Wind Turbine for Power Generation and Storage by Vehicular Movement on Highways with IoT

Safdar Hussain[a], Beenish[b], Anup Simeon[c], Nayana. N. Patil[d], Humaira Ali[e], Abdul Amir Sohel[f]

[a]PG student, Department of Civil Engineering, M.S Ramaiah University of Applied Sciences, Bengaluru, India, safdarhussain313@gmail.com
[b]PG student, Department of Civil Engineering, M.S Ramaiah University of Applied Sciences, Bengaluru, India, beenishzargar662@gmail.com
[c]PG Student, Department of Civil Engineering, M.S Ramaiah University of Applied Sciences, Bengaluru, India anupsimeon@gmail.com
[d]Asst. Prof, Department of Civil Engineering, M.S Ramaiah University of Applied Sciences, Bengaluru, India nayanapatil.ce.et@msruas.ac.in
[e]PG student, Department of Civil Engineering, M.S Ramaiah University of Applied Sciences, Bengaluru, India ali.humi13@gmail.com
[f]PG student, Department of Civil Engineering, M.S Ramaiah University of Applied Sciences, Bengaluru, India abdulamirsohel9@gmail.com

Article History: Received: 11 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 10 May 2021

Abstract: The demand for energy is increasing tremendously with each passing day. The depletion of the energy resources has necessitated the usage of renewable sources to meet the energy crisis the entire world is facing. The most important of all the renewable sources is wind which can be used as an efficient means for generating electricity by using wind turbines. These turbines are employed for the transformation of mechanical energy to electrical energy, thus making the use of a renewable source rather than relying on conventional sources of energy. The current work discusses the fabrication, erection and installation of a wind turbine on a highway which generates power using the vehicular movement. In this study, traffic survey was conducted at different locations to select the best location to set up the turbine giving due consideration to wind speed, vehicular movement and traffic volume. The fabricated wind turbine was installed at the site chosen based on the traffic studies carried out. The power generated was calculated by noting the current and voltage. The power generated was stored in a 12V, 1.3AH battery. The IoT system was installed with the turbine and sensors to record the voltage, current and any faults in the turbine. A boost converter was used which proved to be an asset in amplifying the voltage.

Keywords: wind turbine, IoT, Arduino, sensors, VAWT, battery

1. Introduction

The energy demand in every country is exponentially increasing each single day. The available power does not meet the necessity. As energy shortage and environmental problems are increasing, energy saving and environmental protection has become a prime topic of the scientific and technological development. The energy crisis that is being faced today is a matter of great concern for the entire world. The demand for the energy is increasing but the supply in due course of time will fall short as all these sources of energy are dwindling day by day. The resources are getting depleted and the large-scale use of the non-renewable energy sources is creating a harsh impact on the environment as well. All this will come down to a point where the demand will outstrip the supply. Renewable energy has been attracting more and more attention as it is non-polluting in nature and these resources must be utilized as much as possible to cut down the demand rate.

In the recent years, the focus of generating electricity from the renewable energy sources has gained momentum, giving due consideration to the growing environmental pollution, the increase in energy demand and the exhaustion of the fossil fuel reserves. The various sources of such energy include solar, geothermal, biomass, hydroelectric and wind energy. Wind energy system is more effective and a reliable form of renewable energy available. The present issue is how to utilize and manage these resources. This work addresses the utilization of wind energy to enhance the power management. For this reason, the highways are a good option as and when the vehicle passes it, the wind velocity is more. The vehicles when moving compress the air in front and pushes it to the sides thereby creating a vacuum while it moves forward. This kinetic energy and the turbulence of the wind that is created by the vehicles moving on the highways becomes an aid for the generation of electricity. Though this idea of generating electricity from the wind turbine is not a path breaking technology but its employment will reduce our dependence on the fossil fuels to a great extent.

2. Literature Survey

The wind turbines are an effective means to generate power. Much work has been done in this field but certain modifications are always required for every work. For getting an idea about the work done in the record on wind turbines and IoT systems, it is necessary to carry out the literature survey.

