

# Design Analysis of PV-Wind Energy System with Pumped Hydro Storage using HOMER Pro

Himanshi Koli, M.P.S. Chawla



**Abstract**—Renewable energy in the recent era world-widely has proven to be a major shift for clean energy generation. It is a great opportunity or solutions to address increasing clean energy demand especially in a developing country such as India. As wind energy and solar energy are most commonly used renewable resources, gives their abundance in the region. Focusing aim of the analysis is to present the reliability of pumped hydro storage (PHS) system with respect to battery banks on the basis of operation and maintenance (O&M) cost with minimum loss. Thus, this system will have feasibility and practical capability to provide persistent supply operation to remote areas. The Hybrid Optimization Model for Electric Renewable (HOMER) software also known as HOMER Pro is used to conduct simulation of the system.

**Keywords**— Renewable energy system, PV-wind energy system, PHS, HOMER Pro.

## I. INTRODUCTION

Energy plays a vital role in the life of humans. Thus, increase of negative impact on environment and human life due to the fossil fuels, the renewable energy came into existence for contributing in the increasing demand of energy. With the continuous increase in the population growth the energy demand rises. Therefore, constant use of conventional resources has increased the cost of energy (CoE), primary fuel cost and the emission of CO<sub>2</sub> gas in the atmosphere[2]. All of the above reasons raise points to work for the environment betterment for clean future. Various mitigations are proposed through the help of renewable energy technologies. Thus, the clean power supply is now a trend around the world. The modification in the renewable technologies into today's electrification solution is appreciable. Through the solar energy power generation has grabbed attention recently. However solar-wind energy are present in abundance and their technologies depends on the meteorological conditions. As the renewable energies are great sources for future in turns of absence of conventional resources. Thus, in the field of power generation, energy storage is an important research sector now-a-days. Various energy storage techniques are available from those lead acid batteries are mostly used as backup energy storage. But batteries have their certain drawbacks of less life-span, complex maintenance and it can also damage to our environment[3].

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\* Correspondence Author

**Himanshi Koli**, Electrical Engineering Department SGSITS Indore, India Email.himanshikoli2012@gmail.com

**M.P.S. Chawla**, Electrical Engineering Department SGSITS Indore, India. Email. [morschawla@gmail.com](mailto:morschawla@gmail.com)

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In the present analysis, batteries are providing valuable replacement by the pumped hydro storage system. The design of photovoltaic system and wind energy system with pumped hydro storage system came to concern for remote areas. The aim of current study is to develop the profitable study of the above mentioned system.

## II. PHOTOVOLTAIC ENERGY SYSTEM

The expeditious depletion of fossil fuels and the reduction of carbon dioxide emission resulted into worldwide emergency. More than 80% of world's energy depends on non-renewable resources for power generation. Due to which the challenges for environment impact are at greater risk. So to reduce this risk technologies are shifted to renewable sources and one of such source is solar energy. The solar energy is a source which is present in huge amount in the universe. Solar cells generates current in a large range independent from the load. Much of the efforts are in the direction of conversion of large energy into profitable efficiency. Generally solar cells are modeled with single diode equation but to avoid the limited irradiation issue we may use two diode topology which give great results; another topology with parallel resistance provides more accurate results[4]. The design of PV system consists of the different PV panels, that are dependent on quantity of the connected load & output power desired for the PV array. The current produced from the PV panel depends on the factors of temperature, solar irradiation, cell voltage. The HOMER Pro uses all the factors and provides large variety of PV modules to work for different criteria.

## III. WIND ENERGY SYSTEM

In the recent years, the use of wind turbines for production of electricity has increased. Wind turbines are capable of producing electricity with no bad impact on global environment. They neither releases harmful gases nor induce harmful pollutants in the environment. Sufficient amount of wind speed is required for operational performance. Homer pro provides detailed analysis of the area through the data incorporated by it. In order to meet the desired power requirement of any system history of wind data is studied and according to the required power generation wind turbines were established[5]. Working on standalone wind energy system may increase installation costs and require more land area to ensure sufficient power generation.



## IV. HYBRIDIZATION OF SOLAR AND WIND ENERGY SYSTEM

The standalone system requires continuous advancement in the technologies which increases cost of the system, to avoid this increment hybridization turned out to be a boon for researchers. Hybridization of the renewable energy systems provides a lot of facilities to manage the economic balances.

A hybrid solar-wind energy based system has been investigated to counteract the fluctuations in the system and improve the reliability of the system. Homer is to get the optimized combination of RES system for the specific sites. The feasibility of hybrid system enhances the overall energy output, attenuates the individuals shortcomings, reduces the need of storage system and reduce the need of component[5].

