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Electrical Power Generation by Hybrid Renewable Energy Source (Solar, Wind & Hydro)

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Abstract - *Wind-Photovoltaic-Hydro hybrid generation is a new multi-energy hybrid system combined with respective advantages of wind energy, solar energy and hydropower. Renewable energy today is seen as an effective alternative energy source for meeting the exponential growth in the energy demand of the world. With this integrated scheme, it is viable to generate electrical power from inexhaustible resources in regions having favourable meteorological conditions with limited or no connectivity to grid. This paper builds cost effective system for residential township.*

Key Words: **Wind, Solar, Hydro, Hybrid renewable energy system, battery storage, inverters**

1. INTRODUCTION

Electricity is most needed for our day to day life, with increases in demand for electrical energy, there is a need to search for alternative sources of power generation. Hybrid renewable energy systems such as wind and solar are receiving national and worldwide attention due to the rising rate of utilization of fossil and nuclear fuels. The coupling of solar energy, hydro energy and wind may provide continuous power supply as long as the hybrid power meets the power demand. However, the hybrid power is highly depending on weather variations and is not able to meet the constant power requirement. When the hybrid power is insufficient in meeting the load, main power supply can satisfy the requirement[1]. There are two ways of electricity generation either by conventional energy resources or by non-conventional energy resources. The conventional energy resources are depleting day by day. Soon it will be completely vanishes from the earth so we have to find another way to generate electricity. [11]The non-conventional energy resources should be good alternative energy resources for the conventional energy resources. The solution for this problem is the concept of renewable energy source that includes Solar, Wind, and Hydro etc. [3] Sources and the intermittency of the power generated by them create stability, reliability and power quality problems in the main electrical grid. The term hybrid energy system refers to those applications in which multiple energy conversion devices are used together to supply an energy requirement.

These systems are often used in isolated applications and normally include at least one renewable energy source in the configuration. In this proposed system solar, wind and hydro power system is used for generating power. [12]Solar and wind has good advantages than other than any other non-conventional energy sources. Both the energy sources have greater availability in all areas and it needs low cost. The importance of hybrid systems grown as they appeared to be the right solution for a clean and distributed energy production.[2]

The basic concept proposed hydro energy system is that renewable energy sources like the wind system, solar system and hydro-systems are made such that the solar system is connected to DC-DC converter , wind system is connected to AC-DC-AC and similarly hydro system is connected to AC bus-bar which is later sent to rectifier to DC bus-bar [13].A charge controller is provided to the storage battery and power is sent to load from DC bus-bar through inverter[4].

2. Need for Hybrid power generation

The increasing costs of coal, oil, petroleum, nuclear and extension of power grid, and to reduce global warming ,leads to enhancement in the development of the hybrid power system which suits for distant locations.[5] Hybrid power system is discovered for the generation and utilization of electrical power.[6]

3. System Description

The hybrid wind-solar-hydro power generation system includes wind turbines, photovoltaic cells, hydropower generators, energy storage devices, energy conversion devices and the relative energy, scheduling control center as shown in the Fig.1.

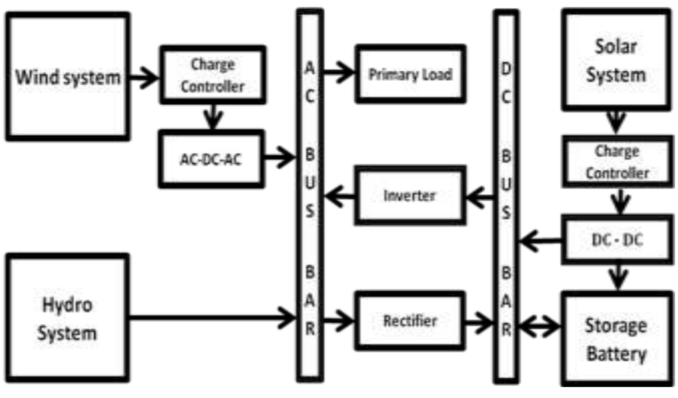


Figure1. Structure of hybrid wind-PV-hydro power generation system

3.1 Photovoltaic Subsystem

Photovoltaic is the static device that converts solar energy into electricity in the form of direct current. The power output depends on solar radiation and temperature conditions [10]. The output power of photovoltaic can be written as:

$$P_{PV} = f_{PV} Y_{PV} \left(\frac{I_T}{I_S}\right) \quad ...(i)$$

where , f_{PV}, Y_{PV} are the PV derating factor and the PV array capacity, respectively; I_T is the real-time solar radiation level on the PV array; I_S is $1kW\ /m^2$, which is the standard amount of radiation used to rate the capacity of PV modules.

