Electricity Generation from Artificial Wind Generated by The Moving Vehicles

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Abstract- The improvements in renewable energy sources are increasing rapidly for controlling the pollution in the atmosphere caused by non-renewable energy sources. In that renewable sources, Wind energy is the fastest-growing green energy but naturally, it is limited and not always available continuously and it is not at same speed in every area and every time. Artificial wind energy is the wind/turbulence generated by vehicles moving at a speed on the roads. The vehicles like cars, buses, trucks and large vehicles like containers passing on the road at a speed can generate wind, which is called artificial wind energy. We can capture that wind by placing a wind turbine on the divider of the road. For this type of application, the Vertical Axis Wind Turbines are perfectly suitable.

Indexed Terms- VAWTs, Turbulence, Savonius, PMSGs, Median, Converter.

I. INTRODUCTION

The utilization of electrical energy is increasing day by day due to the increase in population all over World. Transportation depends on the products of crude oil to but they cause high air pollution. To reduce the air pollution caused by vehicles that use the road as means of transport, Electrical vehicles are introduced. The E-Vehicles run using electrically rechargeable batteries, so to charge the batteries we need electricity. To generate the increase in electricity utilized for these applications we need to increase the generation of electricity. The easy way to increase generation using Non-Renewable energy source power plants. So, the innovative idea of the E-Vehicles is to reduce air pollution caused by petroleum-consuming vehicles, we are achieving it. But the power used to generate increased electricity is done by using fossil fuels like coal, petroleum, etc. so the pollution reduced by vehicles is compensated by the additional electricity generating units in power plants. So, to reduce fossil fuel utilization we need to improve power generated by renewable energy sources, the efficiency is less but the advantages compared to non-renewable energy sources overcome it. To improve the ways of power generation using renewable energy sources, this idea has come to our mind, which is to generate power using artificial wind generated by the moving vehicles on the road.

It is an innovative way of capturing the wind/turbulence generated by the moving vehicles passing on the road. Large vehicles like trucks and containers can generate very high wind turbulence and can generate more power. Thereby we can install the VAWTs at a specified distance on the median (divider) which is present on the national highway can generate a significant amount of power. The power generated by the movement of VAWTs can be used to lighten up the roads and can be transmitted to the nearest toll plazas to utilize this power otherwise, we can supply this power to the nearest distribution stations which can deliver this to the villages/towns.

India is the 3rd largest producer and consumer of electrical energy. In that whole energy generation, only 26% is from renewable energy sources. As of 30th September, of the year 2020 a total of 38.124 GW is generated from wind power. It is the 10% of total power generation in India and it is the 4th largest country to generate that much wind power in the world. According to NHAI (National Highway Authority of India), our country has the 2nd largest road network in the world i.e., 58.9 lakh kilometres. In that 1.42 lakh, kilometre of the road is under national highway. The majority of existing highways are two-way with two-lane roads. Each two-way road has a median(divider) to separate two ways, the width of a median can be 0.6 meters to 2.0 meters. On that particular median, we can install our VAWTs with a specific distance between the turbine for electricity generation.

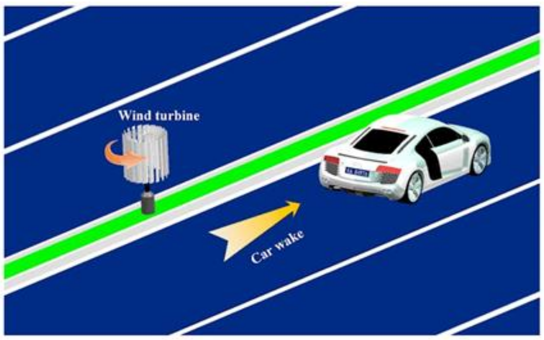

Fig.1: Model of VAWTs on the divider.

