Design and development of hybrid turbine to extract energy from renewable energy sources

P Raviteja¹, P Nikhil Sai¹, P Mohan Rajkumar¹ and G C Vishnu kumar², ³

¹Department of Aeronautical Engineering, Hindustan Institute of Technology and Sciences, Chennai, Tamilnadu 603103, India.
²Professor, Department of Aeronautical Engineering, Hindustan Institute of Technology and Sciences, Chennai, Tamilnadu 603103, India.
Email: ³gevkumar@hindustanuniv.ac.in

Abstract. This paper represents the experimental study of hybrid turbine. This hybrid turbine system has a number of potential advantages over a conventional wind turbine. The present turbine is integrated with solar cells and piezoelectric crystals comparing to conventional wind turbine and it has been illustrated. The performance results are presented for various cases of different wind velocities, blade angles and for different intervals of day time. The results show that hybrid turbine still produces energy without any rotation during rain, day time. This single turbine is more useful and better than using solar panels, rain energy generators and wind mills individually to extract energy from renewable energy sources.

1. Introduction

Energy is the source for all the working things around the world. We are running out of fossil fuels and need to move on to the next revolution in renewable energy resources. The combination of wind, rain and solar renewable energy sources is used to develop power throughout the year in all 3 seasons. The turbine uses wind energy to rotate the turbine, piezoelectric crystals which are incorporated in the turbine uses rain energy to produce electricity and solar panels which are placed in turbine blades for solar energy. This reduces multiple devices used for extracting energy which automatically decreases cost of producing multiple devices and increasing the efficiency of this hybrid turbine.

The combination of wind and solar renewable energy sources is employed to supply power called the wind solar hybrid system. This device is meant to supply electricity by using solar panels and little turbine generators. We need to know the operation of the solar energy system and the wind energy system to better understand the operation of the solar wind hybrid system. It is possible to describe a solar power system as a system that uses solar energy for solar panel power generation. In the figure in which the solar panels and the wind turbine are used for power generation, the block diagram of the solar wind hybrid system is shown.

Wind power is also one of the alternative energy sources that can be used by wind turbines coupled with generators to produce electrical energy. A wind turbine can be described as a fan consisting of 2 or 3 blades that rotate so that the axis of rotation must be aligned with the direction of the blowing wind due to the blowing wind. A gear box is used using a mechanical process to transfer energy from one
device to another device; it is also called a mechanical machine of high precision. There are various wind turbine types, but horizontal axis turbines and vertical axis turbines are the most widely used wind turbines. There are three primary blocks of the Solar Power System, including solar panels, solar photovoltaic cells, and energy storage batteries. Electrical energy (DC power) generated by solar panels can be stored in batteries or can be used to supply DC loads or to feed AC loads through an inverter. Solar energy is available only throughout the day, while, depending on the ambient conditions, wind energy is available during the day.

Wind and solar energy are complementary to each other, which makes the power generating system nearly year-round. Wind aero generators and poles, solar photovoltaic panels, batteries, wires, charge regulators, and inverters are the key components of the Wind Solar Hybrid System. The Wind-Solar Hybrid System produces energy that can be used to charge batteries, and we can power AC appliances using an inverter. A tower with a minimum height of 18 mtrs is mounted on the wind aero-generator. From the level of the ground. The aero-generator gets wind at a faster speed because of the height and hence produces more power.

Piezoelectric materials are commonly available in many types, including single crystal, piezoceramic, thin film, piezoceramic powder screen-printable thick film, and polymeric material. The piezoelectric process is used to transform vibration energy into electricity. In recent years, the issue of energy harvesting through the piezoelectric process has drawn considerable interest by raindrop impacts upon it, the piezoelectric substance can vibrate. The most common types of piezoelectric material used are polyvinylidene fluoride (PVDF) and lead zirconate titanate (PZT).

To ensure the increase in efficiency of renewable energy sector, research on hybrid power systems needs to developed in Tamilnadu.

