting its size [13]. Fixed-pitch rotor designs allow for yaw mechanism-free designs. VAWTs have slower wind start-up speeds than HAWTs do. Usually, they start to generate electricity at about 6 MPH (10 km/h). VAWTs' noise characteristics might be reduced [14]. Most VAWTs only generate energy at 50% of HAWTs' efficiency because of the additional drag that occurs when their blades rotate in the wind direction [15]. Even if the VAWT parts are on the ground, the weight of the structure above them still bears down on them. If this structure is not built correctly, replacing portions without demolishing the entire thing can be almost impossible. Because VAWTs have rotors close to the earth, where wind speed is reduced due to wind shear, they cannot produce as much energy at a given place as a HAWT [16].

The blocks will take in one direction of the wind at the ends of the rod, while the blocks in the center should take in both directions of wind—Varying lateral separations from the paved shoulder [17]. Measuring wind intensity and speed on highways is very important so that designers can determine the required size and specifications for wind turbines [18]. Simultaneously, the three anemometers were positioned on the ground plane. For producing power, these turbines can be put on express HWs and other locations with fast speeds traffic [19]. The turbine should be able to provide street lamps and other public infrastructure with limitless electricity worldwide [20].

By mounting a VAWT on the HW's partition so that it can collect wind from both directions and have wind speeds greater than at one side of the road, it is possible to produce power in HWs [21]. Batteries have been used to keep the power generated so that the HW may be lit at night [22]. Furthermore, other elements like the efficiency of the wind turbine are significantly influenced by wind speed, blade length and form, tower height and design, which is surface treatment, and tip speed ratio (TSR). Additionally, blocks should be positioned on the partition area and at the two verges of the HWs to generate extra power [22, 24]. The blades design process is based on the wind direction in the middle of the road, in contrast to the blocks at the sides, which will only get wind from one direction [25]—varying lateral separations from the paved shoulder. Wind speed assessments at lateral positions from the road will be conducted to determine the amount of vehicle-induced turbulent wind at these distances. Simultaneously, the three anemones were positioned at ground level [26, 27]. These turbines can be deployed on express highways and other high-speed traffic locations to generate power. In an ideal world, the turbine might provide a limitless source of electricity for street lighting and other public utilities worldwide

The contribution of the current work is that it used vertical axis wind turbines with an electrical power generator on one of the roads in Iraq at a suitable cost compared to the other designer work. It is considered the first experience in Iraq. The project's manufacture also used simple materials such as water pipes and an iron object. It is also considered a means of measurement for building larger projects in the future by building simple, low-cost smart meters such as (Arduino Uno type and SD- card Reader for data storage).

In this current work has been designed the VAWT from simple components like Mechanical energy are transformed into electrical energy by a DC motor half blades. Blades have been designed from 8ing half pipe to designing vertical blades according to suitable values. The charger control is used to keep the generated power level and control the DC energy from the wind and battery energy storage. The Arduino type Uno and the two sensors (voltage sensor and SD card reader) have been used to control and take the suitable read and write results. The iron body is shaped to provide solid support and to resist weather fluctuations as shown in *figure 1*.

Figure 1: The current design of real work

2. METHODOLOGY OF REAL DESIGN WORK

Figure 2 shows the stages of the air conversion produced by the velocity of moving cars into the DC load. Each of the stages has been designed practically according to the standard world. The major goal is to collect and recover as much wind energy from the cars using the HWs as possible [28]. The vertical wind turbine is propelled by a large, unused amount of wind, which will utilize the wind's kinetic energy to generate electricity. More turbulence causes the wind to change direction and speed more often. Vertical axis wind turbines, unlike conventional VAWT, are effective at capturing turbulent winds common in urban environments. A 500W capacity vertical axis windmill is being worked on.