II. SELECTION OF WIND TURBINE

A wind turbine is a rotor that converts the wind's kinetic energy into mechanical (rotational) through shaft this rotational energy is transferred to the generator through the shaft that the turbine and generator are coupled. The generator converts this mechanical energy to electrical energy by the principle of Faraday's laws of electromagnetic induction. Wind turbines are manufactured in a wide range of sizes, with either horizontal or vertical axes. Wind turbines are an important source of renewable in many countries and they are researching to develop the architecture to increase the efficiency in existing models of wind turbines. There are two types of wind turbines, they are:

1. Horizontal Axis Wind Turbine (HAWTs)
2. Vertical Axis Wind Turbine (VAWTs)

The HAWTs are widely used for electricity generation. But a HAWT for our application is not suitable because of its high space requirement, tough maintenance, high-level foundation requirements, etc. But a VAWT is more suitable for our mode of operation and type of application. Because of its simplicity, easier maintenance, less space occupancy, and a minimal foundation requirement compared to HAWTs, etc. are the reasons approve it to be our selection.

2.1 VERTICAL AXIS WIND TURBINES.

A vertical axis wind turbine (VAWT) is a type of turbine where the main rotor shaft is set to the wind (but not necessarily vertically) while the main components are located at the base of the turbine. This arrangement allows the generator and gearbox to be located close to the ground, facilitating service and repair. VAWTs do not need to be pointed into the wind, which removes the need for wind-sensing and orientation mechanisms. A vertical axis wind turbine has its axis perpendicular to the wind streamlines and vertical to the ground. A more general term that includes this option is "transverse-axis wind turbine" or "cross-flow wind turbine". The different types of VAWTs are:

- Savonius rotor
- Darrieus-rotor
- H-Darrieus rotor
- Helix shaped rotor

From the above-mentioned four rotors according to our application and usage, the Savonius wind turbines suits better for our type of application.

2.2 SAVONIUS WIND TURBINE

The savonius wind turbine is one of the types of VAWTs, It was invented by the Finland Architect and Engineer Sigurd J. Savonius in the year of 1994. The savonius turbine works on the principle of difference in the drag. Due to its S-shaped curvature when the wind hits one of the blades, the differential drag causes the turbine to rotate.

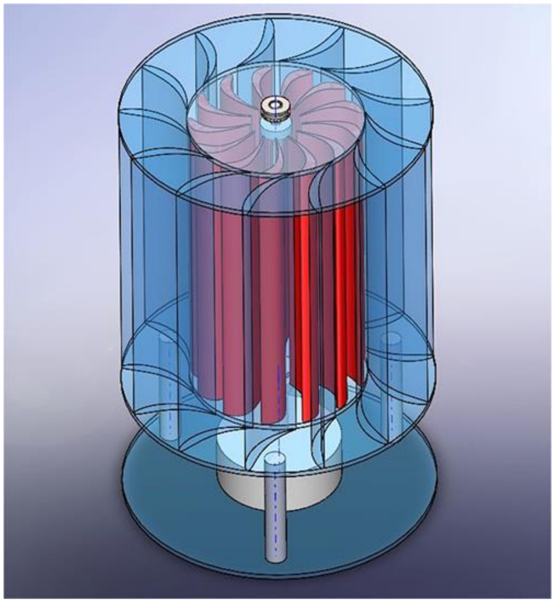

Fig.2: Savonius wind turbine.

Fig 2. Shows the model of savonius wind turbine with both fixed blades (Blue Curved blades) on the outer surface and moving blades (Red-coloured blades) mounted to the shaft. The fixed blades force the wind towards the moving blades.

The turbine consists a number of blades/aerofoils in normal mounted vertically but can be mounted in different ways for some applications. It is usually ground situated but can also be tethered in airborne systems. The savonius turbines are mainly used where the reliability and cost in consideration. According to our application, the most reliable option of the turbines is the savonius wind turbine as it has to be placed on the median(divider) of the road. By using a suitable generator in combination with this turbine we can generate maximum power.

