Assessment And Feasibility Analysis Of Off-Grid Solar PV- Pico Hydro Hybrid System

Tapas Chhual Singh, G R K D Satya Prasad, Ch Saibabu, Kali ch Rath

Abstract*: As hydropower is one of the commonly available renewable energy sources, so it is experiencing a development in the large part of the world. Pico hydropower is used as a distributed system based renewable energy system meant for rural or remote area load . It is, hence, of most significant to propose an effective methodology to assure the better making reimbursement of a combined Pico hydro system with solar pv system. The proposed method mainly estimates the feasible of installing Pico hydropower in a run-of river. The Methodologies to assess the feasibility and sustainability of such mechanism were depicted. The orderly designing of plant is defined by considering some optimal technological method that considers the dimension of components plus the estimation of the gross energy generation. Economical plus Technical data studies performed to examine the profitability and practicability of the system. This planned method can be examined as a study and the feasibility of developing a PHP in a run of river system is possible. The environmental impact on fixing this plant measured and possibly reduced. This results obtained are demonstrated for already existing infrastructure and analyzed that the cost can be reduced by using an optimized model. A simulation result has obtained the financial expand is more by the technique used for the combine hydro-PV hybrid system. In Addition to the environmental impact and effect an analysis has exposed that yearly more than 200 tons of carbon emission is reduced by producing clean and green liveliness by means of the environmental and ecological solution.

Keywords: Feasibility analysis, HOMER software, Solar PV Pico Hydro system.

I. INTRODUCTION

This proposed paper represents environmental and economical study to look into the practicability and possibility of hydro-PV based electrical and mechanical installation. The technical and economical parameters are examined for a run of river pico hydro power plant before installation with some environmental constraints. This study is carried out to make easy and accurate evaluation and overall profit on assembling such installation. The design and viability of proposed pico hydro system has been implemented to examine possibility of generation and cost minimization. Both economical and technical parameters are analyzed by considering various boundary functions. This is through by predicting costs with revenues utilization of proposed model above plants continuous operation. Economical parameters have been measured to investigate the net profit obtained from various scenarios. Which includes the final value of the system, the normal electric energy cost price (kWh), and the period of reimbursement of the total investment held. This study is planned by a method for increasing strategy concerning on combination of Pico hydro pv power plant in a run of river. The projected design challenges to investigate the investment and feasibility of such installation. An optimization problem by considering both water flow variation and the desired location for installing the Pico hydro turbine could be developed. The main objectives of this proposed work are summarized as:

- A proper optimal model is formulated for proper sizing of the Hydro-PV based plant by way of a propose to increase its economic add.
- A technical model is developed to perform the dimensionality problem using HOMER with a case-based study.
- The proposed model given that a new tactic which evaluates the probability and effectiveness results in different scenarios of implementing Pico hydro-plant in run-of river water flow system.

This paper gives some numerical form of modeling the turbine in the sizing of the Pico hydro hybrid power plant.

II. PICO HYDRO POWER PLANT

Electrical power is developed by allowing the sufficient water through the turbine situated at the lower stream. The potential of the water at the upper stream makes it possible when flows through turbine from a certain vertical height. That is generally called as pressure head. This also finds the difference in height from the point of turbine installed to the top allowable head of the stream. In practical gross head is lower than the calculated head because of other factors like friction, water flow rate, radius of the nozzle tip.The net difference obtained in between gross head (H_G) and the head losses (H_L) is expressed in below Eq which is known as the net head (H_N).

$$H_N = H_G - H_L$$

The stored water in the reservoir will have some potential energy which can utilize and allowed through the pipe from a certain height. With Minimum height optimal power generation is the main concern over here for less cost of electricity.

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* Correspondence Author
Tapas Chhual Singh, Asst. Professor in EE Department, GIET University, Gunupur, India.
G R K D Satya Prasad , Department of EEE, GIET University, Gunupur , India.
Sai Babu. Ch. Professor in EEE Department, JNTUK, Kakinada, India
Kali Charan Rath, Professor , Department of Mechanical Engineering, GIET University, Gunupur, India.

