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Techno Economic Feasibility Assessment for Optimizing Micro grid System in Islanded Mode of Operation

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ABSTRACT

To address the power demand in the rural area of Ramanujganj, Chhattisgarh, micro grid systems have emerged as a significant solution. These systems combine two or more renewable energy sources, offering a promising approach to meeting energy needs sustainably. Conducting a techno-economic analysis of such micro grid systems is crucial for maximizing the efficient use of renewable energy sources. This study focuses on preparing a site survey report for the designated location, which includes assessing the actual load demand, existing load, solar radiation levels, and hydro resources. Based on the findings from this survey, two types of micro grid renewable energy systems—PV/DG and PV/Hydro—are explored for application in the rural area. The simulation of these micro grid systems is carried out using HOMER Pro software. Various economic parameters such as Net Present Cost (NPC), Cost of Energy (COE), fuel consumption, electricity production, carbon emissions, and payback period are assessed for both proposed micro grid systems. The results of the analysis indicate that the PV/Hydro system is the most suitable option for meeting the electricity demand in the rural area.

Keywords: Micro grid System; Net present cost (NPC); Cost of Energy (COE); CO_2 Emission; Annual cost.

1. Introduction:

The demand for electricity is on the rise, driven by increasing living standards, industrial development, agricultural production, and overall national progress. However, despite these advancements, many areas have remained in darkness for several decades [1]. One such area is Ramanujganj, situated in the Balrampur district of Chhattisgarh, India, as depicted in Figure 1 on the world map, positioned between 24O 2.3’ N latitude and 83O 17.9’E longitude. This village serves as a case study in our analysis. To address the energy needs of Ramanujganj, we have developed a simulation model utilizing Micro grid PV/Hydro and PV/DG configurations, employing HOMER Pro software version 3.8. We present an economic feasibility analysis of these proposed systems and compare their potential for power generation in the identified rural location.

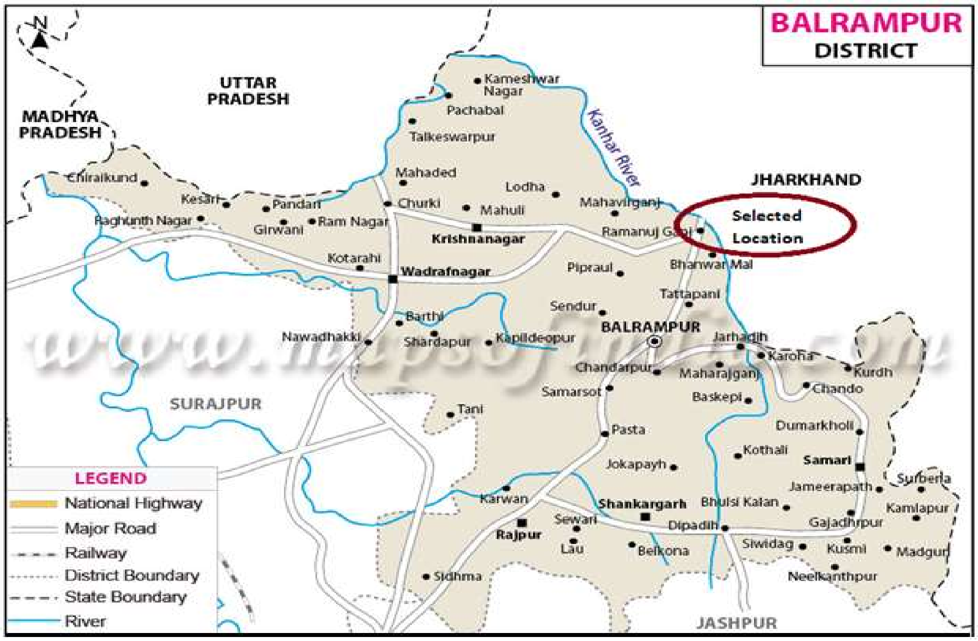

Figure 01:-Map of (Surguja)Chhattisgarh showing selected location

2. Site Survey Report:

Conducting a thorough survey of the selected rural area is essential for assessing the techno-economic feasibility of the proposed micro grid power generation unit. Key factors taken into account for installing PV/Hydro and PV/Diesel systems include estimating the load, solar radiation, and hydro resources, specifically the flow rate of water.