Rita et. al.,(2014) have described the efficient wind turbines for specific applications. A combination of the Darrieus and Savonius type, vertical axis wind turbines has been designed for highway application. The design of a charge controller circuit has been described that provides charge monitor and flow control with the aid of microcontroller through the whole circuitry. The operation and feasibility of the proposed model has been analyzed.

Somnath et. al., (2019) have described the use of wind as an effective and reliable energy source for the generation of power. The increasing demand of power can be met with the wind turbines employed on highways. The model developed consists of solar panels combined with the turbine system that can be efficiently utilized for power generation on the highways.

Hassan et.al., (2011) have described the usage of wind resource as the main source for generating power. A solar power plant with a solar tracker was chosen to hybridize with wind energy resource. To enhance efficiency, sun tracker has been used which increases the energy absorbed by the photovoltaic panels. The output dc energy of the hybrid power plant was converted to ac and was made to synchronize with electric power grid by the power conditioning unit.

Mukesh (2014) has described that the wind pressure from vehicles compresses the air and rotates the turbine to generate electricity. The turbine can be aided for pumping water and develop full maintained irrigation system along with the production of energy free electricity of 6.357 W generated by the DC motor.

S. Bharathi et. al., (2014) have worked on initiating electricity using high wind pressure generated by fast moving vehicles. The production of power could be about 1,481,000 MW. This system can supply a unit with lighting fans. Their study also showed that employment of this source of energy would reduce the carbon emissions in the country.

Lina Alhmoud et. al., (2019) worked on the wind resource evaluation and lifetime estimation of wind power modules utilizing IoT. A model was developed, built with sensors for measurement of different wind parameters. The simulations were structed with thing speak. It was found that IoT has increased the reliability of measurements, monitoring, accuracy and quality assurance.

3. Wind Turbine technology

The wind turbines have evolved from simple devices based on aerodynamic drag forces to heavy drag devices and the recent advancement have employed to the use of light weight, efficient aerodynamic lift devices. These lift devices use blades that interact with approaching wind. The wind turbine is employed for the conversion of kinetic energy of wind into electricity. This is achieved using a wind turbine with propellers and a generator. The turbines can further be classified as horizontal and vertical axis wind turbines. In this study, the vertical axis wind turbine has been used.

3.1 Vertical Axis Wind Turbine

VAWT is one of the most popular and coveted wind turbine. It has a good longevity, durability, reliability and is found to be cost effective. In this work, “Gyro Mill” type vertical axis wind turbine is fabricated. The direction of wind does not matter as it self adjusts and can be placed at the ground level or on a highway median.

The wind turbine fabricated to carry out the current study is shown in Figure 1.

3.2 Swept Area

It is that portion of air that is enclosed by the turbine while it moves. The geometry of this area depends upon the rotor configuration. For a VAWT, with a straight blade, the swept area is either rectangular or circular. The area is calculated by using Equation 1:

$S=2RL$ (Eqn 1)

Where,

S: swept area(m^2)

R: Rotor radius (m)

L: blade length (m)

Figure 1 Vertical Axis wind Turbine with color coating

3.3 Number of blades

The smoothness of rotor operation depends upon the number of blades, as they can expiate cycled aerodynamic loads. The solidity σ may be defined as the ratio of the total blade area and the projected turbine area. It is a non-dimensional parameter affecting the self-starting capabilities and for a straight bladed VAWT, it is calculated as in Equation 2:

$$\sigma = \frac{N*C}{R} \quad \text{(Eqn 2)}$$

Where N: Number of blades

C: Blade chord

L: Length of blade

4. Power from Wind

The static characteristics of a wind turbine rotor can be defined by the relationship between total power in the wind and mechanical power of the wind turbine. The power generated from a VAWT can be calculated from the Equation 3.

$$Pw=\tfrac{1}{2}\rho S V_0^3 \quad \text{(Eqn 3)}$$

Where, V_0 is the velocity of the wind [m/s].

ρ is the air density [kg/m^3].