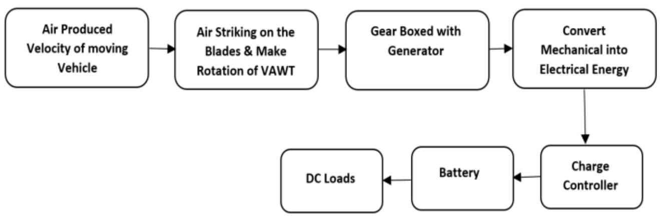

Figure 2: Simple block diagram for current design

By positioning the turbine at the ideal location and height, we want to maximize wind generation in all directions while considering system cost and safety. This technique may provide a significant quantity of usable electrical energy when employed in large quantities. The idea of design prompts us to consider many factors like production, noise, and cost, which brings us to our secondary goal of studying the system to fix common technical issues. The project aims to create a tiny wind turbine that can be mass-produced and installed on every HW median to help people use less electricity [29].

3. Implementation and Description Hardware System

Practical parts used in the current work are explained as follows:

3.1 DC Generator (12V)

Currently employed in design work is (an automobile vehicle alternator), which is also a well-liked option for usage as a low-voltage DC generator for wind turbines by many do-it-yourselfers. However, they aren't proficient because they frequently use combustion engines or automobile alternators fastened to the side to generate electricity. An external power supply voltage is also required to power the electromagnetic magnets that create the inner magnetic field in automobile alternators [30].

3.2 Battery (12V-150Ah)

The battery or bunk of batteries stores energy to continue electrical power demand for a long time.

3.3 Charge Controller

Batteries are often used in wind energy applications like solar systems to store excess power and energy for low- and medium-power loads. Due to deep discharge and overloading problems, the power sources are weak. This shortens the battery life and is a weakness for renewable energy sources. A controller should be utilized to safeguard the batteries and increase their lifespan. The basic idea of photovoltaic controllers is to cut the batteries' power from the PV generator. When the batteries are completely charged or severely drained, this disconnect happens. The same theory does not apply to wind turbine applications. Keeping the turbine in a vacuum and disconnecting it from the batteries would raise the chance of its overspending annihilation, which we cannot afford. This restriction must be considered in the control strategy used for wind system battery charge/discharge. The batteries and other charges (usage, discharge resistors) must always be used to load the wind turbine [31].

3.4 Blades design and Mathematical of wind turbine

A two- or three-bladed propeller moving around a horizontal axis has traditionally been the basic component of wind turbines intended to generate power. A wind turbine's blades are formed like an airplane wing, with one side (the rear) being much more curled than the other (the front). A wing allows air to flow over the top more quickly, which lowers pressure and creates the lift an aircraft needs to fly. To function, turbine blades also rely on pressure differences brought on by variations in airspeed. The air behind the blade starts moving faster than the air in front as the wind blows and passes over it. The front edge's rounded corner experiences the most velocity, which generates a pocket of low pressure.

The essential mathematical equations of the design of Wind turbines and blades in the present work are clarified from *equations (1) to (6)* [32].

$$ke = ½mV2 \qquad (1)$$

Where
ke: is kinetic energy.
m: is equals Mass.
V: is velocity.

$$M = \rho\ av \qquad (2)$$

Where
ρ: is the density of air (1.2250kg/ m3).
v: wind velocity.
a: is the wipe area of the turbine.
By substituting into the *equations (1) and (2)*.

$$ke = ½\rho av\hat{}3 \qquad (3)$$

Let's use 120 watts as the maximum power generation of the current work, and considering the efficiency of the turbine, which is 30%, we can say the power generation is 80%.

P= 120/ (0.30*0.8) = 500 W.

The wind velocity is (6.67 m/s) and the values are applied in the *equation (3)*.

500 = ½*1.1225*a*(6.67)3
a = 2.75 Sq.m

$$a = d * h \qquad (4)$$

d: is the blade diameter

The diameter has been taken as 2 meters, and from *equation (4)* is find the height and equal (1.375) m. The design of the blade is taken from *equations (5) and (6)*.

$$fly - width = d * 0.14 \qquad (5)$$

= 2*0.14
= 0.28m = 280 mm

$$fly\ chord = circumference * .09 \qquad (6)$$

= π*2*0.9
= 0.565m = 5652mm

As a result, the blade is pushed forward, and the rotation begins. As seen in *figure 3*. Once the blades move, they produce headwinds (similar to what we experience on our faces when riding) [32].