Water runs through pipe will have kinetic energy which in turn rotates the turbine thereby electricity is generated through the generator attached to the turbine.
Turbine power (P_h) is the output power that is produced by the turbine.

$$P_h = \rho g Q H_N$$

Here ρ is the density of water in kg/m³, 'g' is the gravitational acceleration in m/s^2. Q is the water flow rate in m^3/s
Total head loss due to major and minor loss that is resulting from the friction within the fluid and form the fittings, bandings and valves.

$$h = h_{major} + h_{minor}$$

$$h = f' \frac{L\, V^2}{D r 2g} + K_L \frac{V^2}{2g}$$

Here 'f' is the friction factor, 'D' is the inside pipe diameter, 'V' is the velocity of water flow through turbine in (m/s), and 'L' for pipe length. Loss coefficient 'k_L is used that depends upon the obstacle faced. It is provided by the manufacturers.

Optimization of Plant Size

An optimization model of a pico- hydro plant integrated with water distribution system, has been proposed. Minimization of the overall cost of the system and optimal sizing of this installation is the prime objective of this optimization model by maximizing the plant revenues.Input parameters are initial installation cost, market price of energy, process and protection cost and Characteristics of the energy generation by the turbine. The optimal input parameters include: pipe diameter, optimal head, gross value, annual cash flows, and yearly savings.The best possible profit will be obtained from optimal sizing of the hydro power plant components. This can be achieved by Maximizing the energy production and by reducing the plant losses. the objective function is given in terms of maximum net present value i.e.

$$(NPV)_{max} = PV_{hr} - PV_{cost}$$

Investor's profit must be maximized by the model developed by considering PV system for Hydro plant. Here PV_{hr} and PV_{cost} is hourly revenues and costs of the plant, respectively.When net present value of the particular process is made positive, implies a profitable project. Investment costs and revenues are observed for a certain period of time by such economical analysis; Many factors that are having direct or indirect impact on the project price and returns such as inflation, interest rate, and risk investment.
The present value for 'n' no of year at a discount rate of 'r' and C_i is the periodic payment occurring in year 'I'is expressed as

$$PV = \sum C_i\, (1 + r)^{-1}$$

Where 'i' varies up to 'n ' th no of years.
The variable cost and plant energy production cost is regarded as operation and maintenance cost which is very much expensive. It is expressed in terms of hourly produced energy $E_P(t)$, project capital cost (C_a) and operation and maintenance cost ($C_{O\&M}$).

$$V_{cost} = C_a + C_{O\&M} \sum (E_P(t))$$

The revenues generated by selling energy to the grid are based on the selling tariff and plant produced energy.

$$Rev(t) = \sum (E_P(t) \times P_E(t))$$

The plant generated energy E_p during 'n' th period is expressed as

$$E_P(t) = \rho g \Delta t Q H_n \eta$$

The objective of the model is to increase the key parameters by selecting suitable value for the plant net head (H), diameter of the pipe (D) that satisfy all constraints. Therefore, the suitable optimal system is constrained by the plant
Gross head depends upon the site location. This proposed plant gross head will be considered and used as an input for the model.

$$H_n < H_G$$

A reduction in plant losses requires an optimal sizing of the conduit; this regarded as an output of the optimization model. Some of the parameters like diameter of the pipe, net head and energy generation should be strictly positive.

$$D, E_p, H_n > 0$$

Optimal flow rate through Pico hydro turbines

The Power generation on any hydro power plant depends upon the characteristics of reservoir as well as the rate of water discharge through turbine. The power output of small hydro generator depends upon the volume of the reservoir V_K, rate of water discharge Q_t and net hydraulic head H of the small hydro turbine to generate a particular power, the flow rate at which the water injected into the turbine is articulated as a parameter for power output 'P_{hj} 'and is set by a quadratic equation.

