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Hybrid Solar PV-Micro-Hydro System for Sustainable Electrification of Remote Communities in Arunachal Pradesh, India

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ABSTRACT

Existence is challenging without power. The load demand indicates the condition or benchmark for that specific zone/region. It is a metric that represents the standard of living. Natural, clean, renewable resources abound in Arunachal Pradesh, particularly in the state's rural areas, where electricity demand remains unmet. This study focuses on resources that could be used to generate small-scale energy to meet the electrical needs of economically disadvantaged rural areas with dispersed populations and low living standards. Field observations, conversations with locals, and other data were gathered throughout the site study to help sketch out a workable off-grid technology. Additionally, the paper addresses barriers to entry, as well as the implications and opportunities that come with sustainable energy technology. It concludes that in areas with lower population densities and remote locations from grid-connected systems, it makes more sense and is more cost-effective to focus on a modest-scale renewable energy system using locally available natural resources.

Keywords: Hydro Energy, rural areas, solar PV, sustainable development

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INTRODCUTION

Electricity is a necessity of life. To narrow the gap between well-being and livelihoods, the only measure is to find the most economical and feasible way. Exploring the renewable resources will encapsulate the difficulties. Renewable resources are an alternative for isolated areas with smaller populations, where off-grid power is more

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economical. Furthermore, the cost of renewable energy (RE) technologies has dropped significantly in recent years, coinciding with a significant decline in the price of electricity produced by wind, photovoltaics (PV), hydropower, and concentrated solar power between 2010 and 2018 (Figure 1). Over 80% of solar photovoltaic (PV) and 75% of wind projects scheduled for commissioning in 2020 will generate energy at a lower cost than any natural gas, coal, or oil option, according to a report from the International Renewable Energy Agency (2019). For low-load power and remote locations, solar photovoltaics (PV) and wind turbines (WT) are the most popular green energy alternatives (Javed et al., 2019; Roberts & Mosey, 2014; St. Croix Tribal Council, 2005). Yet, as demonstrated by a recent work by Fasihi and Breyer (2020), these RE resources' inherent intermittency, volatility, and randomness typically render them unsuitable for direct integration to the grid.

Arunachal Pradesh is one of the 7th northeastern-most states of India. It shares international borders with Bhutan; Myanmar is separated from China in the north by the McMahon Line and the state border with Assam and Nagaland. This state consists of 25 districts, with more districts proposed and in development. Itanagar is the capital of the state. Geographically, it is the largest state among the Northeastern states. Arunachal Pradesh consists of the sub-mountainous and mountainous ranges. With 94% of the area rural, life is scattered across 3,257 villages under the umbrella of 48 integrated rural development blocks. Off-grid generation must be considered to meet electrical demand at a reasonable cost (Rehman et al., 2012). Due to geographical features and current grid restrictions, which make grid extension economically infeasible in many places, it is frequently technically difficult (Nouni et al., 2006). National policy documents commit to the long-term objective of ensuring that everyone has access to clean energy by 2030 and acknowledge that environmental concerns are also very real. They also state that off-grid energy provision is necessary to raise the living conditions of the rural poor (Ministry of Population and Environment, 2016). The lives of the rural can be improved with respect to primary health care and education centres if alternative means, such as the use of more renewable energy, are embedded in people's minds through awareness camps and seminars, or by interacting with the well-being. The people of Arunachal Pradesh are abundant in natural resources, including hydropower, and are among the largest generators of hydropower, but many places remain inaccessible due to dense forests, creating a significant gap in transportation and communication facilities. Some districts, such as East Siang and Lower Subansiri, have been 99% electrified.

Study on the Selected Site

The selected site area has a population of 600 and 150 households, two primary schools, and 10 mini commercial local utility centres. People's livelihoods depend solely on farming. To fulfil the basic requirement, a power plant with a generating capacity of 27 kW is to be installed. The most economically feasible approach is to adopt a hybrid system (Come Zebra et al., 2021). In the current context, research studies emphasise raising awareness

and facilitating access to off-grid renewable energy sources, particularly in isolated regions (Ma & Javed, 2019; Khodayar, 2017). In their evaluation of the importance of remote places, Liu et al. (2019) found that hybrid RES systems can significantly increase off-grid electricity output (Jithendranath et al., 2021). It is important to consider a cost-benefit analysis for energy sector interconnection.