2.1. Load Estimation- The houses present in selected are of the town are 100. The average number of family members is 5. The total population of village is 500. Table-1 presents the load estimation of selected rural areas.

Table 1 – Load estimation

Rural Area	Actual Existing Load	Required Load as Per Survey
Location (Tendua)	2 kW	10 kW

2.2. Natural resources-

The solar radiation data, hydro flow rate data from the Kanhar River, and wind sources are acquired from NASA (National Aeronautics and Space Administration). Monthly solar radiation data are provided in Table 2, and a graphical representation of the solar resources available in the surveyed zone is depicted in Figure 2, based on the survey data.

Table 2: Solar radiation data of Tendua location

Month	Radiation Data	Clearness index
Jan	5.66	0.798
Feb	6.38	0.783
March	6.24	0.661
April	5.83	0.557
May	5.24	0.477
June	4.44	0.399
July	3.32	0.301

Aug	3.30	0.311
Sept	4.05	0.415
Oct	5.06	0.658
Nov	6.13	0.838
Dec	5.82	0.863
Average	**5.12**	**0.588**

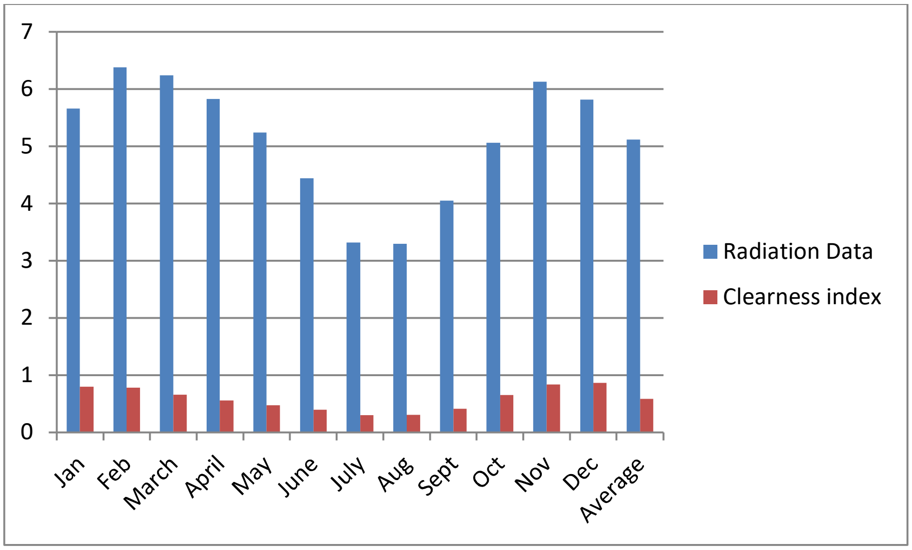

Figure 2:-Solar Resources at Selected location

The survey report provides concise details regarding the solar energy source and micro-hydro energy distribution in Balrampur district, particularly at Tendua locations. This information aids in the development of a micro grid renewable energy system comprising both hydro and solar sources, which are continuously replenished.

3. Simulation of Proposed System:

In this section, based on the survey report conducted for the rural site and considering the availability of solar radiation and water sources, a simulation model of a microgrid system is created using HOMER Pro. The objective is to design a system capable of meeting the power needs of the remote area as indicated by the survey report specific to Balrampur District. Additionally, cost optimization is carried out in HOMER software for both the PV/Hydro and PV/Diesel systems. The required load for the site is 10 kW.

An autonomous micro grid renewable energy system is devised, with separate models developed for micro grid PV/Hydro and PV/Diesel configurations, illustrated in Figure 3 and Figure 4, respectively. Tables 3 and 4 present the architectural parameters for the PV/Hydro and PV/Diesel systems, respectively

Table 3:- System Architecture of MG-01 (PV/Hydro)

Component	Name	Size	Unit
PV	Generic flat plate PV	10	kW
Storage	Generic 1kWh Lead Acid	52	string
System Converter	System Converter	3	kW
Hydroelectric	Generic Hydro 100kW	98	kW
Dispatch Strategy	HOMER Cycle Charging	-	-