2. Literature Survey

Robert Howell et al [1] considered a small, produced and tested VAWT Turbine model (NACA 0022). With an aspect ratio of 4:1, the straight turbine rotor blade operates at relatively low top speeds and its capacity depends on the surface finish of the rotor blade. The output is increased below a critical Reynolds number (30,000), by making a rough turbine surface but above that, the power coefficient is
degraded. The tests also reveal the identical peaks in output coefficients for the two and three bladed rotors, but the three blades did so with much lower TSR. The 2D simulations have shown higher performance than the 3D simulations, mostly because the big tip vortex vortices in the actual turbine and the 3D simulations are present. When higher lift amounts are formed, stronger tip vortices exist, while the vortices are significantly reduced during phases when little lifting is produced.

Ehsan et al [2] investigated wind power by placing a conical-shaped duct in front of a conventional turbine, which is connected to a generator and solar panel for backup power. For high wind velocity at the turbine inlet, a conical shaped duct is designed. The velocity profile at the duet's inlet and outlet was studied using ANSYS tool. The turbine inlet with conical shape coupled with the generator and photovoltaic cells could be designed using simulation results. To provide electricity in rural areas, a hybrid photovoltaic wind power plan is being implemented. Where the wind speed is insufficient, this feasible design could be implemented.

W.T. Chong et al [3] In this paper in order to improve wind turbine efficiency, analysis was carried out on the new power increase-guide-vane (PAGV) surrounding a wind turbine of Sistan. It has been demonstrated how the PAGV can be integrated into a 3-in-1 wind, solar, and rain water harvester on high-rise buildings. The rotational speed of the wind rotor was increased by 75.16 percent (with the PAGV). Meanwhile, a computational fluid dynamics (CFD) simulation reveals a 2.88-fold rise in rotor torque.

CM vigneswaran and vishnu kumar GC's [7] paper mainly focuses on co-flow jet concept which was implemented on NACA 0018 airfoil for acquiring maximum lift coefficient. Spalart Alimares turbulence model is used for solving 2D unstead and incompressible flow RAMS equation. The injection slot and suction slot are placed in leading and trailing edge. After performing tests, the results shown that CFJ airfoil has higher aerodynamic lift coefficient than baseline airfoil and this coefficient is decreasing when injection slot is towards the leading edge.

Corina covaci in her paper mainly focused on extracting energy using piezoelectric crystals, studied various types of transducers based on the materials and their shapes. In this paper they also represented different types of circuits for extracting maximum energy.

Mohammad shafi Al-Ajmi [6] in their paper proposed an small power production foot print (PPF) for using new design of renewable energy power generator. In their design they used Hybrid wind solar generator where solar panels are made to rotate with wind turbine and combined using electromagnetic coupling mechanism. In their result they found out that for producing 1mw energy using pv cell arrays and wind turbine separately needed 4 acres of land but by using hybrid solar wind turbine they extracted 1mw energy from 1.06 acres of land which thus new turbine design uses approximately quarter of land used by conventional solar or wind forms.

Soon ching chun's report presents the design of hybrid solar wind turbine system. using solidworks wind turbine CAD model is designed. For conducting CFD, solidworks flow simulator is used. Results are obtained using internal flow analysis on wind turbine at several wind speeds using virtual wind tunnel simulation. HOMER, simulational tool is used for analysis on system configuration using wind speed and solar radiation data. 12.06kw of primary load is needed for single household per day. The amount of load needed for house is determined and analysis is done for generating most feasible system and generate energy is stored using batteries.

3. Methodology

3.1 Wind

A Wind Electric Generator is a mini power plant which generates electricity from wind energy. It consists of a 30 M high tall steel tower with the wind turbine mounted on top. The wind turbine has 3 main components. (i) rotor blades (ii) gear box and (iii) generator. The wind force striking on the blades
is initially converted into mechanical energy and this mechanical energy operates the Wind Electric Generator to produce AC electricity. The Wind Electric Generator has no battery bank and the power produced is directly fed into the grid of Electricity Board. The entire operation of power generation is controlled automatically by means of electronic control system mounted at the bottom of the tower.