A comprehensive cost-benefit analysis of energy sector interconnection should consider a range of economic, technical, and environmental benefits. These include reductions in the value of lost load, improvements in energy security, and environmental benefits from increased utilisation of cleaner energy sources. Greater interconnection may also enhance competition within the energy sector, potentially resulting in lower electricity prices for consumers. Furthermore, access to interconnected energy systems can defer the need for additional investments in generation capacity required to meet domestic demand. Transmission and distribution costs may also be reduced when lower-cost and geographically closer generation sources are utilised in place of more expensive alternatives. In addition, improvements in power system stability and reliability can contribute to local economic development by supporting commercial activities and essential public services. Reduced electricity expenditure may increase households' and businesses' disposable income, thereby generating positive spillover effects on the local economy, infrastructure development, and public service provision. Moreover, the integration of neighbouring energy markets through enhanced interconnection may stimulate further investment in domestic power generation facilities and strengthen the overall resilience of the energy system.

Objectives of the Study

The installation of small hydropower plants is a growing focus because they are more reliable, have lower environmental impact, and, most importantly, can supply energy at low cost (Patel, 2018). It has been found that a Pico Hydro Power plant can provide power in the most efficient way to small, scattered populations and remote communities that require power only for lighting. Pico-hydro setups are typically run-of-stream, as water runs downhill, it has potential energy that can be captured. The advantages of a steady stream of flowing water over solar and wind power systems are substantial (Islam et al., 2013; Javed et al., 2020). Because Micro-Hydro systems only require a steady flow of water through the turbine, they can operate day or night and in any kind of weather. The objective is to identify un-electrified villages, survey potential renewable energy sources in remote, un-electrified villages where grid connection is not feasible or economical and provide basic household lighting systems to improve the quality of life (Javed et al., 2021).

Identification of Un-Electrified Villages

Still, around the globe, many efforts and steps are being taken by governments, NGOs, and even private firms. Many rural homes lack power, according to government statistics

(as of October 12, 2018) derived from the Saubhagya dashboard. The goal of Saubhagya, which was introduced in September 2017, was to electrify 35 million homes by March 2019. Subsequently, the government announced that it would electrify every home by December 31, 2018, pushing the deadline forward. However, as of October 12, 2018, data from the Saubhagya Dashboard shows that approximately 25-30% of rural households in four states, Uttar Pradesh, Arunachal Pradesh, Nagaland, and Meghalaya, still lack electricity (Indian Express, 2018; Singh, 2016). According to a recent government release, 2,217 villages in India lacked electricity. Arunachal Pradesh made up 1,069, or 48%, of this total. It is important to note that the rugged terrain and the scattered nature of communities across hills and forested areas make comprehensive village electrification appear to be a daunting endeavour (Aquino et al., 2011). In Arunachal, a state with a total land area of 83,743 square kilometres, roughly 82% is covered in dense evergreen forests. Nevertheless, village electrification has accelerated recently, particularly since the announcement of the goal of achieving universal village electricity (Rehman et al., 2012). According to the survey, villages such as Norbing in Lower Subansiri District, Machang in Papumpare District, Sijirarkhsap in West Siang District, and Lokpeng in East Siang District are yet to be electrified. Dwellings in a cluster of disconnected, unelectric homes, images taken during the research fieldwork for the site study, are shown in Figures 1 and 2.