3.2 Wind-Turbine Subsystem

The wind turbine is the mechanical device that turns wind's kinetic energy into mechanical energy. The size of output power depends on wind speed [7]. Experiments show that the relationship between output power and wind speed as follows:

$$P_t = \begin{cases} 0 & 0 \le V < V_{ci}, V \ge V_{co} \\ f(V) & V_{ci} \le V < V_R \\ P_R & V_R \le V < V_{co} \end{cases} \quad ...(ii)$$

where P_R is the rated power of wind turbine; V_{ci}, V_{co}, V_R are the cut-in, the cut-out and the rated wind speed, respectively;[8]

3.3 Hydro power Station

Hydropower is to generate electricity by using the potential energy difference of water at different heights. The output of the hydropower station is determined by power discharge, water head and the energy loss, which depends on the efficiency of hydro-generator [11]:

$$P_h = \eta QH = AQH \quad ...(iii)$$

Where Q is the water flow volume per unit time in the measured profile through the turbine inlet; H is the net water head; η is the hydropower efficiency.

3.4 Storage Battery Subsystem

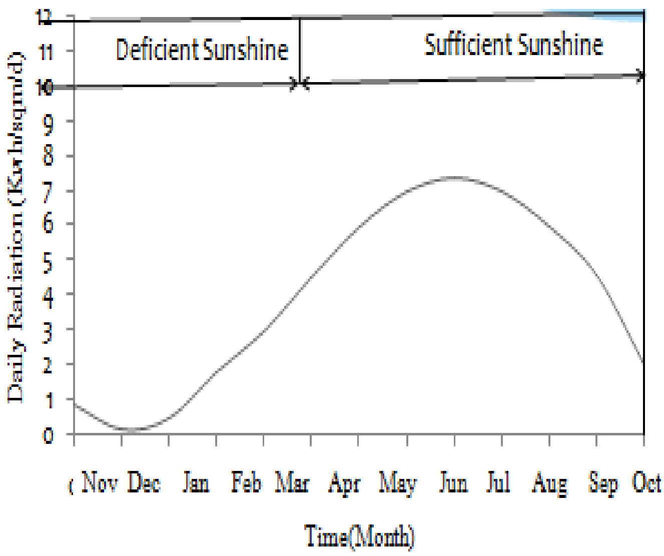
Storage battery plays an important role in balancing power in the distributed generation system. It can make up for the randomness and fluctuation of wind and solar power, and improve the supply reliability.[9] The energy of the battery is constantly changing. The status at the moment t is related to the status at the moment t -1and electricity supply and demand between the two statuses. When the system's total output power is greater than the load consumption, the battery is in the charge state, otherwise, the discharge state [12]. Rule for updating battery power can be expressed as:

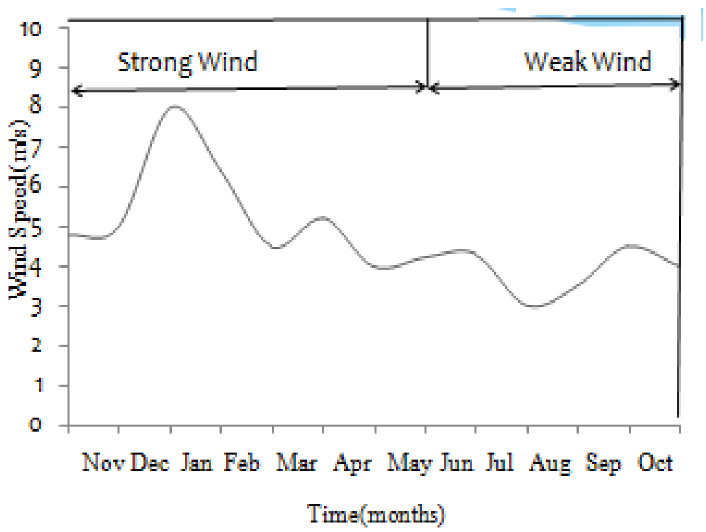
$$P_{b,soc}(t) = \begin{cases} P_{b,soc}(t-1) - (P_{sys}(t) - P_{load}(t)\eta_b \\ P_{b,soc}(t-1) - (P_{load}(t) - P_{sys}(t)) \end{cases} \quad ...(iv)$$

Where η_b is the battery efficiency; $P_{sys}(t)$ is the system's total output power; $P_{load}(t)$ is the load electricity consumption.