III. GENERATION OF POWER & FREQUENCY

3.1 POWER CALCULATION

The power generated by the wind turbine can be calculated by using Betz's law. The maximum power generated from the rotor is,

$P_{max} = (16/27) *(1/2) * \rho*d*h*v^3$ ……… (1)

Where ρ is the density of air,

h is the height of rotor,
d is the diameter of the rotor,
ν is wind speed.

But in practice the power extracted is half as the theoretical value calculated from the above equation, practically the maximum power (approximately) obtained is,

$P_{max} \approx 0.18*h*d*v^3$ ……… (2)

Where 0.18 is an approximate product of the density of air (ρ) and constant values mentioned in equation (1).

3.2 FREQUENCY CALCULATION

The angular frequency of the generated power is given by,

$$\omega = (\lambda*\nu)/r \quad ………..(3)$$

Where, r is the radius of the rotor,
ν is wind speed,
λ is tip speed ratio.
Tip speed ratio changes for different rotors for the savonius wind turbine the wind ratio is nearly equal to unity (≅ 1).

We can see the top view, rotation of turbine with respect to wind direction is shown in below Fig.3.

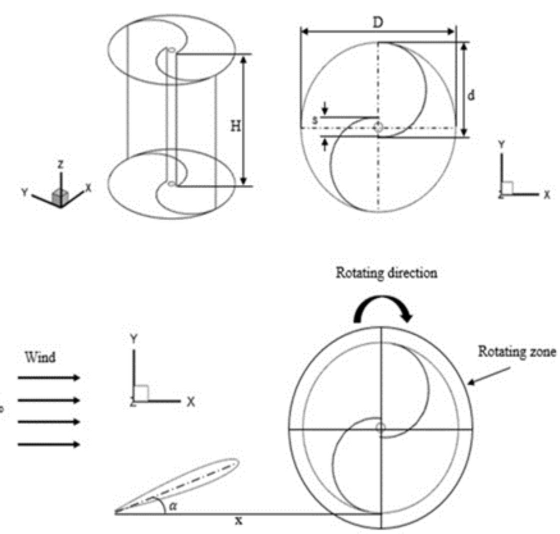

Fig.3: A sectional view of savonius wind turbine

IV. SELECTION OF GENERATOR AND POWER TRANSMISSION

4.1. SELECTION OF GENERATOR

A Generator is a machine which converts the mechanical energy to the electrical energy by the principle of faradays laws of electromagnetic induction. The two fundamental types of generators known as D.C (Direct current) & A.C (Alternating Current) generators. The present type of appliances that work on the supply are A.C only, D.C appliances are only used for special applications only. The advantages of A.C generators are more than D.C. Due to these reasons A.C generators mainly used to generate electricity at power stations. There are two types of generators according to number of phases in A.C generators, they are:

1. Single Phase.
2. Three Phase.

The single-phase generators are very rarely used for power generation. The three phase generators are most commonly used in any method of power generation. These generators are further classified into two types, they are:

i. 3-phase Synchronous Generators.
ii. 3-phase Induction Generators.

The mainly used generators for power generation in any method of operation i.e., thermal, hydro, nuclear are the synchronous generators. We know that the wind is not constant and our application is to place this on highways, the vehicles does not pass continuously. It also depends on the length of vehicle and speed at which the vehicle is moving. So, obviously the wind forced towards the turbine will never be constant. Due to this fluctuating nature of wind. It is advantageous to operate the wind turbine generators to operate at variable speed which in-turn reduces the physical stress on the turbine blades.

The generators used in present wind turbine applications are Doubly-Fed Induction Generator (DFIG) and Permanent Magnet Synchronous Generator (PMSG). The DFIG requires gearbox in order to adjust the speed from the turbine. But our main aim is to simplify the equipment and by using the DFIG it will become more complex. If we use the PMSG for our application it can be operated without the Gearbox so it is more suitable.