## V. PUMPED STORAGE SYSTEM

Energy storage is an important part of the power generation. For the continuous power generation and delivering of the energy to the required amount we needed the energy storage system. The available energy storage technologies are fuel cells, batteries and flywheels etc. among these techniques lead-acid battery is the most popular energy storage system. In pumped storage technique electric power is turned in the form of potential (stored) energy and again converted to electric energy for energy storage. In this system, water from a lower reservoir is pumped to a higher reservoir, whenever there is large energy is generated than required, in the grid system. Than if there is demand of energy then we allow water to flow back using hydro-turbine, and it generates electric power to fulfill the impulse or sudden changes in load demands[5].

## VI. HOMER PRO SOFTWARE

HOMER Pro is a micro-grid software by HOMER Energy Solution is setting the worldwide grades for realizing micro-grid designs in every fields, remote island applications to rural power solutions, Off-grid and grid-connected sites and also military bases. The software is designed at the National Renewable Energy Laboratory, enriched and dispensed by HOMER Energy, HOMER roosted three robust tools in a single software package, so that economics and engineers works together. The main purpose of Homer software is to get optimal analysis of any system whether working or not. It provides all the factors summoned up at a single place to work, covers all the database quantities at a place.

## VII. METHODOLOGY

In present work, we have introduced a collaboration of pumped hydro storage system with PV-Wind energy production. The primary aim of this type of topology is to reduce losses and store energy through pumped hydro storage system. Thus, gives idea about the replacement of batteries and diesel engines or generators up to (90-100)% via use of renewable energy. Pumped hydro storage system has the potential to provide persistent power to system with the round trip efficiency of 75% to 80%. The study also directs that the renewable hybrid energy system with pumped storage will be price profitable alternative for energy storage.

## VIII. COMPARISON OF THE STUDIED RESEARCH PAPERS

### 1. *Techno-Economic Analysis of a Renewable Energy Solution for an Off-Grid Residence*

#### Overview

The objective of the study is to present the economic analysis of a renewable energy for an off-grid residence. The photovoltaic (PV) is used as means of energy generation, complemented with a battery power bank to ensure reliable and continuation of supply. The software known as Homer Pro is used to conduct simulation of the system and the optimal model is unveiled. The system Net Present Cost (NPC) is then deduced to select the best system configuration that satisfies the economic and technical requirements. Thus, constant utilization of conventional means of energy generation through fossil fuels has increased exponentially the cost of energy (CoE), primary fuel cost and the emission of CO<sub>2</sub> gas in the atmosphere. The NPC cost is impacted directly by the sensitive analysis of the present cost and projected cost of components partaking in the generation; particularly the higher cost associated to the storage system[8]

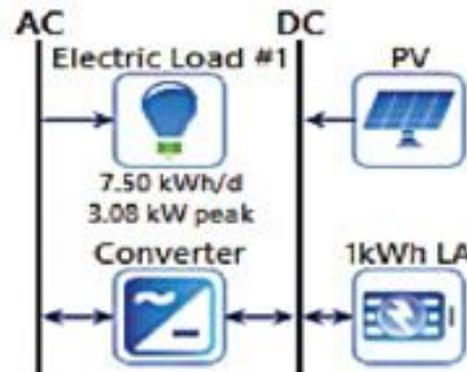


Figure 1 – System Topology[8]

### 2. *Feasibility Study of Replacement of Hybrid Renewable Energy – A Case Study*

#### Overview

This research describes the potential study of making a feasibility assessment of switching the conventional grid connected system into a renewable energy system which could be used as a possibility for supplying power to VIT located at Chennai. The idea for this research study is to make VIT, Chennai energy self-sufficient in such a way that it meets its load requirements though roof top installed solar panels and installing small-scale domestic wind turbines. First the ability to meet the load requirements from solar standalone system is analyzed followed by a wind standalone system. The primary aim studied is minimum cost and the components' size of the RES system and arrive at an optimal solution to meet the energy demand. Initial Costs, the Operating & Maintenance Cost (O&M), Net Present Cost (NPC) and Levelized Cost of Energy (CoE) have been used for Cost analysis. The results in this study show that the integration of this hybrid system into the existing campus provides a cost savings of \$ 3, 59,087 (2, 50, 58,634.93 ₹) NPC and \$ 28,442.01 (1984805.76 ₹) operating cost when compared to the cost of grid. The above results are obtained by doing the analysis using the HOMER software[6].