FOREX Publication
Open Access | Rapid and quality publishing
International Journal of
Electrical and Electronics Research (IJEER)
Research Article | Volume 12, Issue 1 | Pages 126-133 | e-ISSN: 2347-470X

Figure: 3 Wind turbine blades

3.5 Arduino Uno

It has considered the open loop control (microcontroller) board created by Arduino and based on the Microchip Atmega328P microprocessor. As seen in the *figure 4* [18]. The board has several analog input/output pins and digital input/output pins that may be used to communicate with other extension boards and devices.

Figure 4: Arduino Uno

3.6 Voltage sensor

Voltage Sensor 0-25 for Arduino. This module lets you measure voltages between 0 and 25V by supplying a lower voltage to the Arduino for measurement. Once you have this value, you can easily calculate your real voltage using basic arithmetic, as shown in *figure 5* [33].

Figure 5: Voltage sensor

3.7 SD-card Reader

Devices like the Arduino Ethernet Shield may read from and write to SD cards with the SD library. The library supports the FAT16 and FAT32 file systems on regular SD and SDHC cards. *Figure 6* [34]. Illustrates the usage of digital inputs 11, 12, and 13 (on most Arduino boards) or 50, 51, and 52 (Arduino Mega) for SPI communication between the microcontroller and the SD card.

Figure 6: Real-time clock

3.8 Real-time Clock

A real-time clock may schedule actions for a certain time and keep track of the current time. As seen in Figure 7, most RTCs employ a crystal oscillator with a frequency of 32.768 kHz (the same frequency as quartz clocks and watches), similar to the Arduino Zero.

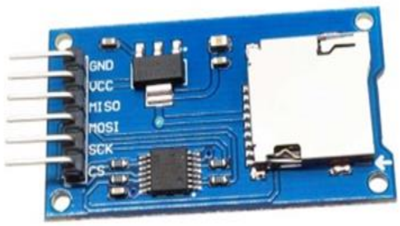

Figure 7: SD card

4. Control And Protection Circuit Of Wind Turbine

Figure 8 shows the connection between a voltage sensor and the real-time clock with the Arduino Uno for collecting and saving data in the SD card. We also connected a battery as the power supply for the Arduino. Then, we connected all components to the charge controller to balance the voltage and protect the wind turbine [35].

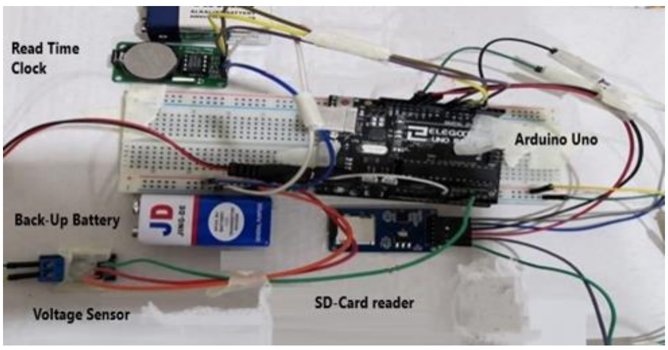

Figure 8: The control and protection real-time circuit

5. PROGRAMMING

Programming has been used in current work to collect data like date, time, and voltage that the DC generator gave us, by this it made a program to read the output voltage of the generator and

FOREX Publication
Open Access | Rapid and quality publishing
International Journal of
Electrical and Electronics Research (IJEER)
Research Article | Volume 12, Issue 1 | Pages 126-133 | e-ISSN: 2347-470X

to get the date and time from RTC (real-time clock), and finally save those data in a micro-SD card that can be used to view the data as an excel file or in notepad. The flow chart below in *figure 9* shows that the program is used to know the results and states of current work.