4. Proposed Hybrid System

The main topic of this paper involves the system that includes more than one renewable energy sources. This provides the continuous supply as the system is hybrid. In cases of any breakdown or failures or any type of the faults, the alternate systems work. So, such kind of the systems are easy to operate and maintain. There will be no recurring charges for the costs of fuel as the system is based on natural renewable resources. In Fig.2 shows the graph of the weather changes in all twelve months based on daily radiations of sunrise. solar energy , wind speed i.e. wind energy and stream flow i.e. hydro-energy sources.





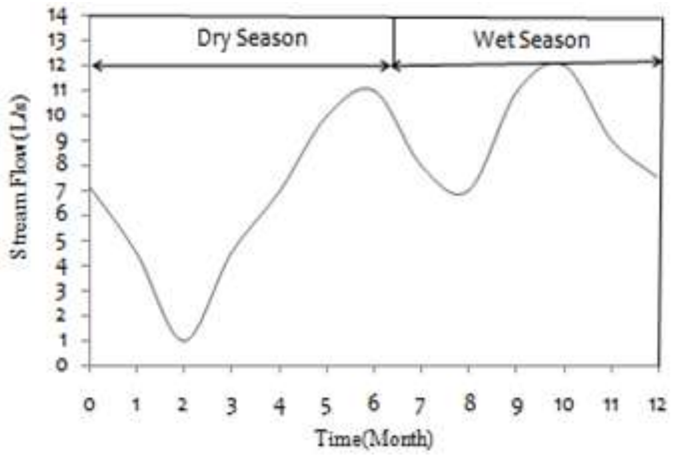


Figure2. Seasonal complementary performance of wind energy, solar energy and hydro resources [15]

From the perspective of seasonal change, there is strong wind, sufficient solar energy and dry season in winter and spring, while weak wind, deficient solar energy and wet season in summer and autumn.

Take a region in southern in India as an example, the seasonal complementary performance of wind energy, solar energy and hydro resources is shown in the Fig2.

5. Case Study and Analysis

To perform the present study, the load data is used as 1000W in the southern part of India, Chennai (Tamil Nadu) whose wind velocity is 5 m/s and solar radiation is 5.08kWh/sq-m.and the water supply is from river.

5.1 Design of solar system for 1000 W load

Now let us consider the optimal sizing for solar energy for real cost estimating,

Load Estimated: 1000 W

Duration of operation: 12 hr

Then Total Watts Required: 1000x12 = 83.3 W-hr

Duration of Solar Panel Exposed to Sun: 8 hr

Therefore Solar Panel Wattage 12000 W/ 8 hr

= 1500 W

Now Number of Solar Panels required, if 150 W are to be used.

Number of Solar Panels: 1500 W/150W = 10 No.'s

Table.1: Ratings of Solar Panel

Specifications for Solar Panel	
Output Power	1500W
Input Voltage	12V
Output Frequency	50/60 Hz
Output Current	10A

5.2 Design of wind system for 1000 W load

Similarly, now let us consider the optimal sizing for wind energy for real cost estimating,

Total Load: 1000W

Duration of operation: 12 hr

Then Total Watts Required: 1000x12=12,000 W-hr

Duration of Wind Turbine in Operation: 12 hr

Therefore, Wind Turbine Wattage

12,000W/ 12 hr=10,000 W

If 1 kW Wind Turbines are to be used.

Number of Wind Turbines Required:

1KW/1KW = 1No.

Table.2: Ratings of Wind Turbine

Specifications for Wind Turbine	
Rated Output Power	1 KW
Rotor Diameter	2.8 m
No. of Blades	3 pcs
Cut-in wind speed	3 m/s
Working Wind Speed	3-20 m/s
Tower Height	6 m
Rated Wind Speed	9 m/s

5.3 Design of hydro system for 1000 W load

Similarly, now let us consider the optimal sizing for hydro - energy for real cost estimating,

Estimated Load for Township: 1000W

Duration of operation: 12 hr

Then Total Watts Required:

1000W x 12hr = 12000 W-hr
Duration of Hydro Turbine in Operation: 12 hr
Therefore Hydro Turbine Wattage
12,000 W/ 12 hr = 1000 W
If 1 kW Hydro Turbines is used.
Then Number of Hydro Turbine Required:
1kW/1kW = 1No.

Table.3: Ratings of Hydro-Turbine

Specifications for Hydro-Turbine	
Output Power	1KW
Blade Diameter	15 cm
Water Head	3 m
Output Current	0.03-0.04 cum/s

Similarly, now let us consider the optimal sizing for charge controller for real cost estimating.