To extract all the kinetic energy from the wind is not possible as it would lead to a situation where the air would still be directly behind the turbine, this would imply that the air will not flow away from the turbine and such a situation cannot represent a physical steady state condition. The wind speed is reduced by the wind turbine by withdrawing the fraction of power from the wind. This is indicated as the power efficiency coefficient C_p of the wind turbine. Thus the mechanical power output of the wind turbine can be stated as in expression 4.

$$P_{mech}=C_p*P_{wind} \quad \text{(Eqn 4)}$$

Where C_p: Captured mechanical power by blade

P_{wind}: Available power in wind.

5. Components of the turbine

The literature survey helped in arriving at the final components of the VAWT to be used along with the specifications and the materials. The various components used in the turbine are thoroughly studied and all the materials used are presented in Table 1.

Arduino Mega is a microcontroller, that is used for controlling the device and processing the data. It consists of 16 analog pins, 54 digital input/output pins and 4 dedicated UART ports. To measure the external voltages that are greater than its maximum acceptable value, voltage sensor can be used with the Arduino. The ACS712 current sensors offered on the internet are designed to be used easily with microcontrollers. The IR Sensor has been used to detect any flaws in the turbine. When the turbine rotates the sensor records it, and if it stops a message will be sent to Thing speak .Thus they have been used for fault diagnosis.

Table 1 Components of the Turbine

S.No.	Part of turbine	Materials Used	Specifications
1	Blade	Mild Steel	Height=60cm Width=15cm
2	Base	Mild Steel	25.4cm*25.4cm Thickness=3mm
3	Shaft	Mild Steel	Diameter=12mm
4	Frame	Mild Steel	80*140cm
5	Dynamo	Permanent magnet	24V
6	Battery	Lead Acid Battery	12V, 1.3AH

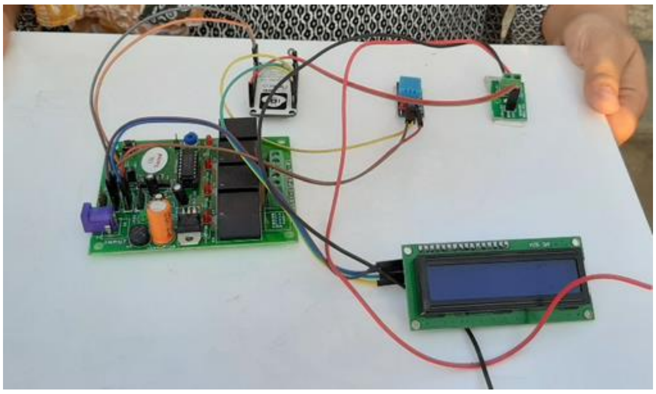


Figure 2 Complete circuit of IoT

Figure 2. shows the complete IoT circuit used in the present study.

NodeMCU is an open source IoT platform. It is interactive, simple and WiFi enabled. It includes firmware which runs on the ESP8266 WiFiSoC from Espressif Systems and hardware based on the ESP-12 module. This system is applicable from any remote location provided there is an internet connection.

6. Importance of traffic survey

To obtain maximum power from the turbine it has to be set up at an appropriate location. The location must have good flow of vehicles and the wind speed should be quite high such that the turbine rotates and sufficient power is generated. To find the best place to set up the turbine, few locations were shortlisted where the wind speed measurement was carried out along with the traffic survey. After conducting these studies, the final and most appropriate location was selected for the setting up of the turbine and generating power. The locations shortlisted were Anchepalya, Jalahalli, Yelahanka and Gorguntepalya in Bengaluru. When traffic studies were carried out, it was inferred that the flow of vehicles on Anchepalya is very high and also the wind speed was found out to be maximum. The wind speed was about 39.6 km/hr.

