Wind-Solar Hybrid Energy Powered for Drip Irrigation System

R. Akhila*, Y. Sai Manohar, J.Bangarraju, V. Rajagopal
Department of EEE, B V Raju Institute of Technology, Narsapur, Medak(Distt.), Telangana

Abstract
This paper explains about cost analysis of drip irrigation system using wind-solar hybrid system. The power generated through the interconnected solar and wind hybrid system is fed to the submersible pump for drip irrigation and is examined continuously for reliability. The drip irrigated system described here consists of a submersible pump that consumes 1.18 kW of electrical energy per day on an average, to drip irrigate mango crop for the 1.5 acres. The corresponding cost analysis curves for solar and wind systems are drawn.

Keywords: Solar Power generation, Wind power generation, Hybrid systems, Drip irrigation system

*Author for Correspondence E-mail: raakhila204@yahoo.com

INTRODUCTION
Due to the degradation of non-renewable sources in India the management is showing interest towards the renewable energy power generation for fulfilling various load requirements mainly agricultural water pumping to achieve clean and low cost electric energy. India possesses a relatively high abundance of sunshine, moderate wind speeds, hydro, and biomass energy resources. Among those, solar-wind energy systems can make a significant contribution to the power sector of our nation. Indigenous development of wind power systems up to 25KW is the objective of new Indian Renewable Energy Act along with the development of solar PV Pumps for irrigation system [1].

The combination of two or more renewable energy sources is called hybrid system. In this paper hybrid system is referred as interconnection of solar and wind energy systems. Electric generation with solar cell or wind turbine has some limitations like high initial cost, unreliable and there exists no technology for storing energy [2]. During day time electrical energy is generated from sun and during night time load remains without electrical energy. As wind is unpredictable, the energy harvesting is much difficult when the speed of wind is less. This interruption of energy may be eliminated by storing of the generated electrical energy in the battery when lightly loaded condition and feeding back to the load from battery when the generation is not sufficient [3]. A study was focused on the newly developed desert agricultural area in East Oweinat, which is located in the south-western desert of Egypt [4].

Drip irrigation is advancement in the irrigation system which minimizes the dependency of the crop on rain through which the annual crop production rate can be increased. This paper deals with drip irrigation using solar and wind hybrid system.

SYSTEM ANALYSIS

Solar Power Generation
The main component of solar power generation is solar cell. Solar cells have higher composition of silica. Photovoltaic (PV) systems use solar panels to convert sunlight into DC power.

Solar cell works in three steps:
1. Sunlight strikes the solar panel in the form of photons and the energy of photons is transferred to the silicon semi-conducting material.
ii. Electrons (negatively charged) absorb this energy and get excited. This frees them from their atomic locking causing an electric potential difference. Due to this, current starts flowing through the material to cancel this potential and thus electricity is produced. Due to the special feature of the solar cells, the electrons are allowed to move only in a single direction.

iii. An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.

The system consists of an inverter (DC/AC power converter), a racking system to hold the solar panels, mounting for few equipments and electrical interconnections. The process of converting sunlight into electricity is noiseless and instantaneous. A small PV system is enough to meet the low capacity load requirements.

**PV Array Performance Model**

The PV module performance depends on weather conditions, mainly solar radiation, PV module temperature and positioning of the panel. A simplified PV simulation model is used to estimate the actual performance of PV modules under varying operating conditions. PV modules represent the fundamental power conversion unit of a PV system.

The voltage and current are the primary variables to the PV array output. If a matrix of \([ Ns \times Np ]\) PV modules is considered, the maximum power output of the PV system can be calculated as below:

\[
P_{PV} = N_p N_s P_{module} \eta_{MPPT}
\]

Where, \(P_{module}\) - PV module power
\(\eta_{MPPT}\) - Maximum Power Point Tracker efficiency

The energy required for 10 hours (daily operation hours) over a 1km distance is calculated as below:

\[
E_{req} = PTC \cdot Toh \cdot N_m
\]

Where, \(E_{req}\) - Total energy requirement
\(Toh\) - Daily operation hours
\(PTC\) - Power consumed by one group of an illumination lamp, SOS, and billboard.
\(N_m\) - Number of groups including an illumination lamp, SOS, and billboard.