4.2. PERMANENT MAGNET SYNCHRONOUS GENERATOR (PMSG)

In recent decades, Permanent Magnet Synchronous Generators have been successfully used in wind turbine applications, because of their high-power generating capability and low mass. The PMSGs are considered as the machine of choice in small wind turbine generators. The PMSGs are rugged in construction and they can be directly connected to rotor without any gearbox requirement. In place of field winding the PMSG uses permanent magnets because of this reason there is also no requirement of external exciter to supply dc current for field winding and its associated power losses. These permanent magnets are mounted on the rotor and the armature on the stator so there are no requirement of slip rings or bushes. Some manufacturers integrate the Permanent Magnets cast into cylindrical aluminium rotor to reduce the cost.

The principle of operation of PMSGs is similar to that of synchronous generator except that PMSGs can be operated asynchronously. Because the actual wind speeds are variable, the PMSGs cannot generate power with fixed frequency. As a result, they should be connected to the power grid through conversion from AC to DC and again to AC by using power converters as shown in Fig. 4.

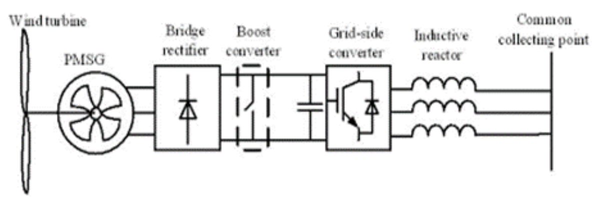

Fig.4: Block diagram of total equipment required.

As shown in the Fig.4, there is a requirement of rectifier, inverter, smoothing reactor, boost converter and filters. This equipment connected to each turbine to match the voltage and frequency of all the generators.

The characteristics of a PMSG is given in the fig.5.

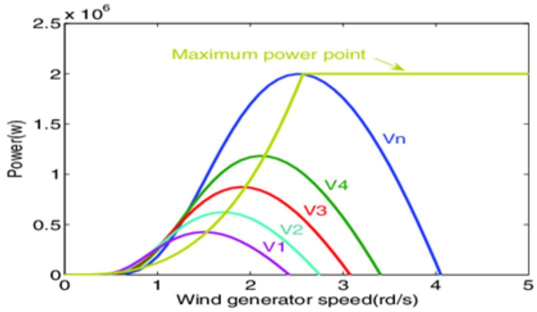

Fig.5: Characteristics of PMSG

4.3 CONVERTING CIRCUITS

4.3.1. GENERATOR SIDE CONVERTER

The generator produces electricity in the form of A.C we are converting it to D.C to obtain a constant voltage for synchronising all the generators. The three-phase fully controlled rectifier using SCR (silicon-controlled rectifier) is used as converter at generator side. The circuit diagram of three-phase fully controlled rectifier is given in fig.6. This type of rectifier is commonly used in the HVDC transmission networks, because these are very efficient than other. This rectifier is also called as six-pulse bridge converter.

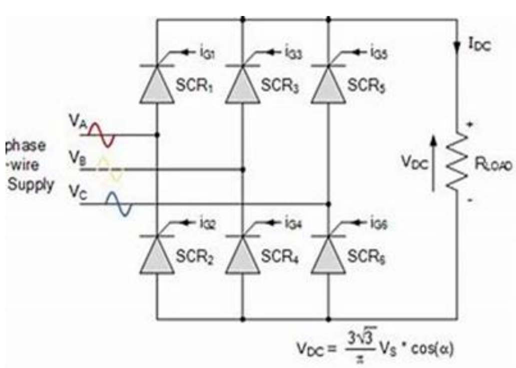

Fig. 6: 3-Phase Rectifier circuit using diodes.

The rectifiers are connected directly to the output of the PMSGs output to convert the 3-phase A.C converted into two wire D.C supply. The input and output waveforms of the rectifier is shown in the Fig.7.

