Design & Integration of Wind-Solar Hybrid Energy System for Drip Irrigation Pumping Application

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***Abstract**: There is increasing demand for the use of alternate or renewable energy sources to achieve clean and low-cost electricity for agricultural water pumping requirements. The potential for non-thermal onsite power generation also remains enormous in India with increasing investment in small-scale solar and wind power. Promotion of energy production from the combination of sources of energy known as hybrid system is represented by an important objective of meeting the energy demand and justified by environmental protection and increase of energy independence. Design & integration of renewable energy hybrid system also involves the process of selecting the best components and its sizing to provide cheap, efficient, reliable and cost effective renewable energy. During this study a solar and wind hybrid system is optimally designed for a standalone drip irrigation system. It consists of a submersible pump that consumes 2.4 units of electrical energy per day on the average, to drip irrigate 1.5 acres of mango crop. Also, cost optimization of the wind-solar hybrid system is done in this paper to provide useful guidelines for small scale wind-solar hybrid system manufacturers.*

***Keywords**: wind, solar, drip irrigation, cost optimization, solar pumping*

I. INTRODUCTION

India possesses a relatively high abundance of sunshine, solar radiation, and moderate wind speeds, hydro, and biomass energy resources. Small scale solar-wind energy systems can make a significant contribution to our nation's energy needs. Indigenous development of small wind power systems up to 25 kW (and hybrids) for stand-alone applications is the objective of new Indian renewable energy act along with the deployment of solar PV Pumps. Drip irrigation system has the potential to solve the problem of food, energy and water security arising from the climate change phenomenon. The merit of drip irrigation technology is that it frees the farmer from the limitations of rain fed farming throughout the year with higher yields while conserving water. Electricity generated from solar-wind hybrid systems can help farmers reduce their electricity costs, an important consideration in the cases of remote farming.

1.1 **Definition of hybrid system**: - To overcome the drawback of unavailability of power at all times, and to remote places, hybrid systems are developed. In a hybrid power system, different methods of producing electricity are combined to ensure a continuous power supply. An energy system consisting of two or more generating systems, such as the combination of a wind turbine or diesel generator and a photovoltaic system is termed as a hybrid energy system. Hybrid generation system selected in this design, harnesses both renewable sources of solar power and wind power to form an equivalent of a miniature (or virtual) grid. When the systems are connected together, they will have enhanced reliability, higher efficiency, and lower emissions with an acceptable cost.

1.2 Industry scenario of solar energy generation:-

Complete process of fabrication of a solar panel along with merits and demerits of various solar cells, process techniques and Q/A methodologies have been studied.

Large scale manufacturing of photovoltaic cells, coupled with continued research and development is expected to further make Photovoltaic's within the economic reach of rural areas in India. Cost of multi crystalline solar panel is almost 1$/Watt now.

II. Configuration Of Hybrid System

The specifications of a hybrid system are derived from a comprehensive understanding of the pumping requirements of the drip irrigation system. Research & development has been carried out to design & develop an integrated and sustainable renewable energy system that supplies electricity to a submersible pump that would cultivate a land of 1.5 acres of mango crop located at Dr.B.V.Raju Institute of Technology, Narsapur, A.P, India. At this area, water depth has been found to be at 120ft below the ground level.

2.1 Water Pumping Requirement:

Submersible pumps are easy to install, have no suction problem, and require no water level guard. Submersible Pump is selected based on the below factors:

- Source of water (well, river, pond, etc.)
- Required pumping flow rate
- Total suction head
- Total dynamic head

To lift this water to the ground levels pump is selected with specifications given in table1:

Table 1. Pumping System Specifications

Total head(meters)	73.1
Discharge(lpm)	90
No of Acres irrigated	1.5
No of liters required/day/acre*	11,100

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.

No. of liters required/day/1.5acre:
11,100*1.5=16,650ltrs/day/1.5acre.
No of liters to be pumped/hour : 5,408
Pump running hours/day/1.5acre:
16,650/5,408 = 3.08hrs/day/1.5acre.

Table 2. Drip System Specifications

Drippers Capacity(lph)	8
#Drippers	672
Drip system Operation(hrs/day)	3.08

A submersible pump is identified that gives the given Discharge Vs Head requirements.