According to this formula, total energy requirement can be calculated as follows:

\(E_{req} = 350 \times 10 \times 20 = 70\text{kWh}\)

**Wind Power Generation**

A wind turbine is an electro-mechanical device that converts kinetic energy of wind into mechanical energy which is used to produce electricity. Small turbines are generally used for battery charging or auxiliary power on boats, while power from the large interconnected arrays of turbines can be synchronized with the grid and can be used for commercial electricity.
Wind turbines are of two types.

a) Horizontal axis Wind Turbine
   Horizontal-axis wind turbines have the main rotor shaft and electrical generator at the top of a tower and are pointed into the wind direction. Large turbines generally use a wind sensor coupled with a servo motor while small turbines are pointed by a simple wind vane.

b) Vertical axis Wind Turbine
   Vertical-axis wind turbines have the main rotor shaft and electrical generator arranged vertically in the ground. The main advantage of this arrangement is that the turbine need not be pointed into the wind direction to give effective results.

Wind Power calculation
Wind is made up of moving air molecules which has very less mass. Any moving particle with mass carries kinetic energy which is given by the equation.

\[
\text{Kinetic energy} = 0.5 \times \text{Mass} \times \text{Velocity}^2
\]  

(3)

Where mass is measured in kg, velocity in m/s, and the energy is given in joules. Air has a known density of around 1.23 kg/m³ at sea level. This mass of air hitting our wind turbine (which sweeps a known area) each second is given by the following equation:

\[
\text{Mass/sec (kg/s)} = \text{velocity (m/s)} \times \text{Area (m}^2\text{)} \times \text{Density (kg/m}^3\text{)}
\]  

(4)

And therefore, the power (i.e. energy per second) in the wind hitting a wind turbine with a certain swept area is given by simply inserting the mass per second calculation into the standard kinetic energy equation given above resulting in the following vital equation:

\[
\text{Power}=0.5\times\text{Swept area}\times\text{AirDensity}\times\text{Velocity}^3\times\text{Ng}\times\text{Nb}\times\text{Cp}
\]  

(5)

Where power is given in watts (J/s), the swept area in square meters, the air density in kg/m³, the velocity in m/s.

Air density = 1.2kg/m³
Cp - performance coefficient (0.35)
Ng - generator efficiency (50% to 80%)
Nb - gear box efficiency (95%)

\[
\text{Swept area} = 3.14 \times r^2 \text{ square meter}
\]

Rotor Diameter = 6 feet = 1.8m
Area = 3.14×0.9×0.9 = 2.543 square meter

For an average wind speed of 3.5m/s,

\[
\text{Wind Power} = 0.5\times1.2 \times 2.543\times0.35\times0.7\times0.95\times (3.5)^3 = 15.226W
\]

HYBRID SYSTEM
In a hybrid power system different methods of producing electricity using renewable energy sources are combined to ensure a continuous power supply. When both the systems are connected together they will be having enhanced reliability, higher efficiency than stand-alone wind, solar, geothermal systems by themselves. The block diagram representation of the solar wind hybrid system is as shown in Fig.1. Hybrid energy system used here is a photovoltaic array coupled with a wind turbine. As we are using solar panels and wind turbines to charge the same battery bank, we use a regulator that can handle both the inputs. This would contribute more proportion of output from the wind turbine when winds are more, whereas during the summer the solar panels would produce their peak output.

A. Drip Irrigation
Drip irrigation has got prominent importance due to the increase in scarcity of water day by day. Drip irrigation system delivers water to the crop using a network of mainlines, sub-mains and lateral lines with emission points spaced along their lengths. Each dripper/emitter, orifice supplies a measured, precisely controlled uniform application of water, nutrients, and other required growth substances directly into the root zone of the plant.

