# Proposed Design and Analysis of Hybrid Configuration of Mini Hydro, Solar And Wind Power Plants: A Study

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**ABSTRACT**
*Electricity is one of the driving forces in a growing economy and increasing demand puts incredible pressure on the countries' energy infrastructure to match that demand. India as a developing country, where majority of the population lives in rural areas without access to electricity, the problem assumes greater importance. Extension of the central electricity grid to such areas is either financially not viable or practically not feasible as these locations are geographically isolated, sparsely populated and have a very low power demand. The best suited configuration of a hybrid renewable energy system out of various combinations to meet the village load requirement reliably, continuously and sustainably. The minimized cost of energy generation from the Hybrid renewable energy technology system. The system's cost-effectiveness, to calculate the cost of energy from hybrid Renewable Energy Technologies, then compares it to the cost of grid extension to determine the economic distance limit using homer software.*

## I Introduction:

**(A)** Decentralized electricity generation with the help of renewable energy technology systems has received considerable attention in recent years and is the best suited alternative solution. Moreover, from an environmental perspective renewable energy sources are sustainable and environment friendly. In the generation of electricity from conventional sources, the combustion of fossil fuels emits greenhouse gases, which are a major cause for global warming leading to climate change. Village electrification is a vital step for improving the socio-economic conditions of rural areas and crucial for the country's overall development. The villages' welfare is one of the main aims of the rural electrification program. Enormous benefits can be achieved in irrigation, food preservation, crop processing, agriculture and rural small-scale industries. This model analyses the techno-economic factors with respect to the cost of energy generation and then compares these performance indicators to grid extension related costs. In study of a hybrid system, this intermittent nature of renewable energy source can be overcome with the help of system engineering and designing with HOMER software.

## (B)  Solar, wind and hydro Energy Resource data:

The solar resource wind resource and hydro resource monthly data is approximated. The        solar resource profile considered over a span of one year. The annual average solar radiation was scaled to be 5.17KWh/m2/Day and the average clearness index was found to be 0.548.The graph plot shows that solar radiation is available throughout the year; therefore a considerable amount of PV power output can be obtained. The monthly average wind resource data was approximated. It shows that the annual average wind speed for selected location is 52 m/sec, with the anemometer height at 25 meters. The wind speed probability and average monthly speed throughout the year can be observed from the table and graph. It also shows that there are 15 hours of peak wind speed. The wind speed variation over a day (diurnal pattern strength) is 0.25 and the randomness in wind speed (autocorrelation factor) is 0.85. Both the monthly and annual average flows in the River.

## II Hybrid Optimization Results & Discussion:

The renewable energy potential and economic analysis of electricity generation with a hybrid renewable energy technology system for rural electrification in India are performed in this study. Different scenarios have been considered and future developments in the fuel price and in the costs for renewable energy technology (which can be expected to sink due to technical progress) have also been taken into account. The sizing of the various components paid regard to the necessity of an operation reserve to enable the system to provide reliable energy supply and also allows for a rising energy demand in the future. The system's feasibility and its independence of the grid are furthered by the

sinking costs for renewable energy source and the possibility to use a DG as back-up, which allows meeting the village's energy demand twenty four hours and seven days in a week.

### (i) Optimization Results:

For the off-grid electrification of remote villages, various combinations have been obtained of hybrid systems with SPV, wind turbines, Diesel, batteries and convertors from the HOMER Optimization simulation. This is shown in figure 1.1(a)
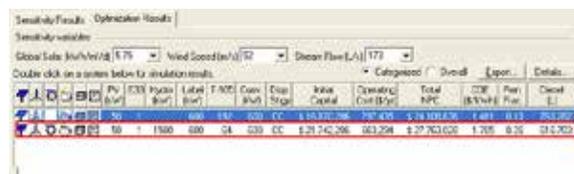