5.4 For Design of charge controller for 1000W

P = V I Where, I is the expected Charging Current.

V is the Voltage of Battery = 12 V

P is the Power Supply Rating = 1000 W.

Hence I = P/V = 1000 W/12 V = 83.3 A.

Since 83.3 A, Charge Controllers are not readily available in market. Hence 100 A, 2 no.'s Charge Controllers will be used for solar system and wind system.

Table.4: Ratings of Charge Controller

Specifications for Charge Controller	
Max. Current	100 A
Rated Voltage	12V

5.5 Design of battery for 1000W

Now let us consider the optimal sizing for storage battery for real cost estimating,

Total Load P =1000 W

Duration of Operation = 12 hr

Watt Hour Capacity = 1000 W x 12 hr = 12000W hr

For operation purpose ¼ Capacity is used to avoid Over Discharge of Batteries.

i.e. 12,000/ ¼ = 48,000 W hr.

The choice of Battery depends on AH rating. If we use 1500 AH rating with 12 V.

Then, 48000 W hr/1500 AH

= 32 No.'s

Hence we require 32 Number of Battery for 1000W Similarly, now let us consider the optimal sizing for storage battery for real cost estimating.

Table.5: Ratings of Battery

Specifications for Battery	
Voltage	12 V
Ampere Hour	1500 AH
Type	Lead

5.6 Design of inverter for 1000W

Since the total load is 1000 W, it is safe & advisable to use the size required for Inverter i.e. 1500 W as designed for Solar Panel rating.

Table.6: Ratings of Power Inverter

Specifications for Power Inverter	
Output Power	1500 W
Output Voltage	12 V
Output Frequency	50/60 Hz
Output Current	10 A

6. Cost Estimation

Average demand per house per day = 6 units

Average demand per day (12 hrs) = 500W

Average demand per day is divided into 3 categories:

(i)Solar Energy = 2units

(ii)Wind Energy = 2units

(iii)Hydro-Energy = 2 units

6.1 Cost estimation of solar system

Now, the cost of required solar panels of 150W,

12V = 10 no. x Rs., 3,000/-

= Rs.30,000/-

Cost for erection fixing rate 30% of the cost

= Rs.9,000/-

Total cost for solar system = Rs.30,000/- + Rs.9,000/-

=Rs.39,000/-

6.2 Cost estimation of wind system

Now, the cost of required wind turbines of 1kW = 1kWx1xRs.10,000/-

= Rs.10,000/-

Cost for erection fixing rate 30% of the cost

= Rs.3,000/-

Total cost for wind system = Rs.10,000/- + Rs.3,000/-

=Rs.13,000/-

6.3 Cost estimation of hydro- system

Now, the overhead tank of 5 m height capacity 1,000 lit. Is existing with water pump, hence no expense incurred.

Cost of hydro turbine generator including fixing charges = Rs. 7,500/-

Total cost of hydro-system = Rs. 7,500/-

6.4 Cost of charge controller

Now cost of charge controller 100A capacity

=Rs. 2,100/-

Total cost of charge controller = Rs. 2,100/- x 2

=Rs. 4,200/-

6.5 Cost of storage battery

Now cost of storage battery 1500AH capacity

=Rs. 2,600/-

Total cost of charge controller =2,600x32

=Rs.83,200/-

6.6 Cost of inverter

Now cost of inverter 1500W capacity

=Rs 5,000/-

7. Total Cost of Hybrid Renewable System

* Estimated cost for Solar system = Rs. 39,000/-
* Estimated cost for Wind system = Rs . 13,000/-
* Estimated cost for Hydro turbine generator System excluding over head tank & pump

  = Rs.7,500/-

* Other accessories Charge controller, Inverter & storage Battery = Rs 92,400/-
* Total Expenditure incurred for 1 house = Rs. 1,51,900/- (This is arrived by considering subsidies provided by Indian govt. subsidies)
* Now let us consider a house, average 200 units per month, for years.
* i.e. 200 x 7.30 x 12 x 9. = Rs. 1,57,680/-
* The cost incurred for Hybrid project can be recovered in 9 Years.

8. Results and Conclusions

Development and utilization of renewable energy, such as wind, PV, hydropower, is an effective way to solve the energy crisis and environmental pollution problems. But there are some drawbacks, mainly due to fluctuations in wind and solar energy. Especially the wind energy has a great influence on the stability of the grid. This paper focuses on the investment cost and recovery of the hybrid renewable energy system combining the solar system, wind system and hydro- system. The cost estimation for this system which shows the recovery period i.e. pay back period of 9 years.

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