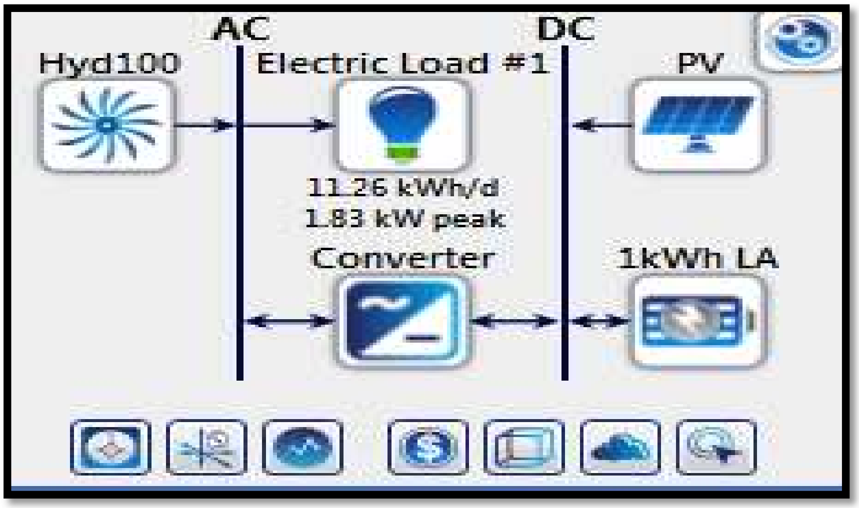

Figure 3:- Energy Model of Microgrid-01(PV/Hydro) systems

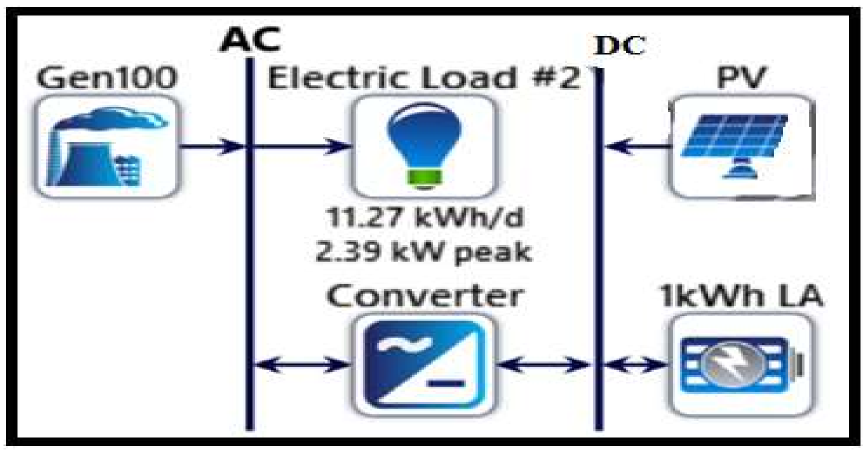

Figure 4:- Energy Model of MicrogridPV/Diesel systems

Table 4:- System Architecture of MG-02 (PV/Diesel)

Component	Name	Size	Unit
PV	Generic flat plate PV	10	kW
Storage	Generic 1kWh Lead Acid	52	string
System Converter	System Converter	3	kW
Diesel Generator	Generic 100kW	98	kW
Dispatch Strategy	HOMER Cycle Charging	-	-

3.1. Component Description

To assess system performance under various scenarios, HOMER simulates the aforementioned two setups in the same location and with the same load, considering different cost factors including installation, operation and maintenance, replacement, interest, and energy costs [2,3]. The primary components of the microgrid system comprise a hydro generator, diesel generator, PV array, battery bank, and power converter. For the techno-economic analysis, Table 5 displays the parameters utilized for power generation units, converter systems, and storage systems.

Table 5:- Components details for the MG-01 & MG- 02renewable energy system

Components	Type	Efficiency	Lifetime	Installation Cost	Operation & Maintenance Cost

PV Array	Generic flat plate	25%	25 years	65000 Rs per KW	3000 Rs
Converter	System Converter	92%	20 years	16000 Rs	1000 Rs
Battery Storage Bank	CELLCUBE FB10-40	64%	10 years	15660 Rs	2400 Rs
Hydro	Hydro Generator	70%	15 Years	99999 Rs per KW	3000 Rs per KW/hr
DG	Diesel Generator	70%	25 Years	64000 Rs per KW	2000 Rs per KW/hr

4. *Simulation Output:*

The implemented model, supported by accurate data, yields three types of results. Firstly, it provides equipment sizing information; secondly, it conducts system analysis regarding production and capacity; and thirdly, it offers optimized outputs for electricity production analysis for both the PV/Hydro and PV/Diesel systems. This section presents the optimized combinations of power production analysis for both systems, as detailed in Tables 6-8. The analysis primarily focuses on maximizing power production rather than cost optimization, which will be discussed in the results section for all proposed systems at the Tendua locations where the survey was conducted. The optimization results presented demonstrate total production, architectural details, total consumption, and system capacity. The consumption summary remains consistent across all three proposed systems, as the site load remains unchanged.