**Figure 1.1(a): - Optimization Result Details**
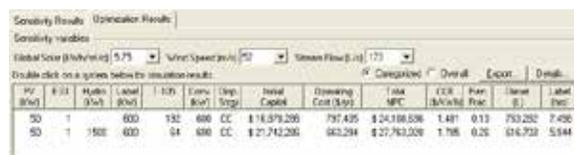


**Figure 1.1(b): - Optimization Result Details**

All the possible hybrid system configurations are listed in ascending order of their total NPC in the figure shown above. The technical and economical details of all the configurations of the hybrid systems from the optimization process are shown in detail in figure 1.1(a), where the best possible combination of solar photovoltaic, Wind, DG and batteries is highlighted in blue and the next best possible combination is marked with a red coloured box. The blue highlighted combination is able to fully meet rural load demands at the lowest possible total NPC. According to the optimization results, the optimal combination of renewable energy technology system components are a 50KW PV, 330KW wind, 600KW DG, 192 Trojan T-105 Batteries, 600KW Inverter and a 600KW Rectifier with a dispatch strategy of cycle charging. Details of this configuration are shown in figure 1.1(a). This system is considered at 52m/s of wind speed, 5.75KWh/m²/d of SPV and 173l/s of design flow rate as shown in figure 1.1(a). The total NPC, Capital cost and cost of energy for such a hybrid system are Rs.24, 109, 990, Rs.16, 870,286 and Rs. 1.481/KWh, respectively. As per the results obtained, the cost of energy of Rs. 1.481KWh from this hybrid system is cheaper than that of Rs. 1.705/KWh from grid extension as considered for this study. Therefore there is no need for a grid extension to meet the village load. But, if the cost of electricity from the grid supply falls below Rs. 1481/KWh, grid extension becomes viable.The effect of

wind reduces the diesel fuel consumption. As the output from the PV increases, the generator's operation hours decrease. In the months when hydropower output is high diesel is not used at all. For this selected system the diesel operation hours and fuel consumption shown in figure 1.1(b) are 7498 hours and 763282 litres respectively. In the summer months and during September to October, as the PV penetration increases with maximum wind output, there is a lot of excess electricity generated.

**(ii)      Sensitivity Results:**
Sensitivity analysis eliminates all infeasible combinations and ranks the feasible combinations taking into account uncertainty parameters. HOMER allows taking into account future developments, such as increasing or decreasing load demand as well as changes regarding the resources, for example fluctuations in the river's water flow rate, wind speed variations or solar insolation variation. Here, the various sensitive variables are considered to select the best suited combination for the hybrid system to serve the load demand. Figure 1.3 shows the sensitivity analysis detail. It can be observed that with change in the sensitive variables, the configuration of the system changes. Even in this analysis, HOMER ranks the configurations in descending order of their total NPC.



**Figure 1.3: - Sensitivity Analysis Details.**

In figure 1.3 the least cost configuration is marked in blue, further suitable configuration is marked in red. First red box show how the configuration changes with changing sensitivity variables. In the first red box there is no mini hydro plant in the configuration due to a 173 flow design; hence the component sizes, number of batteries and the costs related to the system increase rapidly. The cost of energy for this hybrid configuration of 50KW SPV, 600KW DG & 192 batteries is noted to be Rs.1.481/KWh. This configuration can be used at off-grid locations where hydropower is not available. The second red box adds Hydro to the configuration when the flow rate increases from 173L/s, 160L/s to 165L/s. Hence with an increasing number of components the related capital cost and total NPC also increase Therefore MHP is the cheapest technology compared to other renew-

able energy technologies.It can be seen that as the wind speed increase above 53m/s, the system configuration changes from Hydro, Wind, SPV, Label, Battery to Wind, SPV, Label, and Battery. It shows that the economic distance limit varies from 949 kms to 978 kms depending on the total net present cost and levelized cost of energy.

**III      Summary and Conclusion:**
A hybrid combination of renewable energy technologies (RETs) is generally considered to be the best suited alternative to an expensive grid extension for remote areas around the world. It focuses on creating a model for electricity generation from a mix of renewable resources to satisfy the electrical needs of an off-grid remote location. Using and applying Homer software (2.81 Version), this study presents an analysis for choosing the best hybrid renewable energy technology system and then compares it with conventional grid extension. Firstly, the load demand pattern of location over different seasons is studied yearly and suitably modelled. With the help of HOMER simulations, the optimized sizing of Mini-Hydro power (MHP), wind turbine generator, solar photovoltaic's (SPV) and diesel Generator (DG) systems is obtained. On the basis of minimized cost of energy (COE) generation obtained, Homer then calculates the economical distance limit (EDL), that is the relation between a RET system's lifecycle cost (LCC) and the cost of an extension from the existing grid allowing to determine the distance where the use of the former method is more cost-effective. The solution obtained shows that the use of decentralised RET systems at an Off-grid location is the best alternative to grid extension. Homer results show that the solution is sustainable and techno-economically viable and environmentally sound. The approximated data is taken for analysis and the hybrid RET system selected by Homer for rural village scenario from the various other prospective combinations of the sensitivity analysis was a combination of Wind, SPV, DG and Batteries having a COE generation of Rs.1.481/KWh as the best optimized system, which means that this hybrid RET system is cost-effective even in areas where the grid connection would be possible. The second best optimized hybrid system combination obtained by sensitivity result contains combination of Wind, SPV, MHP, DG and Batteries having a COE generation of Rs.1.705/KWh.

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