Water and nutrients enter the soil from the emitters, moving into the root zone of the plants because of the combined forces of gravity and capillary. In this way, the plant’s suction of moisture and nutrients
are replenished almost immediately, ensuring that the plant never suffers from water stress, thus enhancing quality, its ability to achieve optimum growth and high yield. Drip irrigation saves up to 70% of water when compared to flood irrigation as more land can be irrigated with the same amount of water. Crop grows consistently, healthier and matures fast. The type of motor used in this system is a single phase open well submersible monobloc motor.

B. System Specifications
- Solar PV panels: 240W, 24V DC (2 in number)
- Wind generator: 700W, 24V DC (1 in number)
- Battery Bank: 12v, 120Ah (2 in number)
- Inverter: 3.6 kVA
- Capacity of each dripper (LPH) = 8
- Total number of drippers installed = 672
- Average water requirements for drip irrigating of 1 acre of mango crop, which is at yield stage, in Dr. BVRIT campus, Narsapur, Medak District is: 11,100.923 L
- Area of Land: 1.5 acres
- Maximum Water requirement per day per 1.5 acres is: 11,100.921 × 1.5 = 16651.385 L.
- The Number of liters required/day/acre is calculated by considering the annual average rainfall as zero and also, this value is for the water required for the crop during the dry summer month of May. This value is nearly 1.5 times the annual average requirements of water for the crop.

C. Project Site
- The project site details are as shown below:
  - Location: B V Raju Institution of Technology, Narsapur
  - Latitude: 17.7276104°N
  - Longitude: 78.2545959°E

COST OPTIMIZATION

The Cost analysis is done with the help of solar and wind hybrid system to drip irrigate the mango crop in our campus. In order to analyze subsystems of the wind and solar generation units we need cost analysis of this small scale renewable energy system. Main goal is to get an optimized cost model for the best selection of the renewable energy system.

For an interconnected wind and solar hybrid system, the combined output power, PT is expressed as:

\[ PT = P_{wp} + P_{sp} \]

Where, \( P_{wp} \) = Wind turbine output power (W), \( P_{sp} \) = Solar output power (W)

\[ PT = \text{Hybrid system output power (W)} \]

The main objective in designing the Hybrid Power Generator is to select the optimum number of solar panels (Nsp) and wind turbines (Nwt).

Assuming the cost to be a linear function of the size and the total cost of a hybrid system (\( C_{HS} \)), then it can be written as

\[ C_{HS} = \text{NspCsg} + \text{NwtCwg} + \text{Nb*Cb*} + \text{Structural cost} \]

Where Csg and Cwg represent the cost per unit power of individual solar and wind power generators, \( \text{Nb*} \) represents number of batteries, \( \text{Cb*} \) represents the cost of individual battery.

\[ \text{NspCsg, NwtCwg - Variable cost} \]

\[ \text{Nb*Cb*, Structural cost - Fixed cost} \]

The optimization problem of combined solar and wind system is given by the equation below:

\[ \text{CHs} = \text{NspCsg} + \text{NwtCwg} \]

Subjected to \( P_{sp} \geq 1 \); \( P_{wp} \geq 1 \);

\[ P_{sp} + P_{wp} \geq 1.18 \text{KW} \]

The output power from the combined solar and wind hybrid system i.e 1.18kw is taken as a constraint as per the requirements given for irrigating 1.5 acres of mango crop. Similarly, cost of the system for different power requirements with structure is shown in table 2.
The Objective function is solved by using an optimization solver of Microsoft Office Excel 2007. The solution results in optimum number of solar panels, \( N_{sp} = 2 \), number of wind turbines, \( N_{wt} = 1 \), number of batteries = 2 and the total cost of the system is being calculated as 1,38,800/-. Similarly this optimization problem can also be solved by using an optimization solver using MATLAB software instead of Microsoft office Excel 2007 [5].

<table>
<thead>
<tr>
<th>Table 1: Pumping Specifications.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge (in liters/minute)</td>
</tr>
<tr>
<td>Land irrigated (in acres)</td>
</tr>
<tr>
<td>Water required/day/acre* (in liters)</td>
</tr>
<tr>
<td>Potential head(in meters)</td>
</tr>
</tbody>
</table>

**ANALYSIS**

Graphs are drawn between energy generated and the cost of the system. Projecting kWh on x-axis and cost on y-axis. Data is acquired from the super nova technologies ltd. of the following wind generators. To prove the hypothesis and to arrive at the cut-off point (cost vs. kW), to know the region of feasibility of particular energy system which is developed using four graph as shown in Fig.2- Fig.5.