Wind Electric Generators can be installed only at specific locations with adequate wind potential as notified by the Government based on studies. (ii) Available in various capacity ranges from 225 KW to 750 KW (now upto 2.0 MW). (iii) Tower height can be in the range of 30M to 50 M to tap wind energy more effectively. (iv) Wind Electric Generator of 250 KW can generate 4 lakhs to 6 lakhs units of electricity per annum depending upon the wind potential of the area. The cost of a single 225 KW or 250 KW which is widely preferred is about Rs.1 Crore. The total project cost of a one MW wind farm will be about Rs.5 Crores including charges payable to TNEB.

3.2 Solar

Solar offers a clean, climate friendly abundant and inexhaustible energy resources to mankind. The costs of energy have been falling rapidly and are entering new areas of competitiveness. Solar power installations worldwide are growing rapidly with nearly 18-20 Giga Watt (GW) expected to be installed in 2012. Tamilnadu has reasonably high solar installation (5.6-6.0 kWh/sq.m.) with around 300 clear sunny days in a year. Southern Tamilnadu is considered to be one of the most suitable regions in the country for the development of solar power projects. There are remarkable opportunities in solar domain with substantial which enhances cost reduction in power sectors.

As solar power is expensive compared to other renewable energy, a unique model is required to be evolved to promote solar power generation systems. The initial cost of purchasing a solar system is very high and the efficiency of solar energy drops during cloudy and rainy days. It also uses lot of space as the requirement of large open area is suitable for solar energy harvesting.

3.3 Rain

Scientists from CEA/Leti-Minatec, an R&D institute in Grenoble, France, specializing in microelectronics, have recently developed a system that recovers the vibration energy from a piezoelectric structure impacted by a falling raindrop. The system works with raindrops ranging in diameter from 1 to five mm, and simulations show that it’s possible to recover up to 12 milliwatts from one among the larger “downpour” drops. When a raindrop impacts a surface, it produces a wonderfully inelastic shock. The amount of energy generated by the impact can then be estimated employing a mechanical-electric model. To capture the raindrops’ energy, the scientists used a PVDF (polymethylpentene fluoride) polymer, a piezoelectric material that converts energy into electricity. When a raindrop impacts the 25-micrometer-thick PVDF, the polymer starts to vibrate. Electrodes embedded within the PVDF are used to recover the electrical charges generated by the vibrations.

The group experimented with raindrops of various sizes, falling heights, and speeds. They found that slow falling raindrops generate the foremost energy because raindrops falling at high speeds often lose some energy thanks to splash. By employing a micropump to get and test the properties of raindrops, the researchers demonstrated that, for low drop heights, the electricity is proportional to the square of the drop’s energy, while voltage and energy are directly proportional. The largest raindrops caused the most important vibrations on the PVDF, and thus generated the best amount of electricity. The researchers demonstrated that their system could generate 1 microwatt of continuous power as a worst-case scenario, while simulations showed that one large raindrop might generate up to 12 milliwatts of power. The recoverable energy depends directly on the dimensions of the piezoelectric membrane, the dimensions of raindrops, and their frequency. The available energy per drop varies between 2 μJ from 1 mJ counting on its size. The corresponding instantaneous converted power starts from a couple of μW up to 10 mW for a converter area of a several square centimetres. An interesting figure to stay in mind could even be the available rain power per annum in common France regions with a continental climate:
almost 1 Wh per square meter per year. In the future, the scientists decide to develop a way to store the electric power to supply a gentle current for practical use.

![Diagram of a hybrid model](image)

**Figure 2:** Front view of the initial stage of hybrid model

To generate affordable electricity from renewable natural energy resources on all seasons. Hence to obtain continuous electricity, the present approach will be to utilise sunlight, rain and wind power which will be available at regular intervals of seasonal change over entire year.

To identify the location for experiment, the anemometer is held at different places around the college premises to measure the wind speed. The optimized location with a speed around 3m/s is observed in college NCC ground which is chosen to be research location as shown in the below.