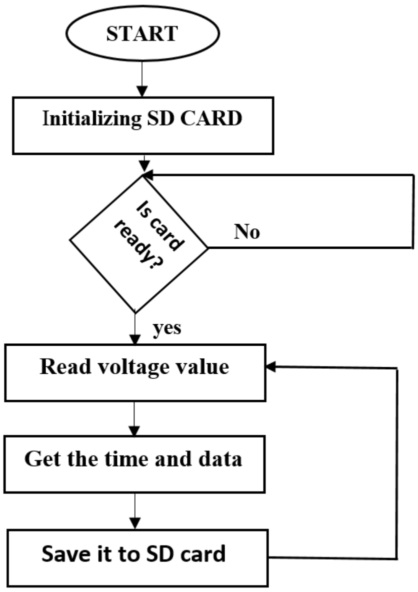

Figure 9: Flowchart of the read and write the voltage vs time in the SD

6. Choose The Suitable Place of (VAWT)

For the measurements of the suitable place VAWT, Anemometers have been positioned side-by-side at various distances measured from the road shoulder, all at the same level for the earth. The chosen separations from the road were 0.5, 1.0, and 1.5 meters. For various measurements, the height levels from the ground were varied to 1.5 m, 1.0 m, and 0.5 m [36]. A measuring device's heights were adjusted while maintaining these separations from the road, as seen in *figure 10*.

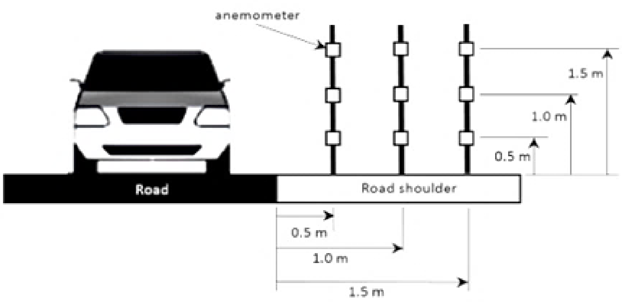

Figure 10: An illustration of the anemometer's location next to the road

According to an evaluation of the information, the turbine should be positioned at a height of 1.5 meters to accommodate large vehicles like buses and lorries that pass by the anemometers. To calculate the optimal place to height from the earth where the (WT) could be positioned, three wind intensity meters have been installed at this lateral distance from the road, as illustrated in *figure 11*. This choice was informed by the assessment of cross space, which revealed that 1.0 m is the best space to position the wind turbine.

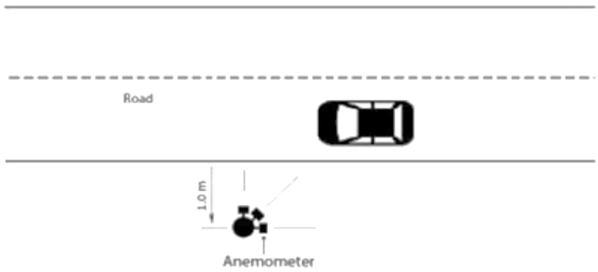

Figure 11: Set up anemometer in various orientations.

Figure 12 shows the finishing design and places the VAWT on the Dohuk-Zakho-Iraq road, which is the perfect place to test current work as it is an HW that includes all types of vehicles.

Figure 12: VAWT on DZI

7. Results of Current Design Work

Figure 13 shows the results have been taken from the Arduino sensor's voltage vs time, where it has been worked the VAWT from time (1:31 pm) minute into (16:7 pm) minute, during which the period of operation the system (3 Hour:39 minute) the peak voltage reached in the (13:41 P.M) and equal (5.78V), and from (2:00 pm) into the (14: 3) the highway road don't have any vehicles, so the voltage measurement (0 V), and after the time (14:4 pm) Cars were noticed passing by, so the voltage began to increase again till the last time in take from the sensor (16:7pm) where the voltage is became(0.32 v). From the results, voltage have been produced at different times of the day and analyzed the times when the traffic hours hit the peak. These data showed that on average the turbine can generate electricity for about 17 street lights each with a 0.5A, which proves the proposal design.