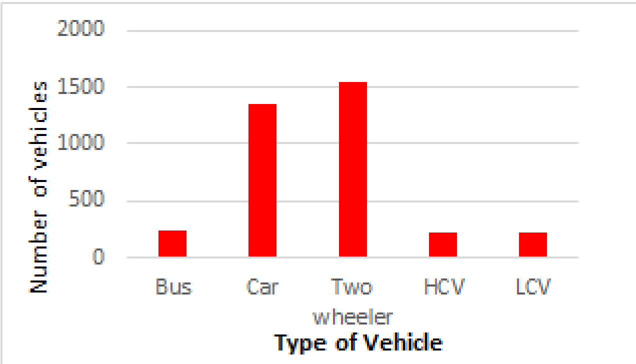
Table 2 Traffic volume count in the morning peak hour (8:00 to 10:00 am)

Bus	Car	Two wheeler	HCV	LCV
242	1354	1553	213	227

Figures 3 and 4 show the variation of traffic volumes in the peak hours in the morning and evening.

Table 3 Traffic volume count in the evening peak hour (5:00 to 7:00 pm)

Bus	**Car**	**Two wheeler**	**HCV**	**LCV**
291	1474	1539	261	296



peak hour

Figure 3 Traffic volume in morning peak hour

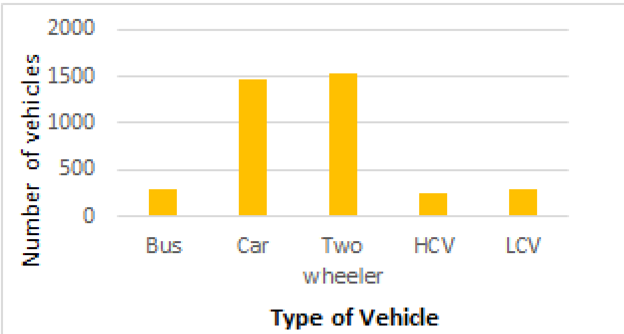


Figure 4 Traffic volume in evening peak hour (5:00 to 7:00 pm)

7. Collection of Output data

The data analysis is carried out by collecting the data and communicating it to the cloud server. The sensors send the data every microsecond and this data reaches the data collector. The data acquisition takes place and data is stored in cloud server that is an online database and is accessible both with a web browser and mobile app. The cloud server being used is thingspeak which is an open source internet of things (IoT) application and API to store and retrieve data from things using the HTTP and MQTT protocol over the internet. These data can then be used for comparisons.

The graph in Figure 5 represents the variation of voltage with time. The voltage obtained increases when the vehicle wind speed is more and vice versa. The maximum voltage obtained was 4V without the boost converter.

