# Analysis of Grid Connected Hybrid Street Light Using Solar and Helical Savonius Wind Turbine

Sowmya G[1], Alif Ahamed[2], Shashank RA[3], Manoj S[4]
[1]*Assistant professor, Department of EEE, Vidya Vikas Institute of Engineering and Technology, Mysore*
[2,3,4]*Student, Department of EEE, Vidya Vikas Institute of Engineering and Technology, Mysore*

***Abstract-* The abstract begins by introducing the concept of solar street lights and their relevance in thecontext of the global push for renewable energy adoption. It emphasizes the need for eco-friendly alternatives to traditional grid-powered street lighting to reduce carbon emissions and combat climatechange. The historical development of solar street lights is briefly explored, showcasing their evolution from simple prototypes to sophisticated, efficient systems widely used today.**

**Furthermore, the abstract explores the potential impact of widespread solar street light adoption on urban infrastructure and sustainable development. It discusses how solar street lights can complement existing lighting systems, providing cost-effective and reliable lighting solutions for cities and towns around the world. The scalability and versatility of solar street lights makethem a viable option for smart city initiatives and off-grid applications in developing regions.**

***Keywords: photovoltaic panels, rechargeable batteries, LED lamps and intelligent control systems.***

## 1. INTRODUCTION

Recent researches show that street lighting at night can be a costly and complicated matter. Issues such as, no available grid power or expensive trenching and cabling requirements can prevent adequate lighting being installed. An indicated solution is street lighting using renewable energy, solar and wind. With very low maintenance these solar-wind streetlights will pay for themselves. Many applications have been made especially the last decade round the world. This case study develops a method to illuminate energy production from Wind generator (WG) and photovoltaic (PV) panel. The complete system, apart from a PV system, a WG and a luminaireis mounted on a single pole. At the beginning is considered the solar radiance that cascades to the panel and the wind speed that can operate the WG. This permits the selection of the suitable PV panel and WG. The other important devices of the system as the charger, the battery, the control unit and the inverter are also determined. Further calculations determine the total power production of the system, the consumed energy for street illumination and the remained energy.

## 2 MEASUREMENT OF THE WIND SPEED AND SOLAR RADIATION

The solar radiation and the wind speed are key data for the calculation of the output energy of the proposed system. There are many historical data for the solar radiation and wind speed as well as other meteorological data available in national service sand others. For this study all the needed data was collected through the meteorological service on the weather sparks. This service records the solar radiation and wind velocity 24 hours/day, using the appropriate equipment, every day, throughout the year in the urban area of Mysore. For the purpose of the project the measurements of a full year were used (January-December) data.

An application in visual basic was created in process all the measurements. The output of this algorithm were the annual distribution of wind energy and solar energy.

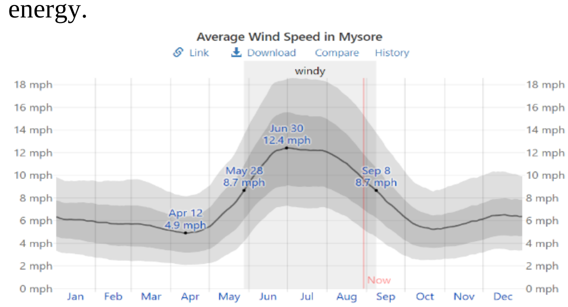



Fig. 1 –Annual wind speed in urban area of Mysore

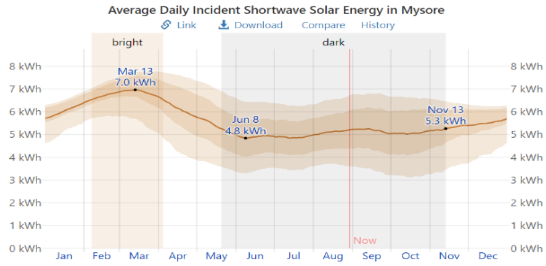



Fig. 2 –Annual distribution of solar radiation in urban area of Mysore

## 3 TRANSFORMATION OF THE MEASUREMENTS

The pyranometer measures solar radiation the daily solar energy that prostrates on the horizontal surface. For different angles of the surface the solar radiation that prostrates varies. A specific method issued, in order to calculate the solar radiation on tilted surfaces. This method transforms the solar radiation values from horizontal surface to tilted surface as shown below. The daily solar radiation on a tilted surface is:

$H_t$ = (Solar beam component + Sky diffuse component + Surface/Sky reflectance component)

or

$H_t = (H-H_d)R_b+H_d((1+\cos\beta)/2)+H^*\rho_s((1-\cos\beta)/2)$

where

H: solar radiation measurements (pyranometer)

β: angle of the PV panel relative to a horizontal surface (varies from $0^o$ to $90^o$)

$\rho_s$: surface reflectance (=0.2)

$R_b=(\cos(\varphi-\beta)\cos(\delta)\sin(\omega_{ss})+(\omega_{ss})\sin(\varphi-\beta)\sin(\delta))/(\cos(\varphi)\cos(\delta)\sin(\omega_s)+\omega_s\sin(\varphi)\sin(\delta))$

φ: latitude (=38° for Athens)

δ: solar declination $(=23.45\sin(2\pi((284+n)/365))$

$\omega_s = \cos^{-1}(-\tan(\varphi)\tan(\delta))$

$\omega_{ss} = \min(\omega_s, \cos^{-1}(-\tan(\varphi-\beta)\tan(\delta))$

$H_d = H(1.391-3.569K+4.189K^2-2.137K^3)$, $\omega_s<81.4^o$

$H_d = H(1.311-3.022K+3.427K^2-1.82K^3)$, $\omega_s>81.4^o$

K: Ratio of solar radiation at the earth level to the radiation before entering the atmosphere

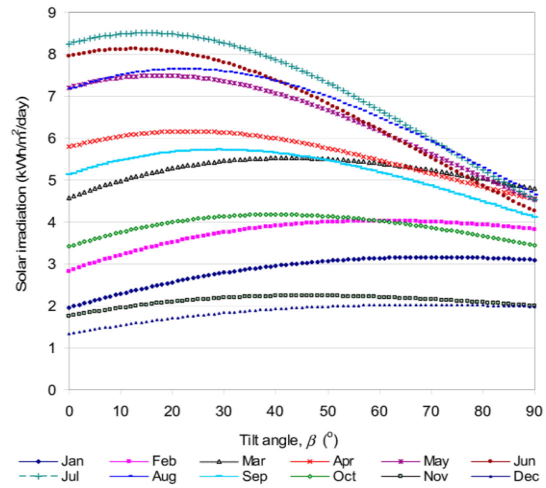



Fig.3 –Calculated annual distribution of solar radiation on tilted surface

According to calculations the wind generator of the proposed. For this transformation of the values was needed the formula for the transformation is:

$$P_{\max} = \frac{16}{27}\frac{1}{2}\rho \cdot h \cdot d \cdot v^3,$$

Where p is the density of air

h & d are the height and diameter of the rotor

v is the wind speed

the theoretical ideal rotor gets

$$P_{\max} \approx 0.18\,\mathrm{kg\,m^{-3}} \cdot h \cdot d \cdot v^3$$

But the average maximum efficiency Cp of the helical savonius wind turbine is around 20% (Cp=0.2). Making the real extractable power of the helical savonius

$$P_{\max} \approx 0.12\,\mathrm{kg\,m^{-3}} \cdot h \cdot d \cdot v^3.$$

The angular frequency of rotor is given by $\omega = \frac{\lambda \cdot v}{r}$, where r is the radius and the $\lambda$ is a dimensionless factor , tip-speed ratio.

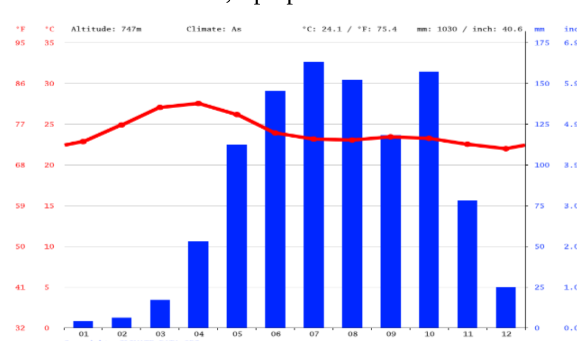



Fig.4 –calculated annual wind speed

## 4 SYSTEM

The proposed system contains of  a PV panel, helical savonius wind turbine, storage device, an inverter, control unit ,luminaire.