Table (1) shows the values of the results drawn in *figure (13)* accurately, as all the real values were taken through the sensor group to be drawn in *figure (13)*. Due to the large amount of data, it was briefly presented for the period from (13.31) to

International Journal of
Electrical and Electronics Research (IJEER)
Research Article | Volume 12, Issue 1 | Pages 126-133 | e-ISSN: 2347-470X

(14:7), that is, the table was drawn up to clarify the values in *figure (13)*.

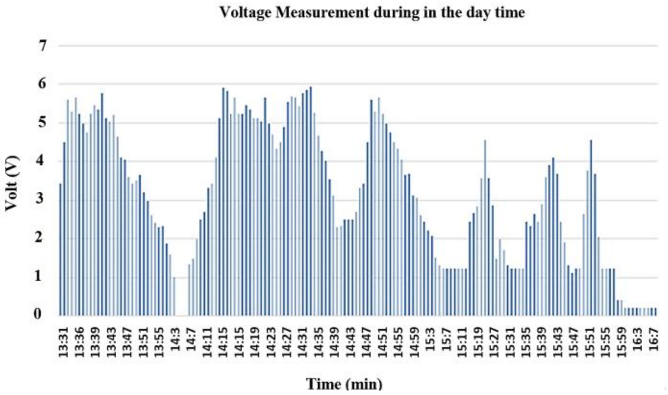

Figure 13: The data of result VAWT (Volts vs Time)

Table 1. The data of result VAWT (Volts vs Time)

Date	Time (pm)	Volt (V)
/5/17 2022 Date:	13:31	3.44
	13:32	4.5
	13:33	5.6
	13:34	5.3
	13:35	5.65
	13:36	4.98
	13:37	4.76
	13:38	5.23
	13:39	5.45
	13:40	5.34
	13:41	**5.78**
	13:42	5.12
	13:43	5.03
	13:44	5.22
	13:45	4.65
	13:46	4.12
	13:47	4.04
	13:48	3.6
	13:49	3.42
	13:50	3.51
	13:51	3.65
	13:52	3.19
	13:53	2.99
	13:54	2.6
	13:55	2.4
	13:56	2.3
	13:57	2.34
	13:58	1.87
	13:59	1.59
	14:00	1
	14:1	0
	14:2	0
	14:3	0
	14:4	1.34
	14:5	1.49
	14:6	1.98
	14:7	2.5

Table 2 below shows the details of the cost from the current design proposal work; it shows the total cost (345$) compared with the produced, which is good.

Table 2. Cost of the current design work

Item	Quantity	Item Cost ($)	Total cost ($)
Blades (type PVC)	6	4.8$	29$
Steel Shaft (di=10mm)	1	17$	17$
Poly (fits the shaft)	2	5$	10$
Base (iron)	1	90$	90$
Blades arm (iron)	12	2$	24$
Gearbox (135) notch	1	9$	9$
Gearbox (11) notch	1	3$	3$
Generator base (iron)	1	14$	14$
Generator (12v DC)	1	34$	34$
Charge controller (12/24v DC)	1	6$	6$
Gel battery (12v-55Ah)	1	85$	85$
Wires (2.5mm flexible)-20m	6	0.7$	4.2$
Arduino microcontroller	1	6$	6$
RTC (Real time clock)	1	1.5$	1.5$
Micro SD card reader	1	2$	2$
Voltage sensor	1	1$	1$
Arduino battery	2	1.5$	3$
Arduino wires	18	0.2$	3.6$
Total cost of proposal design			345.3$