$$Q_j(t) = a_j P_{hj}^2(t) + b_j P_{hj}(t) + c_j$$

Commonly, optimal transmit of pico hydro power plants is the purpose of the power generation in all hydro power station such that total production cost of the system could minimized, while satisfying various system constraints and meeting the electrical load demand. However, the main purpose of the optimal dispatch for the proposed case is to decide the minimum flow rate of water for the normal power dispatch of small hydro turbines at each time. The objective function after minimizing the flow rate of water delivered into turbine within a planning period is given by

$$\text{Min } (F) = \sum_{j=1}^{N} \sum_{k=1}^{T} F(P_{hjk}) \frac{L}{S}$$

Where

$$F(P_{hjk}) = Q_j(t) = a_j P_{hj}^2(t) + b_j P_{hj}(t) + c_j$$

This subjected to various constraints like Reservoir Volume, Water Discharge, Power balance and Hydro power Generator Constraints.
For a total planning period it must be ensured that there should be an average of 40 % of the water stored in between the initial and final water volume V_K and that has upper and lower bound.

$$V_{min} \le V_K \le V_{max}$$

This arrangement ensures availability of sufficient amount of water for the electricity generation in a successive planning period. A Each pico hydro turbine generates power based on the quantity of water available in the reservoir during a particular interval (say kth interval). Hence the water volume in the reservoir at this interval is given by

$$V_k = V_{k-1} + (w_{jk} r_k - x_{jk} q_{jk} - s_k) \Delta t$$

When pico hydro turbine is in service through the time 'k', w_{jk} value is equals to zero and one if otherwise. The value of x_{jk} for jth pico hydro turbine is one during the interval 'k'and zero if othwerwise.

The stream flow speed is controlled within a limit as

$$Q_j^{min} \leq Q_{jk} \leq Q_j^{max}$$

The limit for operation must have to lie between maximum and minimum value

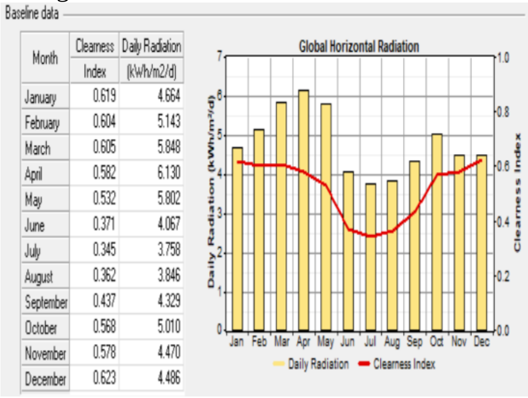
$$P_{h,j\,min}(t) \leq P_{h,j}(t) \leq P_{h,j\,max}(t)$$

Power equilibrium in between the whole power generation for small pico hydro plant and total load require with the loss during an interval of 'k' is given by

$$P_{bk} = \sum_{j=1}^{N} P_{hjk} - P_{lk}$$

II. SOLAR PV INSTALLATION

Solar photovoltaic radiation based performance investigated for each days of the year. Monthly average solar radiation data considered for optimal output and to lower the overall electricity cost. For which average daily radiation for all the months of year varies from 3Kwhr/m2 to 6Kwhr/m2 as shown in the figure-1 is considered.



Month	Clearness Index	Daily Radiation (kWh/m2/d)
January	0.619	4.664
February	0.604	5.143
March	0.605	5.848
April	0.582	6.130
May	0.532	5.802
June	0.371	4.067
July	0.345	3.758
August	0.362	3.846
September	0.437	4.329
October	0.568	5.010
November	0.578	4.470
December	0.623	4.486

Fig1:- Monthly global horizontal radiation

Solar Photovoltaic system is used during day hour to run the motor to pump back the water into the reservoir. The utilization of this PV system mostly required for three months and rest of the months can be utilized for residential application.