The selection of solar panel and the wind generator is made after the calculations of the total consumption of the luminaire plus losses of inverter and the losses of the battery. The total consumption of the system is 50.5W

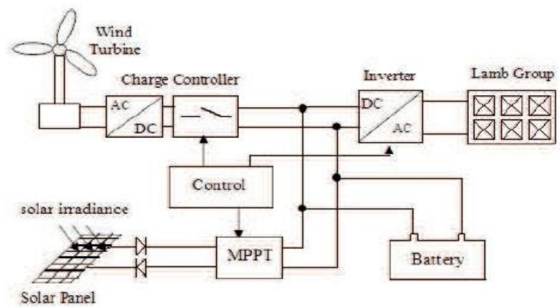



Fig.5 –Block diagram of the system

The selected solar panel is a SIEMENS SM100with rated power 100Wp. It is obvious thatthe PV panel must be fixed on the pole, over theluminaire, in a suitable angle so as to collect themost energy at winter period and also enoughenergy at summer period. After calculation andexamination, for all possible PV panel tilt angle, theappropriate angle appears to be 50° (southorientation). The selected WG is anHELICAL SAVONIUS WIND TURBINE, low weight suitable for fixing at the top of the pole.

The mean capacity factor of the WG as itcalculated is 0.07 (or 7%). This happen because thegenerator will operate in an urban area where annualwind speed is much lower than the nominal. Thismeans that the proposed system is designed to beautonomous when it will be installed in an urbanarea. The battery , inverter and other parts of the system will be placed on the bae of the pole , inside a container in order to protect from the weather conditions.

**Table 1** – System's parts characteristics.

| | |
|---|---|
| PV panel | SIEMENS SM100 – 100Wp |
| Wind Generator | Air 403 – 400W at 12.5m/s |
| Lamp | Philips CDM-T 35W |
| Luminaire | Philips, Iridium SGS 252 GB |
| Battery | PowerSonic 24V- 100Ah |
| Inverter | Compa KV 150W |
| Charger | Steca PR 24V/10A |

Fig.6 –The selected photovoltaic panel (SM100)

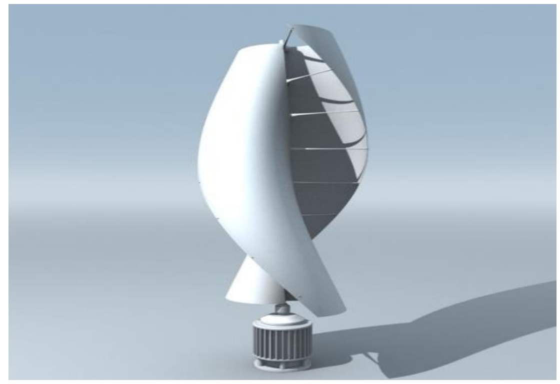
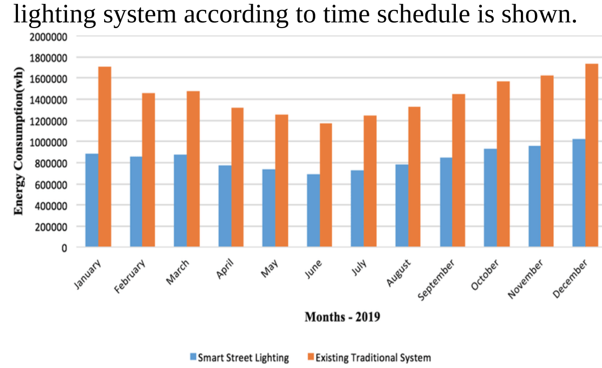


Fig.7 – The selected helical savonius wind turbine

The total energy consumption of the system depends on the time the luminaire must illuminate the road.

The operation schedule of street lightning is scheduled by the Chamundeswari Electricity Supply Corporation (CESC) limited. The proposed system is designed to follow the schedule with the control unit. The unit monitors the charging of the battery by the PV system and the WG and operates the luminaire according to schedule. The extra power is supplied to the grid connection.

The calculated daily energy consumption of the lighting system according to time schedule is shown.




## 5 LIGHTING SYSTEM

For the purposes of this investigation, a commonroad with two lanes is used. Due to the limited potential of the proposed system, a low consumptionlamp with high efficiency is needed. The mostcommonly used types of lamps for street lightingare: An LED street light is an integrated light that uses light emitting diodes (LED) as its light source. These are considered integrated lights because, in most cases, the luminaire and the fixture are not separate parts.