![Location map and chart](image)

**Figure 3.** Experimental location (NCC ground).

**Figure 4.** Wind speed over Chennai.
The materials selected for experiment are

a) Dynamo Output – 12V, 6watt: To get the output power from turbine rotation. The number of dynamos around the turbine will be varied based on the output requirements.
b) Ball bearing: To support the turbine rotation with stationary shaft.
c) Stationary shaft: It will be made up of composites to avoid rusting which will be supporting the entire setup.
d) Solar panels: The solar panels are of rectangular shape. It will be placed over the turbine blades.
e) Piezoelectric crystals: these crystals are integrated in such a way that maximum rain falls directly on it.
f) Electric wires: The wires are connected to solar panels, piezoelectric crystals for its output. Also, separate connections.

Figure 5. CAD model of hybrid turbine.

The above CAD model is designed by using Solid Works software. In future this model can be used for CFD analysis by using ANSYS software.

4. Experimental Model

Figure 6: Front and Top view of experimental model.
The basic rotating structure of hybrid turbine was made by using umbrella. The polythene cover above umbrella is removed, now as there is no support for spokes it continuously moves and breaks the structure of umbrella. So plastic thread is used to tie the spokes. This made the umbrella spokes to be in their position. Now, plastic sheets are used for the purpose of turbine blades. These plastic sheets are attached to each spoke and made to form a curved shape. After this solar panels and piezoelectric sensors are attached at the top of the panel and connected in series. This partially completed hybrid turbine is now attached to ball bearing and this ball bearing is attached to stationary shaft. Thus, the hybrid turbine rotates freely by using bearing. Now the Dynamo is connected to a rotating umbrella by using their gear mechanism. Thus, complete hybrid turbine is manufactured.

5. Results

Table 1. Solar panel voltage at different angles at different day time

| TIME IN (HOURS) | AT 0°ANGLE (Volts) | AT 30°ANGLE (Volts) | AT 60°ANGLE (Volts) | AT 90°ANGLE (Volts) |
|-----------------|--------------------|----------------------|---------------------|---------------------|
| 10 A.M          | 6.40               | 6.30                 | 5.70                | 5.50                |
| 11 A.M          | 6.42               | 6.32                 | 6.05                | 5.50                |
| 12 P.M          | 6.70               | 6.60                 | 6.05                | 5.50                |
| 1 P.M           | 6.75               | 6.70                 | 6.50                | 6.20                |

Table 2. Average voltage obtained for series connection of solar panels.

| SERIES CONNECTION | AVERAGE VOLTAGE (V) |
|-------------------|---------------------|
| 1                 | 06                  |
| 6                 | 36                  |

Each solar panel produce an average voltage of 6 Volts when kept in a sunlight. So, when the 6 solar panels connected in a series connection, they produce an average of 36 volts. These values are tabulated in table 2.
The above graphs are taken for solar panels when they are kept at different angels in day light from 10 am to 1 pm each hour. The angles in which solar panels are kept are 0°, 30°, 60°, 90° angles. There is steep increase in graph from 12 pm to 1pm as sunlight directly strikes the solar panels. So power output from solar panels is entirely dependent on the angle of solar panels with respect to sunlight. The efficiency of solar panels is greatly affected by the temperature. To exact solar panels works effectively only in cold temperatures but not in hot temperatures as solar panels absorb energy from sun’s abundant light energy not heat energy to produce electricity.

Table 3. Maximum voltage obtained for series combination of piezoelectric crystals.

| SERIES CONNECTION | MAXIMUM VOLTAGE (mV) |
|-------------------|-----------------------|
| 1                 | 170                   |
| 3                 | 220                   |
| 5                 | 300                   |

The piezoelectric crystals when Impacted by a rain drop it produced an average voltage of 170 millivolts. When this piezoelectric crystals are connected in a series combination and again experimented then an average of 220 milli volts has been produced for 3 piezoelectric crystals and an average of 300 millivolts has been produced for 5 piezoelectric crystals. The size of rain droplet should be large so that vibration produced by an impact is large.
Figure 11. RPM produced at different wind speeds.

Figure 11 is plotted between wind speed and turbine rpm. We measured turbine rpm at different wind speeds such as 1m/s, 2m/s, 3m/s, 4m/s, and 5m/s. by using anemometer and tachometer. The graph is increasing linearly thus increase in wind speed increases turbine rpm.