IV. SIMULATION RESULTS

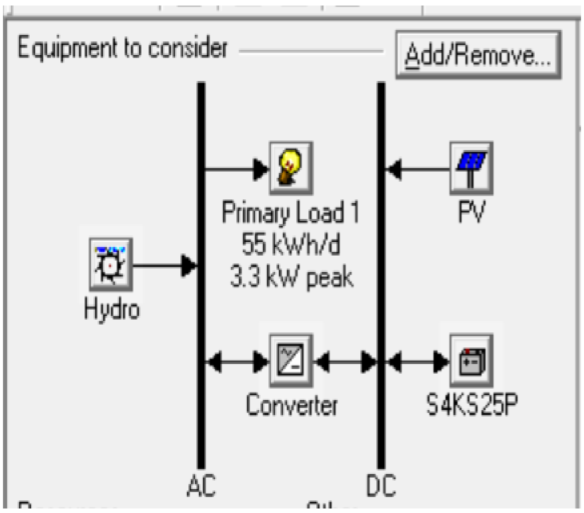


Fig2: Equipments considered for Hybrid model

To support in the continuous run of a pico hydro turbine various parameter in a hybrid system is considered which layout diagram is as shown in the fig2. that operates with a 5Kw hydro turbine which connected to the primary load of nearly 55Kwh/d that connected to a PV system is of 5Kwp through a suitable converter.

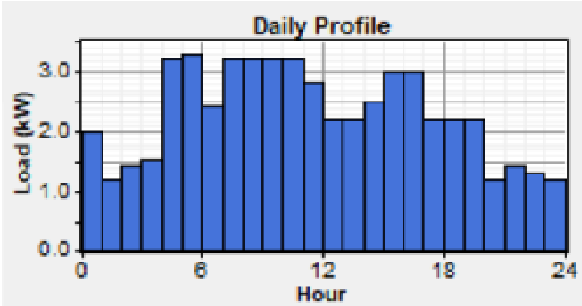


Fig3: Daily load profile

Daily load profile is shown in the figure-3 where hourly load requirement data considered for simulation with that data monthly load profile is developed by using HOMER software. Monthly data map shows that the peak power generated during different hours of the day for all the months and the seasonal profile is observed and the result is obtained. The result shows that average energy per day is 55Kwh and average power is nearly 2.3 Kw where as average peak power demand is 3.3 Kw and simulation result gives a load factor of 0.697 as shown in the fig5. and the cost of electricity calculated and is obtained as less than one rupee. Less electric cost is due to the utilization of surplus PV power during water pumping and use of solar energy for other available load near the area of generation.

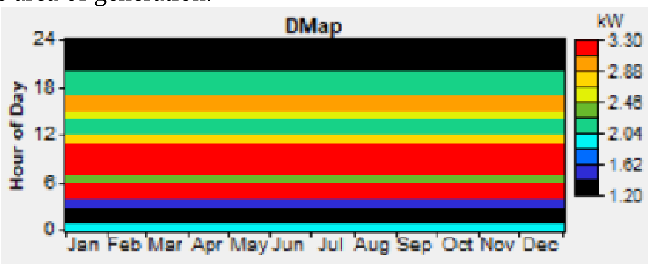
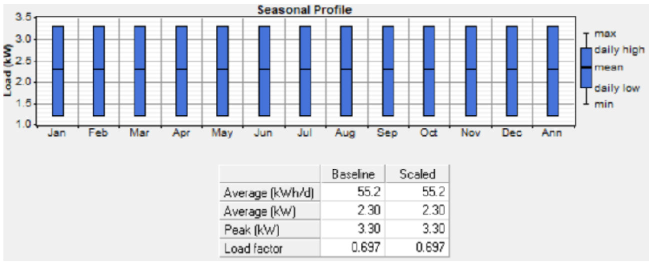


Fig4: Monthly data map of power generation.



	Baseline	Scaled
Average (kWh/d)	55.2	55.2
Average (kW)	2.30	2.30
Peak (kW)	3.30	3.30
Load factor	0.697	0.697

Fig5: seasonal load profile.

V. TECHNICAL VALIDATION

Fig6. illustrates generated electricity of multiple power system resources over a year. It is observed that during the month when less water is available for hydro turbine at such case maximum solar energy utilization will occur for running the turbine as pump to utilize the reserved water during peak load time, even though solar pv is installed but maximum time it will supply the power for the residential use rather than for water pumping hence installation of solar PV tied pico hydro makes turbine suitable for continuous run throughout year and hence the overall electricity cost can be reduced.