8. CONCLUSION

In conclusion, the current design proposal was first started with the measurements and design of the wind turbine. We picked a vertical axis wind turbine because it is the most suitable type for use on highways as it can receive wind from both sides and doesn't take up much space. Much information about the wind patterns caused by moving cars has been gathered on both sides of the HW. The data gathered has created, designated, and installed a wind turbine on the HW middles. Even though one turbine might not be able to generate enough power, a group of turbines on a long stretch of HW has the potential to generate a significant amount of energy that could be used to power lighting and other public facilities or even earn money by selling the electricity back to the grid. This architectural movement strives for sustainability and ecological responsibility. Used iron has been reshaped for the structure; water pipes are blades of PVC type to withstand high temperatures and a smart electronic circuit that is low-cost and practical to store data so that the researcher can know the appropriate places to install wind regulators. Theoretically, any moving device such as a theme park ride may power the turbine. Any city with a lot of traffic may use the HW wind turbine to generate electricity. The current proposal work is considered good from the low cost with high performance, and the power produced is an Acceptable card.

9. ACKNOWLEDGMENTS
We would especially like to thank the Mosul Institute of Technology/Northern Technical University and the College of Engineering, University of Duhok, for their amazing work on the wind turbine along highways, as well as for providing the information needed to complete the project and for their support regarding the turbine system and renewable energies.

REFERENCES
[1] Anand, V. 2019. Power Generation on Highway by Harnessing Wind Power. International Journal of Innovative Technology and Exploring Engineering (IJITEE), 8(12), 329-331. DOI: 10.35940/ijitee.L1085.10812S19.

[2] Sachin, Y. S., Govind, P. S., Pankaj G. P., and Mujahid F. K. 2018. Power Generation on Highway by using Vertical Axis Wind Turbine & Solar System. International Research Journal of Engineering and Technology (IRJET), 5(3), 2133-2137. https://irjet.net/archives/V5/i3/IRJET-V5I3493.pdf.

[3] Shchasiana, A., Andrii H., Oleksandr, D., and Svitlana, P. 2019. A Device for Converting Kinetic Energy of Press into Electric Power as a Means of Energy Saving. Journal of the Korean Society for Precision Engineering, 36(1), 105-110. https://doi.org/10.7736/KSPE.2019.36.1.105.

[4] Pramod, M.S., Naveen, P. N., Chaithra, N. R., Ranjith, K., and Vikas, G. H. S. 2018. Monitoring of highway wind power parameters and controlling highway lights through IOT. 2017 2nd IEEE International Conference on Recent Trends in Electronics, Information and Communication Technology Proceedings, 1750-1753. DOI:10.1109/RTEICT.2017.8256899.

[5] Yuki, S., and Midori A. 2009. Mass-media coverage, its influence on public awareness of climate-change issues, and implications for Japan's national campaign to reduce greenhouse gas emissions. Global Environmental Change, 19(2), 203-212. https://doi.org/10.1016/j.gloenvcha.2008.10.005.

[6] Mahmoud, M. Y, Mohammed A., and Low Y. S. 2020. Development of Vertical Axis Wind Turbines and Solar Power Generation Hybrid System. International Journal of Computing and Digital Systems, 9(4):625-634. DOI:10.12785/ijcds/090410.

[7] Velavan, R., Bharathvaj, A. S., Gokul, K., and Manivannan, I. 2022. Electric Power Generation in Road Ways. International Journal of Creative Research Thoughts (IJCRT), 10(5) May 2022, 461-466.

[8] https://ijcrt.org/papers/IJCRT2205156.pdf.

[9] Hossain, M. I., Akter, R. Mahedi, H., Ahamed, R., Khan, M. F. S., Ali, F. B., Rocky, C., Alam, M. J., Mahtab, S. S. 2021. Generation of electrical energy using road transport pressure at a speed breaker, AIP Conference Proceedings, https://doi.org/10.1063/5.0039999.

[10] Roberto, D. F., Mariangela D. G., Donato C., Carolina D., and Paolo. V. 2023. Energy Harvesting Technologies and Devices from Vehicular Transit and Natural Sources on Roads for a Sustainable Transport: State-of-the-Art Analysis and Commercial Solutions. journal Energies, pp. 1-46,16(7), 3016; https://doi.org/10.3390/en16073016.