Figure 1. Unelectrified village of Norbing, District- Lower Subansiri. Circle –Raga



(a) (b)

Figure 2. Unelectrified at (a) Sibe village, Lower Siang and (b) Sijirarkhsap village of West Siang

METHODOLOGY

The analysis was done in Sibe village (under Gensi circle) in Lower Siang district of Arunachal Pradesh, India. It is located about 60 km away from the main state road and about 40 km from the last electrified point. The study area is administered by the Circle Officer (CO). Most of the population belongs to the Galo tribe community. Solar irradiance data were obtained from a survey conducted in the study area and surrounding regions, and the river flow rate was calculated from it.

Energy Demand Estimation

The total electrical demand for the study area is estimated based on the community's actual needs and divided into categories such as domestic, commercial, and community, as shown in Table 1. The LED-based lighting scheme is considered in the analysis due to its advantages over incandescent and CFL lamps. The power demand is estimated for the average daily demand of the entire village, which is about 270100 watts. The daily energy demand profile is shown in Table 2.

Table 1
Number of lights/ fans/tv/computer

Sl. No.	Quantity	No. of Lights	No. of Fans	No. of Computers
	Residential	300	300	Nil
	Shop	10	10	Nil
	School	20	20	8

Table 2
Estimated daily energy demand profile

Serial Number	Category and Sector (with Quantities) of Load	Appliance	Hours/ Day	Rating (W)	No. of Points (in Each House)	Total No. of Points	Wattage
1	Domestic:						
	Households (150)	LED lamp	5	12	2	300	3600
		Fan	6	45	2	300	13500
		TV	6	70	1	100	7000
2	Commercial:						
	Shops (10)	LED lamp	4	12	1	10	120
		Fan	6	45	1	10	450
3	Community:						
	School	LED lamp	4	12	10	20	240
		Fan	6	45	10	20	900
		Computer	4	150	4	8	1200

Resource Estimation

Arunachal Pradesh is hilly and rich in renewable energy sources such as hydropower and solar power. To estimate the potential of the sources, an extensive survey was conducted in the study area and surrounding regions. According to Synergy Environ Engineers (Indian Express, 2018), the average global solar radiation on a horizontal surface is 4.01 kWh/m^2/day, with a peak of 4.5 kWh/m^2/day in May and a minimum of 3.39 kWh/m^2/day in January. Table 3 shows the daily isolation corresponding to the clearness index of the study area. The village also has many streams that flow year-round, and the flow rate of each stream has been determined using the conventional flow-meter method; therefore, a micro-hydro power plant has been considered in addition to the solar PV system.

Table 3
Solar radiation and clearance index

Sr. No.	Month	Monthly Average Daily Solar Radiation (kWh/m^2/day)	Clearness Index
1	January	3.39	0.53
2	February	3.46	0.51
3	March	3.65	0.57
4	April	4.03	0.53
5	May	4.50	0.57
6	June	4.03	0.49
7	July	3.88	0.33
8	August	4.20	0.41
9	September	4.20	0.22
10	October	4.17	0.51
11	November	4.07	0.29
12	December	3.65	0.54

CONCLUSION

A study has been conducted to evaluate the economic and technical feasibility of combining a micro hydropower plant with a 27-kW integrated solar PV power plant to meet the energy needs of Sibe village in the Gensi circle of Arunachal Pradesh's Lower Siang district. The PV system consists of 60 PV modules, with two connected in series and 30 such series-connected in parallel, three 2400W inverters, and a 2285 Ah battery bank. A centralised battery bank and inverter are connected to the PV modules. The PV system can generate 77.67kWh of energy daily. A 15 kW micro-hydro power plant, along with the PV system, has been analysed to meet the total demand for basic well-being needs.

Thus, most villages with small, scattered populations can be electrified using available renewable energy. Resources are readily available, but due to a lack of transportation and unexplored areas, they cannot utilise the full range of available resources uniformly, leading

to a non-uniform standard of living. Hence, with proper planning and the selection of renewable resources, improvements in their lifestyles and healthcare will be facilitated, which are among the basic and foremost requirements for a healthy life. Exploring more small-scale renewable power plants will be the primary driver to eradicate differences based on geographical region or zone and bring 100% electrification to every corner of the people, regardless of the geographical region or population.

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