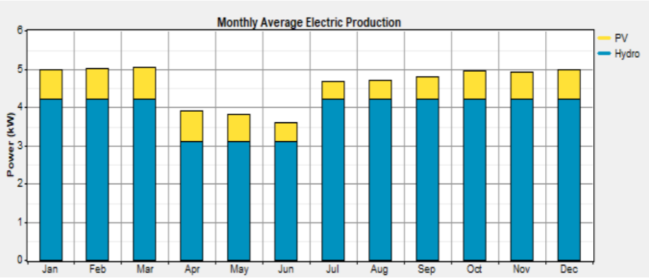


Fig6: monthly average electric production

In the proposed model the net power production by the solar PV aray and by the hydro turbine is obtained as shown in the fig. the total consumption per year of residential load is assumed to obtain the simulation result which shows that excess of electricity is generated from the hybrid generation system per year. Which can be utilized by the pump to lift the water into reservoir therefore electricity cost can be reduced to very lower value as the turbines runs continuously without any interruption and utilization of surplus power when it required to pump the water into upper reservoir .

Production	kWh/yr	%
PV array	5,965	15
Hydro turbine	34,516	85
Total	40,481	100

Consumption	kWh/yr	%
AC primary load	20,148	100
Total	20,148	100

Quantity	kWh/yr	%
Excess electricity	20,319	50.2
Unmet electric load	0.00	0.0
Capacity shortage	0.00	0.0

Quantity	Value
Renewable fraction	1.00

Fig7: Energy production and consumption

VI. CONCLUSION

An efficient optimized smart energy management is developed by the combined solar hydro hybrid system. This effective method is reducing the cost of electricity bill by considering the optimal flow of water into the turbine and the optimal scheduling of solar PV system. Proper utilization of solar system for turbine when worked as pump reduces the overall cost of electricity. Unlike the generation with only small hydro system this system gives a good and continuous response throughout the year.This paper has given a short overview of typical PHP applications, scheduling of PV system, general energy management concepts and principle approach for the power flow based on peak load and utilization. Moreover, four PHP configurations are suitable for the application in dispersed PV-systems that have been briefly discussed. Current research and Technology is focusing on the, investigation, experimental testing and development of new and optimization based power management algorithms and optimizing design concepts for hybrid PHPs.

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AUTHORS PROFILE

Tapas Chhual Singh received M. Tech in Power electronics from Biju pattnaik University of Technology , Odisha with First Class with Distinction (2013-15), Currently working as Asst. professor in the Dept. of EE in GIETU, Gunupur. His area of Interest is on renewable energy, hybrid systems, smart grid, and electric vehicles.

GRKD Satya Prasad received M.Tech in Electrical power systems from JNTU, Ananatapur. He is a research scholar in JNTU Kakinada and currently working as Associate professor in the Dept. of EEE in Gandhi Institute of Engineering and Technology University, GUNUPUR. He is a certified Energy Manager & auditor (BEE, govt. of India). He is also a member of IEEE, Life member in ISTE and SESI. He has published several papers in National and International Journals and Conferences. His area of interest is Power systems, Distributed generation, Energy conservation and renewable energy systems.

Dr. Ch. SAI BABU received B. E from Andhra University (EEE), M. Tech in EM&ID from REC, Warangal and PhD from JNTU, Hyderabad. Currently he is working as a Professor in Dept. of EEE in JNTUCEK, Kakinada. He has published several papers in National and International Journals and Conferences. His area of interest are Power electronics, Distributed generation and renewable energy systems.

Dr. Kali Charan Rath , Received B. E (Mech) & M Tech from BPUT Odisha and PhD from NIT, Rourkella. Currently he is working as a Professor in Dept. of Mechanical engineering, GIET University, Gunupur. He has published several papers in National and International Journals and Conferences. His areas of interest are design, operation and control of hydraulic engines, steam and gas turbines.