[11] Tingsheng, Z., Lingji K., Zhongyin, Z., Xiaoping W., Hai L., Zutao Z., and, Jinyue, Yan. 2024. An electromagnetic vibration energy harvesting system based on freight railroads' series coupling input mechanism. Journal of Applied Energy, Volume 353 part 1, https://doi.org/10.1016/j.apenergy.2023.122047.

[12] Martin, F. and Bikki, J. z. 2005. Global warming, commitment to the Kyoto Protocol, and accounting disclosures by the largest global public firms from polluting industries. The International Journal of Accounting, 40(3), 215-232. https://doi.org/10.1016/j.intacc.2005.06.004.

[13] Khan, M., Alavi, M., Mohan, N., Azeez, A., Shanif, A., and Javed, B. 2017. Wind Turbine design and fabrication to power street lights MATEC Web of Conferences 108, 08010. DOI:10.1051/matecconf/201710808010.

[14] Bani-Hani, E. H. S., Mashael AL-Shemmary, M., Hussain A., Alshaieb, A., and Kakoli, H. 2018. Feasibility of Highway Energy Harvesting Using a Vertical Axis Wind Turbine Energy Engineering. Journal of the Association of Energy Engineering Pages 61-74. https://doi.org/10.1080/01998595.2018.11969276

[15] Vaibhav, H. D., and Thora, M. L. 2017. Performance Analysis of Giromill Vertical Axis Wind Turbine with NACA 63618 Airfoil. International Research Journal of Engineering and Technology (IRJET) 4(7), 566-572. https://irjet.net/archives/V4/i7/IRJET-V4I798.pdf.

[16] Howell, R., Qin, N., Edwards, J., and Durrani, N. 2010. Wind tunnel and numerical study of a small vertical axis wind turbine. Renewable Energy, 35(2), 412-422 https://doi.org/10.1016/j.renene.2009.07.025

[17] Liton, H. M., Abu-Siada, A., and Muyeen, S. M. 2018. Methods for advanced wind turbine condition monitoring and early diagnosis: A literature review, 11(5), 1-14, https://doi.org/10.3390/en11051309.

[18] Bruce, C., Geatjens, A., and Antonia, S. 2013. Highway Wind Turbines Master Thesis Florida International University.

[19] Ogunoh, C., Ezemmuo, Daniel., Ani, M. 2017. Design and Construction of Vertical Axis Wind Turbine. Saudi Journal of Engineering and Technology ISSN 2415-6272 (Print) Scholars Middle East Publishers 2(2), 65-72, ISSN 2415-6264 (Online) Dubai, United Arab Emirates Website, DOI:10.21276/sjeat.2017.2.2.1.

[20] Chong, W. T., Fazlizan, A., Poh, S. C., and Pan, K. C. 2014. Vertical axis wind turbine with the omni-direction-guide-vane for urban high rise application Journal of Central South University of Technology 19(3),1-7.

[21] Sakeln S. S., Siddhesh, T. H., and Abhishek, A. B,. 2022. Vertical Axis Wind Turbine with Inventor. International Journal for Research in Applied Science & Engineering Technology (IJRASET) Vol.10, ISSN: 2321-9653, 43-46, DOI:10.22214/ijraset.2022.42045.

[22] Shubham, N., Tirthraj, L., Vaishnavi, F., and Pranay, B. 2017. Design and Fabrication of Vertical Axis Wind Turbine with Magnetic Repulsion" International Journal of Engineering Research & Technology (IJERT) Vol. 6 Issue 05, ISSN: 2278-0181, page 790-795, DOI: 10.17577/IJERTV6IS050462.

[23] Louis, V. B., Murugaperumal, G., Paramasavan, K., and Hoshila, K. 2014. Design and Fabrication of Three Bladed Giromill Wind Turbine. Final Year Dissertation Anna University Chennai pp 1-69.