<table>
<thead>
<tr>
<th>Models: SNT1 - 700 W</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNT10 - 1400 W</td>
</tr>
<tr>
<td>SNT25 - 2800 W</td>
</tr>
<tr>
<td>SNT50 - 5000 W</td>
</tr>
</tbody>
</table>

![Fig. 2: Cost vs. kW for Solar Generated without Structures.](image1)

![Fig. 3: Cost vs. kW for Solar Energy Structures.](image2)

![Fig. 4: Cost vs. kW for Wind Energy Generated without Structures](image3)

![Fig. 5: Cost vs. kW for Wind Energy with Structures](image4)
Data for the solar panels is acquired from the Andromeda and the following assumptions are made
- The mean annual wind speed is 6.0m/s
- Total no. of radiation hours is nine

From the above graphs it is clear that the cost of solar follows a linear relation whereas the cost of wind generator slightly drops at higher ratings. The comparison of two curves gives an intersection point i.e. the cost of both the system at this point is same. In the region below this point, solar is preferable and wind is preferable above the intersection point as per cost analysis. As the cost of solar panel is reducing with the advancement in technology, the installation cost (fixed cost) of the system is likely to reduce.

**Table 2: Cost Analysis of Wind Solar Hybrid Energy System.**

<table>
<thead>
<tr>
<th>Power Require(KW)</th>
<th>Cost of Solar Csg*10^00</th>
<th>Numb er of solar panels (Nsp)</th>
<th>Cost of Wind Cwg*10^00</th>
<th>Number of wind turbines(N wt)</th>
<th>Sub cost (Csg+Cwg)* 1000(Rs)</th>
<th>Num b er of batter y (Nb*)</th>
<th>Cost of battery bank (Cb*)*10^00(Rs)</th>
<th>Total Cost CHs*1000(Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4</td>
<td>43.20</td>
<td>3</td>
<td>76</td>
<td>1</td>
<td>119.2</td>
<td>2</td>
<td>34</td>
<td>153.2</td>
</tr>
<tr>
<td>1.18</td>
<td>28.8</td>
<td>2</td>
<td>76</td>
<td>1</td>
<td>104.8</td>
<td>2</td>
<td>34</td>
<td>138.8</td>
</tr>
<tr>
<td>2.8</td>
<td>43.2</td>
<td>3</td>
<td>228</td>
<td>3</td>
<td>271.2</td>
<td>4</td>
<td>68</td>
<td>339.2</td>
</tr>
<tr>
<td>5.0</td>
<td>14.4</td>
<td>1</td>
<td>532</td>
<td>7</td>
<td>546.4</td>
<td>7</td>
<td>119</td>
<td>665.4</td>
</tr>
<tr>
<td>7.5</td>
<td>72</td>
<td>5</td>
<td>684</td>
<td>9</td>
<td>756.0</td>
<td>11</td>
<td>187</td>
<td>943.0</td>
</tr>
<tr>
<td>10</td>
<td>14.4</td>
<td>1</td>
<td>1,064</td>
<td>14</td>
<td>1,078.4</td>
<td>14</td>
<td>238</td>
<td>1,316.4</td>
</tr>
</tbody>
</table>

**Table 3: The % of Cost of the Hybrid System Component.**

<table>
<thead>
<tr>
<th>Hybrid System Component</th>
<th>% Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Turbine</td>
<td>54.75</td>
</tr>
<tr>
<td>Solar PV</td>
<td>20.74</td>
</tr>
<tr>
<td>Battery &amp; Inverter</td>
<td>24.50</td>
</tr>
</tbody>
</table>

**CONCLUSION**

The reliability and efficiency of the system is enhanced when solar and wind power production is used together. Additionally, the size of the battery storage can be reduced.

**REFERENCES**