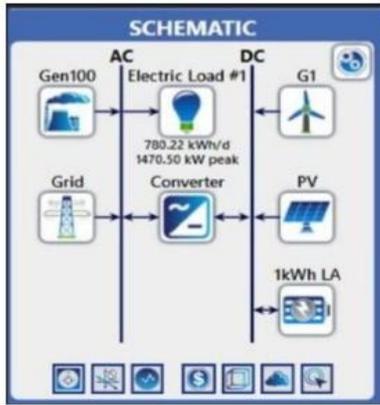


Figure 2- Description of the adopted system[6]

3. Grid-interactive micro-hydrokinetic with pumped-hydro storage: The case study of three South African demand sectors.

Overview

This work explores the different load operation and demand sector i.e. commercial consumers, residential loads as well as industrial loads when connected to a micro-hydrokinetic(MHK-PHS) grid-tied pumped-hydro storage systems.

The motive is to analyze load demand sector that is much profitable to the studied grid-connected hybrid system with TOU (time-of-use) tariff plan is used. This scheme provides the price of electricity as per usage.

Thus, the studied paper thoroughly explained the optimum configuration of the system to elaborate the effect of load demand on sizing & operation on the given hybrid systems.

The optimization was done on the basis of time of use tariff plan and the result suggests that the industrial demand of load enables with minimum cost for energy and maximum capital cost on comparison with commercial loads as well as residential load demand.

Also, from the economical point of view, residential load demand is much more profitable to the analyzed hybrid scheme due to minimum NPC[7].

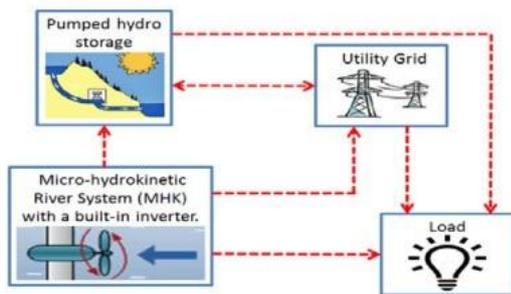


Figure 3- Proposed hybrid system[7]

IX. ANALYSIS USING HOMER PRO

In this article, the detailed analysis of the three case studies has been done. Each case represents a different way of optimizing Homer in every possible way. The outlook for adding a noticeable evolution in the renewable energy perception is analyzed. Homer provides a great stand to the renewable energy technologies to work around the off-grid and on-grid systems. Homer software provides the key factors like optimization, modeling, sensitivity analysis, database availability just by putting longitudes and latitudes on, compared data of all the meteorological quantities, net

present cost and cost of energy were the major economic parameters.

Outcomes shown in the case studies are satisfying enough to encourage the demand of renewable energy generation. It provides the point that the battery dependent power plant is approx 1.5 times costly, as indicated by NPC result.

Analysis also suggests that the probability of around 58% RE penetration which can help to local electric demand with the CoE of only \$0.288/kWh. And this CoE is around 30% reduced of the standalone systems.

The analysis of the papers elaborates economic operation through the studied system and the possibility of reducing battery bank dependency in the electricity business.

X. PROPOSED SYSTEM

After analyzing all of the three research papers, the projected system has Pumped Hydro system for Energy Storage (PHES), wind turbines and solar panels or PV arrays.

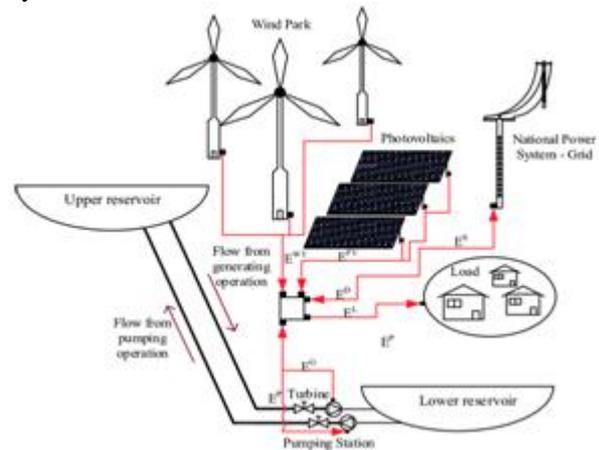


Figure 4- Representation of proposed (PV-Wind-PHS) Hybrid Energy System[1]

To design a hybrid system, modeled with meteorological data inputs that are used to simulate the system configurations, the renewable energy resources, the PHS energy storage system, define the load consumption, with or without-grid connectivity required for the system.