[24] Hegde, S. S., Thamban, A., Bhai, S. P. M., Ahmed, A., Upadhyay, M., Joishy, A., and Mahalingam, A. 2017. Highway Mounted Horizontal Axial Flow Turbines for Wind Energy Harvesting from Cruising Vehicles, Conference: ASME IMECE 2016, pp 1-10.

[25] Samir, J., and Sagar, C. M. 2017. Design and Development of Vertical Axis Wind Turbine. International Conference on Science & Engineering for Sustainable Development, 286-294, DOI:10.21013/jte. ICSESD201728.

[26] Acosta, P. S., Tilvaldyev, S., Anaya, L. G., Sanchez, G. E., and Garay J. F. 2015. Advanced High Efficient Aerodynamic Blades for Vertical Axis Wind Turbine Modular Aggregate. International Journal of Arts & Sciences; Cumberland 8(6), 617-626.

[27] J. Vignesh, C., A. S., Albert, T., C. Pravin, T. S., and Sunil, J. 2020. Designed and fabricated a vertical-axis windmill with a solar system. Elsevier, 21(1), 10-14. https://doi.org/10.1016/j.matpr.2019.05.296

[28] Dinesh, E.A. Kumara, N. K., and Hettiarachchi, K.G. 2017. Overview of The Vertical Axis Wind Turbines. International Journal of Scientific Research and Innovative Technology, 4(8), ISSN: 2313-3759, 56-67.

[29] Saurabh, A K., and Birajdar, M.R. 2016. Vertical Axis Wind Turbine for Highway Application. Imperial Journal of Interdisciplinary Research (IJIR), 2(10), ISSN: 2454-1362, Page 1543-1546. http://www.onlinejournal.in.

[30] Chaitanya, P. S., Slaman, S.K., Teja, V. T., Rakesh, K., and Ahamed, S.K. 2021. Power Generation On Highway Using Vertical Axis Wind Turbine. Dogo Rangsang Research Journal UGC Care Group I Journal Vol-08, Issue-14 No. 01, ISSN: 2347-7180, 421-426. https://doi.org/10.22214/ijraset.2023.49433.

[31] Kalmikov, A. 2017. Wind Power Fundamentals in Wind Energy Engineering. A Handbook for Onshore and Offshore Wind Turbines.

[32] Hongzhong, M., Lin, C., Ping, J., Haihua, L., Ning, J., and Chunning, W. (2009). Feasibility research on DC generator-based wind power

generation system. International Conference on Sustainable Power Generation and Supply. DOI: 10.1109/SUPERGEN.2009.5348170.

[33] Ababacar, N., Cheikh, M. F., Vincent, S., and Papa, A. N. 2014. Development of a Charge Controller Dedicated to the Small Wind Turbine System. Energy and Environment Research, 4(3), 68-77. DOI:10.5539/eer.v4n3p68.

[34] Leo, Louis. 2016. Working Principle of Arduino and Using it as a Tool for Study and Research. International Journal of Control, Automation, Communication and Systems (IJCACS), 1(2). DOI:10.5121/ijcacs.2016.1203.

[35] Doan, D. T., and Ngo, M. K. 2019. An Arduino-Based System for Monitoring and Protecting Overvoltage and Undervoltage. Engineering, Technology & Applied Science Research, 9(3), 4255-4260. https://doi.org/10.48084/etasr.2832.

[36] Ahmed, F.S, and Aljawady, N.A. 2021. Control of prosthetic hand by using mechanomyography signals based on support-vector machine classifier. Indonesian Journal of Electrical Engineering and Computer Science, 23(2), 1180-1187. DOI: http://doi.org/10.11591/ijeecs.v23.i2.pp1180-1187.

[37] Satheesh, M.B., Satheesh, B. S, Veeramanikandasamy, T., and Saravanakumar, O. M. 2007. Microcontroller and SD Card Based Standalone Data Logging System using SPI and I2C Protocols for Industrial Application. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 5(4), 2208-2214. DOI:10.15662/IJAREEIE.2016.0504002.