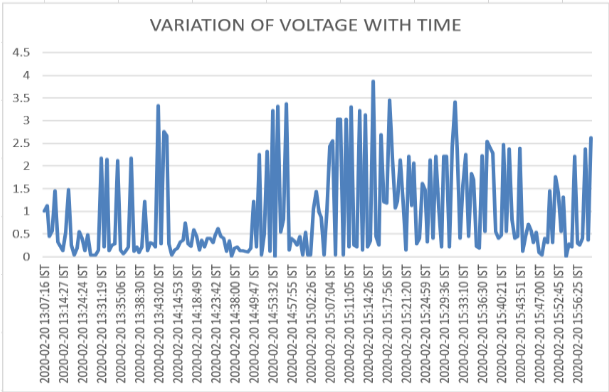


Figure 5 Variation of voltage at different time intervals

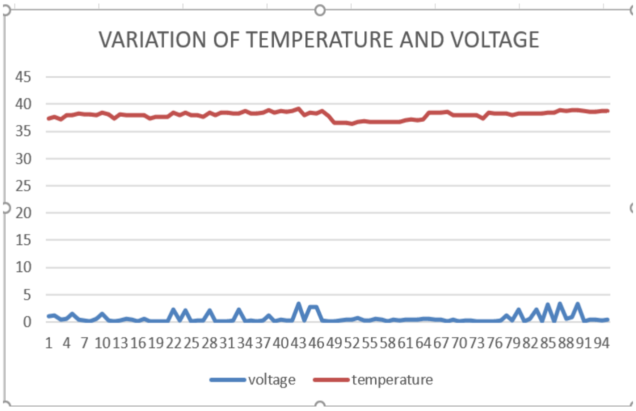


Figure 6 Variation of temperature and voltage

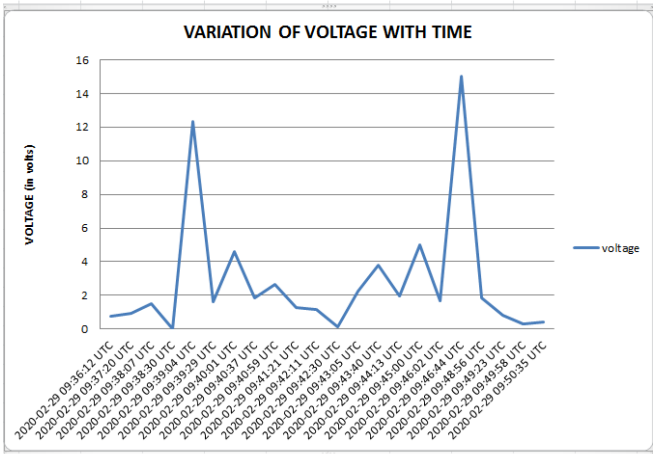


Figure 7 Variation of voltage with time with boost converter

Figure 6 is plotted to show the variation of voltage and temperature with time. When the boost converter was used, the voltage was amplified and the graph plotted in Figure 7 shows the variation of voltage with time. With the aid of boost converter the voltage was amplified to 15 V.

The graph shown in Figure 8 represents the comparison of voltages obtained with the inclusion of step up boost converter and without it. This clearly shows that with the addition of boost converter, the voltage is amplified to a great extent.

8. Calculations For Power Generated And Wind Power

The power generated using wind turbine is stored in a 12V 1.3AH battery which can supply 1.3 amp current in one hour.

For 5 watt street light,

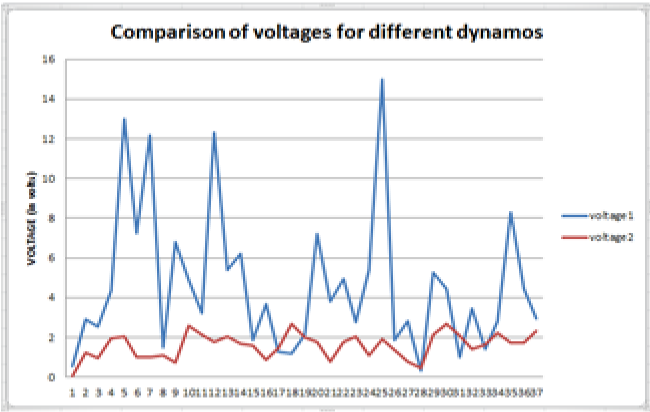


Figure 8 Comparsion of voltages with and without boost converter

Current required with 12 volts of voltage is:

$$I = P/V = 5/12 = 0.42 \text{ amp}$$

Since the battery can supply 1.3amp in one hour, it can lighten a 5 watt street light for 3 hours and 20 mins.In India, 5 to 6 metre high pole street lights are mostly used and the power requirement for these poles is 20 watts.

Current required = $I = P/V = 20/12 = 1.6$ amp

So, this battery can light a 20watt street lamp for 48 mins. The power is calculated using Expression 5.

$$\text{Power} = kC_p \tfrac{1}{2} \rho AV^3 \quad \text{(Eqn 5)}$$

Where:
P=Power output in kilowatts

C_p = Maximum power coefficient, ranging from 0.25 to 0.45

ρ = Air density, lb/ft^3 = 0.0765 lb/ft3

A = Rotor swept area, ft2 or π D2/4 (D is the rotor diameter in ft, π = 3.1416 and D = 2.62 ft.

A = 5.388 ft^2

V = Wind speed, mph = 11.18 mph.

k = 0.000133 A constant to yield power in kilowatts.

P = 0.3*0.5*0.000133*0.0765*5.388*11.18^3

P = 0.114 KW

= 11.4 W.