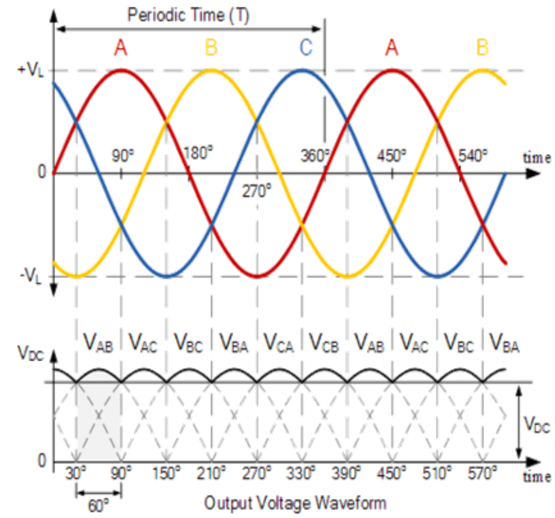

Fig.7: Input and Output waveforms of Rectifier.

$V_{dc(max)} = (((3\sqrt{3})*V_m)/(2\pi)$
The average D.C output voltage is given as above.

4.3.2 BOOST CONVERTER

Boost converter is a D.C to D.C step-up converter. This converter step-up the voltage (while stepping down the current) from input voltage taken from the output of three-phase full-wave converter. The basic converter circuit diagram is given below in fig.8.

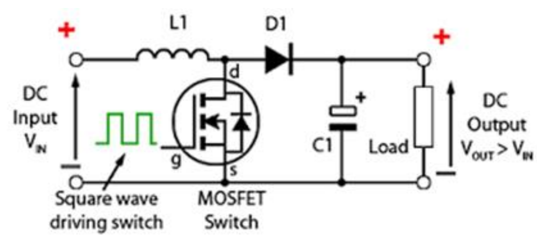

Fig.8: Boost Converter Circuit.

BOOST CONVERTER IN CONTINUOUS MODE OF OPERATION

The input and output characteristic waveform of the Boost converter in continuous mode of operation is shown in the fig below.

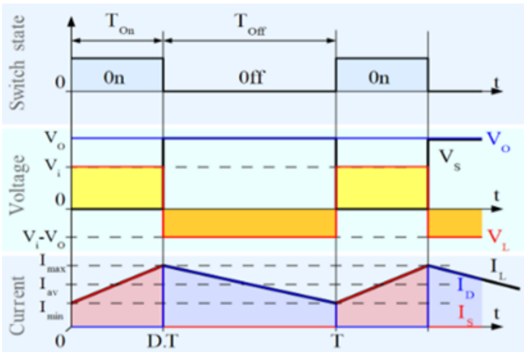

Fig.9: Characteristics of Boost Converter in continuous mode.

The voltage gain of a Boost converter in continuous mode of operation is,

$$V_o / V_i = (1/(1-D))$$

The duty ratio (D) is in range (0 to 1) in continuous mode of operation is

$$D = (1-(V_i/V_o))$$

The input current or average current and the ripple voltage and current is given below

$$I_i = I_{av} = I_O/(1-D)$$

$$\text{Ripple } \Delta V_C = \frac{I_O D}{f C} = \frac{I_O (V_O - V_i)}{f C V_O}$$

$$\text{Ripple } \Delta I_L = \frac{V_i D}{f L} = \frac{V_i (V_O - V_i)}{f L V_O}$$

The ripple is the wasted power which causes the unwanted effects in the circuit like heating the circuit elements, causes distortion and noise. To reduce this ripple, we introduce the filters to the existing circuit.

BOOST CONVERTER IN DISCONTINUOUS MODE OF OPERATION

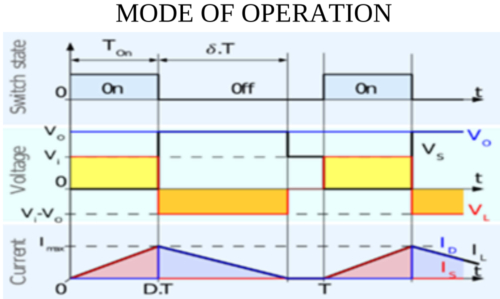

Fig.10: Boost converter characteristics in Discontinuous mode.