2.2 Design of Hybrid Energy System:

Reliability and feasibility study of wind-solar hybrid system solution starts with obtaining the meteorological data of the selected place of installation.

2.2.1 Meteorological data required for Solar System:

1. Annual mean daily duration of Sunshine hours
2. Daily Solar Radiation horizontal (KWH/m2/day)

2.2.2 Meteorological data required for Wind System:

1. Mean Annual Hourly Wind Speed (m/sec)
2. Wind Potential in watts that can be harnessed (obtained from Wind map for the location).

The Parameters* that are obtained for the study location are as follows.
*Data obtained from the Indian Meteorological Department (IMD) Hyderabad.
The array factor for circular array is given

Parameter	Design Value
Annual Average Daily Peak Sunshine Hours (ADPS)	9.31
Daily solar Radiation Horizontal(kWh/m^2/day)	3.83
Mean Annual Hourly Wind Speed(m/sec)	3.277

The Various Components of our hybrid system along with their unit specifications are arrived as follows.

Hybrid System Component	Unit Specifications
Sizing of wind generator	700W, 24V DC
Solar Array	240W,24V DC
Battery sizing	12V,120Ah
Inverter sizing	3.0kVA

Table 3. Hybrid System Components

2.2.3 Steps to determine Battery Bank Size:

1. Identify total daily use (Calculated from the load list) in Watt-hours (Wh)……(a)
2. Identify Days of Autonomy (backup days); multiply Wh/day by this factor…….(b)
3. Identify Depth of Discharge (DoD) and convert to a decimal value. Divide result of Step (b) by this value……(c)
4. Divide result from Step (c) by system voltage. Result is the *minimum Amp-hour (Ah) capacity* of your battery bank as per standard operating conditions.

Calculate Battery Bank Size by above approach to give the values below:

Example:

Step 1: Daily Usage (calculated from the load list.) in Watt hours = 2698.08Wh/day.

Load List:

Appliance	Qty	Watts(V*I)	Hrs/day	Wh/day
Electric Motor	1	876	3.08	2698.08

Step 2 : Days of Autonomy (backup days) multiply with Wh/day: 2698.08*1=2698.08Wh

Step 3 : Depth of Discharge (DoD) 80% and divide step 2 by this value: 2698.08/0.80=3372.6Wh.

Step 4 : Divide result of step 3 by the system voltage (here system voltage is 24V): 3372.6/24=140.525Ah.

Battery Bank Capacity: 24v, 141 Ah.

The recommended battery bank comprises of two LMLA (low maintenance lead acid) batteries of capacity 12v, 150Ah that are connected in series to give a total capacity of 24v, 150Ah.

III. Cost Optimization Of Hybrid Energy System

Solar-wind hybrid energy systems involve a significant initial investment, they can be competitive with conventional energy sources when accounted for a lifetime of reduced or avoided utility costs. The cost of the system itself depends on the system chosen, wind resource on the site, electric costs in the area, and the battery bank required. Cost of the Wind-Solar Hybrid system is to be minimized to provide best value for the customer. So the entire system is analyzed for subsystem costs.

IV. Objective Function And Its Optimization

The power output from a combined solar and wind system, P_{cs} may be expressed as

$$\mathbf{P_{cs}=P_s+P_w}$$

Where $\mathbf{P_w}$ = Total wind turbine power rating in Watts.

The main goal in designing the hybrid Power Generator is to select the optimum number for N_s(number of solar panels) N_w(number of wind turbines).

Assuming the cost to be a linear function of the size, the total cost of a hybrid system C_{cs}, can be written as

$$C_{CS} = N_S C_S + N_W C_W + N_B C_B$$

Where C_s and C_w represent the cost per unit power potential of individual solar and wind power generators, N_s, N_w, and N_b number of PV panel, wind turbine, and battery respectively.

The optimization problem of combined solar and wind systems is expressed by following equation:

Minimize:

$C_{CS} = N_s\, C_S + N_w\, C_w$

Subjected to Ps>=1;

Pw>=1;

Ps + Pw >=1.18KW

The power output from a combined solar and wind system 1.18kw is taken as a constraint as per the requirements given for irrigating 1.5acres of mango crop.