Power generated with 12V DC Dynamo = 3 to 4 W.

Power generated with 24V DC Dynamo with booster = 9 to 11 W.

9. Results

The wind turbine with the application of the IoT made the real time access of voltage, temperature and fault detection using thing speak application. IoT is capable of transferring the data over a network without any human to human interaction.

From the studies carried out on 19th February 2020, between 3:30 to 4:30 pm, average voltage generated was 4V which depicted the heavy flow of vehicles in this time period.

3 to 4 W power could be generated with 12V dynamo and 9 to 11W with 24 V DC dynamo.

Between 10:30 to 11:30 am, the average voltage generated by 12 V dynamo was found to be 1.8 V and with 24 V dynamo was 11.6 V.

12 V 1.3 AH battery can lighten a 5 watt street light for 3 hours and 20 minutes and can light a 20 watt street lamp for 48 minutes from the power generated by the

wind turbine.

10. Conclusions

A small effort has been made in this work to trap the wind energy by utilizing the movement of vehicles on highways. Use of IoT has provided real time monitoring of the power generated by the vehicles.

The minimum and maximum temperatures recorded were 36.2 and 38.9 degrees during the days of study carried out. More the number of vehicles plying on the road more the power generated. Recording the current and voltage along with fault diagnosis in the system was an important task as it indicated the smooth operation of wind turbine.

The wind turbine designed for power generation on the highways is self-starting, easy to install and low in cost turbine.

- The voltage obtained with the aid of boost converter increased by about 4 folds.
- When the maximum temperature was 38.9 degrees, the voltage obtained was 4V.
- The minimum temperature recorded was 36.2 degrees, and the voltage obtained was only 1.7V.
- It could be inferred that with the increase in the temperature the voltage increased.For a temperature rise of around 3.7 degrees the voltage increased by 2.5 times.
- From the survey conducted on 19-02-2020, during the time interval of 3:30 pm to 4:30 pm, average voltage generated was 4V which depicted the heavy flow of vehicles in this time period.
- This led to the conclusion that more the number of vehicles plying on the road, more will be the power generated.

For the time interval 10:30 am to 11:30 am, average voltage generated by 12V dynamo was 1.8V and with 24V dynamo was 11.6V. So the voltage generated increased almost 5 times with boost converter

References

1. R. Devi, and J. Singh, “Design and development of prototype highway lighting with road side wind energy harvester”, International journal of science and research, 3rd ed., vol. 9, pp.2319-7064, 2014.
2. H.Moghbelli, Hassan, H. Toliyat, and H. Abu-Rub, "A Green Hybrid Power Plant using Photovoltaic and Wind energy with Power Quality Improvement in Qatar" , Proceedings of the ASEE Annual Conference and Exposition, Vancouver, BC, Canada, 2011.
3. S.Y.Sayais, G.P.Salunkhe, P.G.Patil, and M.F. Khatik, ”Power Generation on Highway by using Vertical Axis Wind Turbine & Solar System”, International Research Journal of Engineering and Technology (IRJET), 5th ed., vol.3, 2018.
4. M.K.Sharma, “Assesment of wind energy potential from highway”. International Journal Of Engineering Research and Technology (IJERT), vol.1, pp.1-8.
5. S.Bharath, G. Balaji, V.A.Saravanan, and S. Suresh, “ A Method for Generating Electricity by Fast Moving Vehicles”, In Applied Mechanics and Materials, vol. 110, pp. 2177-2182, Trans Tech Publications Ltd, 2012.
6. D.Kalyanraj, S.L.Prakash, and S.Sabareswar, “ November. Wind turbine monitoring and control systems using Internet of Things”, In 2016 21st Century Energy Needs-Materials, Systems and Applications (ICTFCEN) , pp. 1-4), 2016
7. L.Alhmoud, and H. Al-Zoubi, “IoT Applications in Wind Energy Conversion Systems. Open Engineering”, 9th ed. , vol.1, pp.490-499.