The voltage gain of boost converter in discontinuous conduction mode is,

$$\frac{V_o}{V_i} = \frac{1 + \sqrt{1 + \frac{4D^2}{K}}}{2}$$

$$\text{Critical } L_C = L = \frac{D(1-D)R}{2f}$$

$$\text{Critical } C_C = C = \frac{D}{2fR}$$

Critical inductance (L_c) is the least value at which the inductor current becomes discontinuous.

Critical capacitance (C_c) is the least value at which the capacitor voltage becomes discontinuous.

4.3.3 GRID SIDE CONVERTER

The grid side converter is D.C-A.C converter which converts D.C taken from the Boost converter to A.C to a pre-determined value of voltage and frequency.

4.3.4 IGBT BASED INVERTER

The 3 phase IGBT (Insulated Gate Bi-polar Transistor) is shown in fig.11. this circuit converts the constant D.C taken from the Boost-Converter to a standard A.C voltage with a constant frequency.

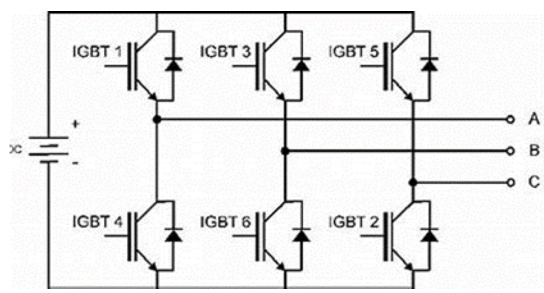

Fig.11: IGBT based inverter circuit.

We use IGBTs in the inverting circuits because it is a fully controlled switches whereas, the S.C.R is a semi-controlled switch. The controlling of the circuit is very easy because we are using IGBTs as switches.

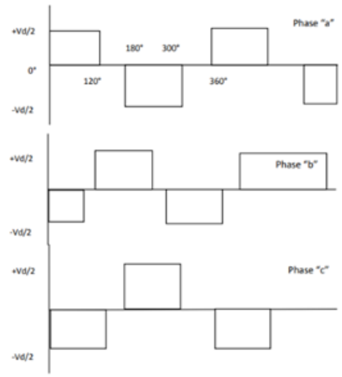

Fig.12: per phase output voltage wave-form.

The per phase output voltages of the IGBT based inverter circuit is shown in the above fig.12.

The line-line voltage of the three-phase IGBT based inverter circuit is shown in the below fig.13.

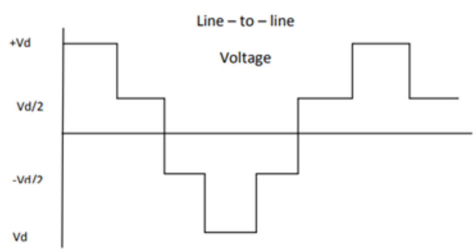

Fig.13: Line-Line voltage output of inverter.

AT 180^0 CONDUCTION MODE:

The phase voltages are given by:
$V_{AN} = V/3$
$V_{BN} = -2V/3$
$V_{CN} = V/3$

The line voltages are given by:
$V_{AB} = V_{AN} - V_{BN} = -V$
$V_{BC} = V_{BN} - V_{CN} = -V$
$V_{CA} = V_{CN} - V_{AN} = 0$

AT 120^0 CONDUCTION MODE:

The line voltages are given by:
$V_{AB} = V$
$V_{BC} = -V/2$
$V_{CA} = -V/2$

The power output from the IGBT based Inverter can be directly fed to the lights on the highway or can be transmitted to the nearest Toll Plazas. If we set up these turbines and connected in series the total power can be transmitted directly to the power grid.