XI. CONCLUSION

In the recent years, tremendous hike was seen in the field of research taking place in the designing, optimizing of energy systems, energy operation & maintenance of the renewable hybrid systems. Currently, the main challenge is the designing of own energy storage strategy that enhances the need of energy at the peak time of load demand, storage of energy along with the cost reduction withstands the highest degree of flexibility. The prominent agenda of this study is to develop a system to distribute the power generated from the renewable energy sources efficiently, and deals with the feasible study of hybrid energy system and profitable output of the pumped hydro storage system rather than the battery backup system on the basis of net cost. The study of the technical analysis of a renewable energy for the off-grid power system is presented. The optimal configuration resulted is suitable to meet the load in the study case.



However, the shortfall associated to the system can be addressed and resolved if the cost and environmental impacts are viable. The modeling, analysis and optimization of a renewable energy replacement system for the university had been done. For a system without grid connectivity, the CoE is higher than a system with grid connectivity. A grid connected system will aid in reducing the pressure on the grid and help in the conservation of electricity from the grid. From the results obtained it is found that there is an increase of nearly 97% in the Net Present Cost savings by the usage of solar standalone system at the given site instead of a grid. Due to the very high initial cost of wind turbine and low wind velocities, standalone wind energy system has more economic implications and is not well suited for the given site. Based on the study of “MHK-PHS grid connected system”, the results obtained describes that the industrial as well as commercial loads have more energy demand than residential loads and comparatively requires the lowest capital cost. It also provided that residential load ensures the minimum NPC with the maintained CoE. Therefore for cost effectiveness, the studied hybrid scheme finds more profitable option available for residential loads. Energy generation and electricity market result suggests that huge energy demand from residential load doesn't occur at the peak time or critical hours. Time of use tariff plan and most of the energy sales is seen in industrial and commercial utility sector. Therefore, it will be the major revenue generating source because of the maximum sales of energy.

## REFERENCES

1. <https://las493energy.wordpress.com/2018/10/01/an-exploration-of-hybrid-pumped-hydro-storage-systems/>
2. A. K. Raji and D. N. Luta, “Modeling and Optimization of a Community Microgrid Components,” *Energy Procedia*, vol. 156, pp. 406-411, Jan. 2019.
3. Shashikant Golande and Manohar Kalgunde, “Utilization Of Solar Energy With Pumped Hydro Storage Based On Standalone Photovoltaic Power Generation,” 2017 *International Conference on Computer Electrical & Communication Engineering (ICCECE)*, Kolkata, pp. 1-4.
4. Afshin Izadin, Arash Pourtaherian and Sarasadat Motahari, “ Basic Model and Governing Equation of Solar Cells used in Power and Control Applications,” *Sept 2011*
5. D.P.Kothari, K.C.Singhal, “Renewable energy sources and emerging technologies”, *PHI Learning Private limited, second edition*, August 2017
6. Motupalli Priyanka, Niranchana R, S Selvakumar, Nithya Venkatesan, “Feasibility Study of Replacement of Hybrid Renewable Energy – A Case Study,” *IJITEE Trans BEIESP*, Volume-8, Issue-6S3, April 2019.
7. S.P. Koko, K. Kusakana, and H.J. Vermaak, “Grid-interactive micro-hydrokinetic with pumped-hydro storage: The case study of three South African demand sectors,” 2017 *International Conference on the Domestic Use of Energy (DUE)*
8. Bruno P. Pougoue Tchintchui, Atanda K. Raji, “Techno-economic analysis of a renewable energy solution for an off-grid residence,” Cape Peninsula University of Technology, Cape Town, South Africa, 2019 *Proceedings of the 27<sup>th</sup> Domestic use of Energy Conference*.

## AUTHOR PROFILE



**Himanshi Koli**, Research Scholar in Power Electronics, Electrical Engineering Department, SGSITS, 23 Park Road Indore-452003. She Received her Bachelor Degree in the Electrical and Electronics Engineering from Chameli Devi Group of Institutions, Indore-452020 in 2016. Her research interests includes power electronics,

power generation analysis, cost and carbon emission reduction analysis, renewable energy analysis, hybrid energy system.



**Prof. M.P.S. Chawla**, Professor-Incharge (head), library, Associate Professor in Electrical Engineering Department, SGSITS, Indore-452003 (M.P.)-India, immediate past chairman, 2017-2018, IEEE M.P. sub-section. He received gold medals in B.E.(Electrical) and M.E.(Power Electronics) degree SGSITS, Indore, India from Electrical Engineering Department in 1988 and 1992, respectively. He is appointed as

Associated Editor in Chief Chair”, on 14<sup>th</sup> december 2018 in Blue Eyes Intelligence Engineering and Sciences Publications, India. His special research interest are in power electronics, devices, intelligence instrumentation, biomedical engineering, signal processing, advanced instrumentation systems, soft computing, higher order statistical techniques and control systems.