Figure 12. Power produced by dynamo at different wind speeds.

Figure 12 is plotted between wind speed and turbine power output. We measured turbine power output at different wind speeds such as 1m/s, 2m/s, 3m/s, 4m/s, and 5m/s. by using anemometer and multimeter.

6. Conclusion

The hybrid turbine successfully produces power with the help of solar, wind and rain energies. This turbine produces maximum power output from wind energy while comparing to solar and rain energy. Piezoelectric crystals produce less energy by using one crystal, if we increase the number of crystals power output also increases. The crystals produce power efficiently when raining slowly because vibrations on crystals are not disturbed by heavy and continuously falling droplets. Solar panels power output is completely dependent on the angle of solar panels and the duration of day.

In future there will be so many ways to increase efficient of hybrid turbine. now a days the efficient of solar panels have increased to 28% but these solar panels are not commercially available in market. once efficient solar panels available then output of hybrid turbine increase much more extent. scientists are also working on solar panel which produce electricity during night time. In future solar panels may start to produce electricity during night too. Wind can to produce vibration in piezoelectric sensors.so, if piezoelectric sensors start produce electricity by the vibration of wind and by the impact of raindrops, the efficiency and output of piezoelectric will be increased. work is underway on this idea over worldwide. The hybrid turbine works efficiently in summer, windy & rainy season but not in winter season as discussed. This issue can be resolved by using striling engine principle where temperature difference produce electricity. To be brief in winter, temperature outside of hybrid turbine will be low and temperature inside the hybrid will be higher due loss of work in the form of heat, friction and heat
produced from machines. Thus, the difference of temperature can be used to produce electricity in winter. The other idea to produce electricity in winter season is to use material of two different coefficient of the thermal expansion. As discussed, earlier temperature difference inside &outside of hybrid turbine can produce bending in stationary shaft due to difference in coefficient of thermal expansions. This bending can be used to produce electricity. In simple, A triboelectric generator in the form of a small metal tab has been developed by scientists to generate power from simple movements such as bending. the tab uses the triboelectric effect that some materials produce electric charge by friction if this type of materials is used in stationary shaft this will produce electricity These are few future enhancements which can be done to increase output of hybrid turbine.

7. References

[1] 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), pp.412-422.

[2] Ehsan, Mohammad & Ovy, Enaiyat Ghani & Chowdhury, Habib & Ferdous, S.M.. (2012). A proposal of Implementation of Ducted Wind Turbine Integrated with Solar System for Reliable Power Generation in Bangladesh. International Journal of Renewable Energy Research, 2, 397-403.

[3] Chong, W., Pan, K., Poh, S., Fazlizan, A., Oon, C., Badarudin, A. and Nik-Ghazali, N., 2013. Performance investigation of a power augmented vertical axis wind turbine for urban high-rise application. Renewable Energy, 51, pp.388-397.

[4] J. Jeslin Drusila Nesamalar, P. Venkatesh, S. Charles Raja, The drive of renewable energy in Tamilnadu: Status, barriers and future prospect, Renewable and Sustainable Energy Reviews, Volume 73, 2017, Pages 115-124, ISSN 1364-0321.

[5] Wong, Chin Hong & Dahari, Zuraini & Abd Manaf, Asrulnizam & Muhamad. (2014). Harvesting Raindrop Energy with Piezoelectrics: a Review. Journal of Electronic Materials. 44, 1-9. 10.1007/s11664-014-3443-4.

[6] Al-Ajmi, Mohammad & Mustapha, Faizal & Mohd ariffin, Mohd khairil anuar & Md Yunus, Nurul & Abdul Halin, Izhal. (2018). A True Hybrid Solar Wind Turbine Electric Generator System for Smaller Hybrid Renewable Energy Power Plants. MATEC Web of Conferences. 215.01015. 10.1051/matecconf/201821501015.

[7] Vigneswaran, C., & Kumar G C, V. (2021). AERODYNAMIC PERFORMANCE ANALYSIS OF CO-FLOW JET AIRFOIL. International Journal of Aviation, Aeronautics, and Aerospace,