V. STRUCTURAL ARRANGEMENT OF TURBINES

The converter unit of our VAWTs with PMSGs consists of two converting circuits, a boost converter and filters. The three-phase fully controlled Rectifier converts the asynchronous frequency power to the constant D.C, the Boost converter step-up the voltage rectified by the converter and finally the three-phase IGBT based inverter circuit converts the fixed D.C from the Boost-converter to fixed three-phase A.C with constant frequency.

This conversion is done at every VAWT setup and the output from the three-phase inverter will be step-up to a rated voltage and frequency so that output taken from each generator set will be connected in parallel to a bus-bar and transmitted to the nearest power grid. So, that it can be supplied to the load centres.

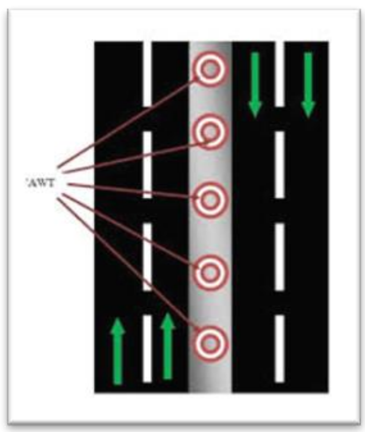

Fig.14. Arrangement of Turbines top view

The schematic arrangement of number of savonius VAWTs placed in a specific distance that one turbine will not interact with each other. So, the outputs of the individual turbines are connected via underground cable such that the danger of open wires on the highway will cause harm. Underground cables are perfectly suitable for this kind of application.

The wind flow and the rotation of a single savonius wind turbine is given in fig.15, below

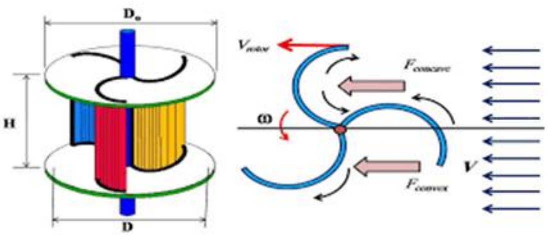

Fig.15: wind flow and rotation of turbine.

VI. ADVANTAGES OF THIS DEVELOPMENT.

The main advantages of this idea of installing a savonius wind turbine on the median of the highway are:

1. This arrangement of VAWTs does not require high foundation as in HAWTs, because it is placed near the ground and the equipment is lighter and smaller.
2. Because of the elimination of the gearbox by using the PMSG, the faults occurred due to the gearbox are completely eliminated and whole complexity in mechanical arrangement is also reduced by removing the heaviest part i.e., gearbox.
3. The copper losses due to the field winding is reduced because of using permanent magnets instead and also no need of exciter for supplying field winding.
4. There is no need of sensing (yaw control) equipment in finding the wind direction, because the VAWT is a bi-directional.
5. The construction and installation are very simple when compared with the HAWTs.
6. The maintenance of each equipment will be easy because, every equipment will be placed near the ground level.
7. These turbines can start generation at very low speeds i.e., 6 m/s.
8. These VAWTs makes very low noise compared to the HAWTs.
9. The savonius turbine is simple in construction and can produce high torque even the wind speed is low.
10. This system occupy very low space compared to the HAWTs arrangement.

CONCLUSION

The main aim of this “ELECTRICITY GENERATION FROM ARHICIAL WIND GENERATED BY THE MOVING VEICLES” is such that to introduce a new way of power generation with the existing equipment.

The wind generated by the moving vehicles is converted int useful electrical energy. This generated energy can be used to lighten up the highways so it could prevent the accidents that are caused due to the darkness on the highways. This power can also be supplied to the toll plazas which work 24/7 in need of electricity. If we organised and established these turbines in series throughout the median of the highway, we can transmit the power to the grid and can supplied to the load centres live villages and towns.