These practical equations may be used to optimize LED street lighting installations in order to minimize light pollution, increase comfort and visibility, and maximize both illumination uniformity and light utilization efficiency.

the LED light cluster is sealed on a panel and then assembled to the LED panel with a heat sink to become an integrated lighting fixture.

The primary appeal of LED street lighting is energy efficiency compared to conventional street lighting fixture technologies such as high pressure sodium (HPS) and metal halide (MH). Research continues to improve the efficiency of newer models of LED street lights (modernizing with LED street lights). However, LED street lighting is not as efficient as SOX street lighting.

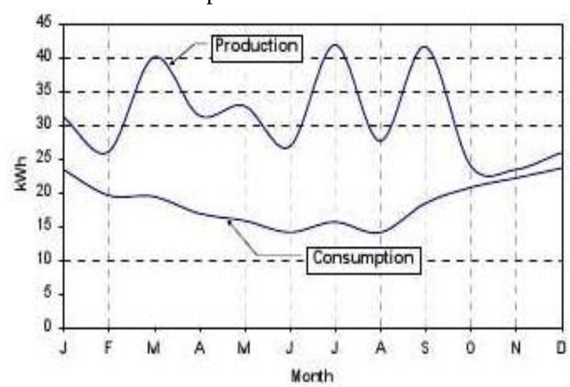
Fig.9 -Led street light

The calculations of the lightning installation has been performed using led.

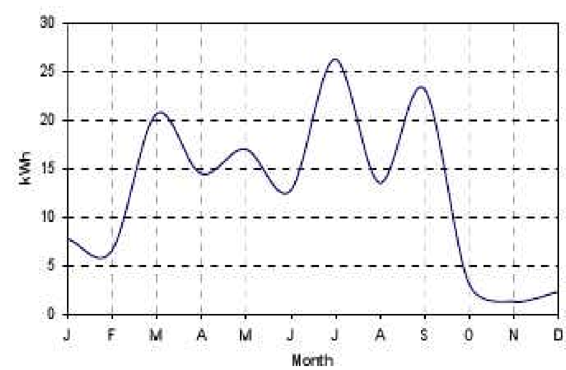
| 250w HPS v. 126w LED Wall Pack | 250w HPS | 126w LED |
|---|---|---|
| Lamp Watts | 250 | 126 |
| System Watts | 295 | 126 |
| Hours | 24,000 | 100,000 |
| Initial Light Source Lumens | 29,000 | 17,724 |
| Mean Light Source Lumens | 27,000 | 15,065 |
| HPS - Adjust for Visible Lumens | 62% | 121% |
| Visually Effective Lumens (VELs) | 16,740 | 18,229 |
| Luminaire Efficacy | 65% | 83% |
| Mean Visible Luminaire Lumens | 10,881 | 15,130 |
| Lumens per Watt | 36.9 | 120.1 |

## 6 PRODUCED ENERGY

The produced energy from the proposed system is calculated as the sum of energy produced from the solar panel and the WG. All losses have been calculated and excluded from the generated energy The total energy production is shown on Fig 13. In the same diagram is also included the energy that the lighting system consumes In summary the annual energy production of the system is 371.7 kWh while the annual consumption is 222.8 kWh.




The energy that remains from the production can be sold to the power utility as the system is designed to be connected to the power grid The calculated annual remain energy is 148.9 kWh The distribution of the remained energy that can be sold.




It is obvious that the energy that exceeds every day varies in the period of one year. At summer moths remains more energy that at winter months, where in some cases the produced energy is almost equal to energy that the lighting system need for full-time operation This happens because the system is designed to produce enough energy for whole year in order to operate alone in places where connection to grid is difficult or impossible.

## 7 CONCLUSION

This experimental and numerical study investigated the suitability of a wind-solar hybrid system in lighting street LED lights on highway poles. The hybrid system includes a combined helicalsavonius wind turbine integrated with a PV solar system to provide energy to light a 30 W street lamp.

Such a detailed experimental apparatus is devoted to give the tools for a comprehensive study of the renewable energy system. Besides, the performance evaluation of wind–solar devices, experimentation allows to test different control strategies e.g. related to LED switching/dimming and rotor braking criteria. Further work is being done about the dedicated hybrid power control of Savonius and PV, in order to optimize the MPPT. Such electronic optimization has the purpose to push the self-sustainability of the system towards lower wind speeds.

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