The above Objective function is solved by using an optimization solver of Microsoft Office Excel 2007.

The solution results in optimum numbers of solar panel and wind turbine as N_s=**2** and N_w=**1** respectively for the desired energy demand.

Similarly, cost of the system for different power requirements with structure are as follows:

POWER REQUIRED (KW)	Cost of solar C_s *1000 Rs	# of solar panels N_s	Cost of Wind C_w*1000 Rs	# of Wind turbines N_w	Sub cost (C_s*+C_w)*1000 Rs	# of battries N_b	Cost of battery bank C_b*1000 Rs	Total Cost C_{cs}*1000 Rs
1.4	43.20	3	76	1	119.2	2	34	153.2
1.18	28.8	2	76	1	104.8	2	34	138.8
2.8	43.2	3	228	3	271.2	4	68	339.2
5.0	14.4	1	532	7	546.4	7	119	665.4
7.5	72	5	684	9	756.0	11	187	943.0
10	14.4	1	1,064	14	1,078.4	14	238	1316.4

Table 4: Cost Analysis of Wind solar hybrid energy System

*Considering the cost of battery bank and inverter is Rs.28/Watt.

V. Results & Discussion

Proposed hybrid system:-

For the given requirement, selected power ratings of solar and wind are: 700watt(1*700W=700W) and 480(2*240W_p=480W_p)watt respectively.

The performance and energy generated by the Wind turbine can be estimated through power curve given on fig1.

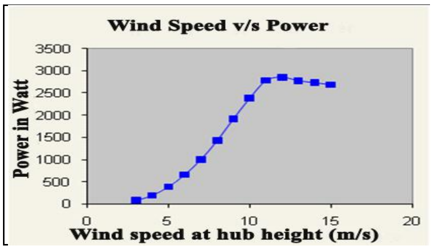

Fig. 1 Power Curve

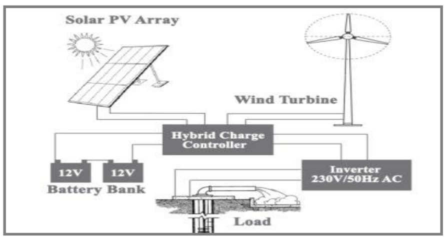

Fig. 2 Hybrid Energy System Model

The optimization problem is solved by using an optimization solver using Matlab. According to the result of the optimization, numbers required for solar panel and wind turbine and battery are computed as 2, 1, and 2 respectively, and the total cost of the system is calculated as **1,38,800/-.**

Hybrid System Component	% of cost
Wind turbine	54.75
Solar PV	20.74
Battery & Inverter	24.50

Drawbacks of independent renewable energy sources are unavailability at all the times and high capital cost, energy availability of rated wind speed requirement. A hybrid energy system helps in overcoming the drawbacks of the renewable energy sources and thus provides continuous supply of electricity.

VI. Conclusions

Solar-Wind Hybrid Systems is the best feasible economic solutions for lowering electricity bills; also they help in avoiding the high costs of extending utility power lines to remote locations, prevent power interruptions, and provide a non-polluting source of electricity. There is a definite need for optimizing the cost of the hybrid Systems based on the various operating and design parameters. In this paper, cost optimization is exercised to minimize the cost of Wind-Solar hybrid system for the given requirement of drip irrigation pumping.

The major advantage of wind – solar hybrid energy system is that when used together, the reliability of the system is enhanced. Additionally, the size of battery storage can be reduced. Thus, the analysis performed in this paper will set guidelines to energy consultants or engineers in designing the hybrid energy system by. considering the current industry costs of various subsystem components in order to meet the energy requirement. Remote communities which cannot be reached by electricity grids, except at prohibitive costs, or which do not have easy access to conventional commercial fuels, can easily adopt these hybrid systems for irrigation. This project will there by promote the use of hybrid renewable energy system as a power source for drip irrigation.

VII. Acknowledgement

Authors wish to thank the DC-MSME, Ministry of Micro, small and Medium Enterprises, New Delhi, India for funding and approving the BVRIT as Business Incubator. Also wish to thank the Management and Principal BVRIT for their constant encouragement and support.

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