The selection and installation of the turbines has to be done with utmost care that it will not interrupt the vehicles travelling in the way. The blades size and diameter of the turbines estimated carefully such that it will not cause troubles to the vehicles passing by on that highway. The foundation must be laid hardly and strongly that it could resist the force caused on the blades to spin the turbine. The electrical equipment of high grade has to be taken that the losses will be minimum.

In future if we install this turbine combines with the solar panel fixing on the top. The of a single hybrid model of this Solar-VAWT combination will increase the production of an individual unit. The power generation is now can be done by two individual renewable energy sources. This increased power can be stored using a battery in day time and can be supplied to the lights along the highway on nights.

REFERENCES

[1] Frederikus Wenehenubun, Andy Saputra, Hadi Sutanto, “An Experimental Study on the Performance of Savonius Wind Turbines Related with The Number of Blades”, In “Energy Procedia”, Volume-68, April 2015.

[2] M. Zemamou, M. Aggour, A. Toui, "Review of Savonius wind turbine design and performance". In "Energy Procedia", Volume-141, 2017.

[3] Y. Errami, M. Ouassaid, M. Maarofi, "Control of a PMSG based wind energy generation system for power maximization and grid fault conditions". In "Energy Procedia", Volume-42, 2013.

[4] Prof. Sachin Y. Sayais1, Govind P. Salunkhe2, Pankaj G. Patil3, Mujahid F. Khatik "Power Generation on Highway by using Vertical Axis Wind Turbine & Solar System". In "IRJET", Volume-5, Mar-2018.

[5] N. Venkata Subbiah, M. L. S Deva Kumar M.Tech, M.B.A, Ph.d "Power Generation by Vertical Axis Wind Mill", "IJCRT",Volume-5, Dec-2017.

[6] Ashar Iqbal, Venkatratnam Chitturi, K V L Narayana, "A Novel Vertical Axis Wind Turbine for Energy Harvesting on the Highways". In "i-PACT" 2019.

[7] Sushant N. Malave and Shivraj P. Bhosale "Highway Wind Turbine (Quite Revolution Turbine)". In "IJREV", Volume-6, Nov-2013.

[8] Somnath S, Abhishek G, Channabasavana Gouda, Kavya B & Kruthi Jayaram **"**Power Generation on Highway using Vertical Axis Wind Turbine and Solar Energy". In "ZENODO", 2019.

[9] S. Vivekanandan, P. Kamalakannan, G. Saravanan, S**.** Krishnaprabhu**, "**Performance Parameters Analysis of Three phase Full Controlled Converter using PSIM Simulation". In "IJERGS", Volume-3, March-2015".

[10] JN Rai, Nikhil Gupta, Prashant Bansal, "Design and Analysis of DC-DC Boost Converter". In "IJARI", Volume-3, 2016.

[11] Antonia Simonis, Bruce Champagnie, Geatjens Altenor, Dr. Boesl, "Highway Wind Turbines", a project thesis in "Florida International University", April-2017.

[12] Highway Helical Wind Turbine Project (Next Generation Highway's Potential For. (2012, November 20). (Department of Mechanical Engineering YCET Kollam. Kerala) Retrieved February 14, 2013.

[13] Shan Varghese Abraham, "Power Generation from a Moving Locomotive by Wind Turbine". In "GRDJE", March-2018.

[14] Diaz, J. 2013. Electrical generator system for capturing wind energy on a moving vehicle. U.S. Patent No.8, 618,683. Washington, DC: U.S. Patent and Trademark Office.

[15] Devi, R., and Singh, J. (2014) Design and Development of Prototype Highway Lighting with Road Side Wind Energy Harvester. International Journal of Science and Research (IJSR), Volume-3, issue 9, 2014.

[16] A. Muthukumar, M. Balasubramanian, "VAWT Which Makes Use of the Turbulent Winds Generated by the Highway Traffic". In "IACSIT International Journal of Engineering and Technology", Volume-4, April-2012.