Table 6:-Electrical Summary

Electrical Summary	**MG-01 (PV/Hydro)**		**MG-02 (PV/Diesel)**	
Quantity	**Value**	**Units**	**Value**	**Units**
Excess Electricity	12,388	kWh/yr	11,300	kWh/yr
Unmet Electric Load	3.98	kWh/yr	3.08	kWh/yr
Capacity Shortage	4.08	kWh/yr	4.09	kWh/yr

Table 7:- Production Summary

Production Summary	**MG-01 (PV/Hydro)**	**MG-02 (PV/Diesel)**
Component	**Production(kWh/yr)**	**Production(kWh/yr)**
Generic flat plate PV	17,874	16,510
Total	17,874	16,510

Table 8:- Consumption Summary

Component	**Consumption(kWh/yr)**	**Percent**
AC Primary Load	4,220	100
DC Primary	0	0
Deferrable Load	0	0
Total	4,110	100

5. *Techno Economic Model*

The economic model is integral to the functionality of HOMER, aiming to minimize system operation costs and determine the most efficient system configuration [4,5]. Economics play a vital role in this simulation, with the optimal combination of components in a Hybrid Energy System (HES) determined based on the Net Present Cost (NPC). These metric accounts for all costs and revenues over the project's lifespan. In the context of the Tendua rural location, the implemented model utilizes accurate data to conduct optimization analysis. Three distinct energy models are simulated in HOMER Pro for the designated site, guided by the survey report. The optimized outcomes are derived for standalone PV, as well as for the microgrid systems PV/Hydro and PV/Diesel at the Tendua site. While the electricity production and capacity details have been previously outlined in Chapter 4 for all three systems, this section focuses on cost analysis, providing a comprehensive comparison of their economic aspects. The results encompass equipment sizing, Total Net Present Cost (TNPC), initial investment, fuel expenses, operation and maintenance costs (O&M), as well as total fuel consumption. Through the comprehensive cost analysis of the three models, an economically viable system meeting the load demand (production capacity) is recommended for the selected Tendua site.

5.1 Optimized Cost analysis of Microgridsystem (Hydro/PV)

The microgrid system is composed of a hydro generator, PV panels, LA battery, converter, DC bus, AC bus, and load. To meet the year-round load demand, a meticulously optimized microgrid system is proposed for the site, based on findings from the survey report [6,7]. The optimization process is conducted using HOMER, and Table 4.9 outlines the electricity production and capacity of the microgrid system independently for the remote area. Additionally, the overall cost-optimized results are summarized in Tables 9 and 10. Figures 5 and 6 depict the Net Present Cost (NPC) and annual cost analysis specifically for the Tendua Site microgrid system. It is noted that the NPC stands at 701,938 Rs, with an annual cost of 54,298 Rs.

Table 9- Optimized Net Present Costs of MG-01 in Rs.

Name	Capital	Operating	Replacement	Salvage	Resources	Total
Generic 1kWh Lead Acid	15,600	6,722	13,782	-1,869	0.00	34,235
Generic flat plate PV	27,045	1,398	0.00	0.00	0.00	28,444
Generic Hydro 100kW	459,845	178,335	0.00	0.00	0.00	638,180
System Converter	802.78	0.00	340.60	-64.10	0.00	1,079
System	503,293	186,456	14,122	-1,933	0.00	701,938

Table 10- Annualized Costs of MG-01 System in Rs.

Name	Capital	Operating	Replacement	Salvage	Resource	Total
Generic 1Kw Lead Acid	1,207	520.00	1,066	-144.54	0.00	2,648
Generic flat plate PV	2,092	108.18	0.00	0.00	0.00	2,200
Generic Hydro 100kW	35,571	13,795	0.00	0.00	0.00	49,366
System Converter	62.10	0.00	26.35	-4.96	0.00	83.49

System	38,932	14,423	1,092	-149.50	0.00	54,298

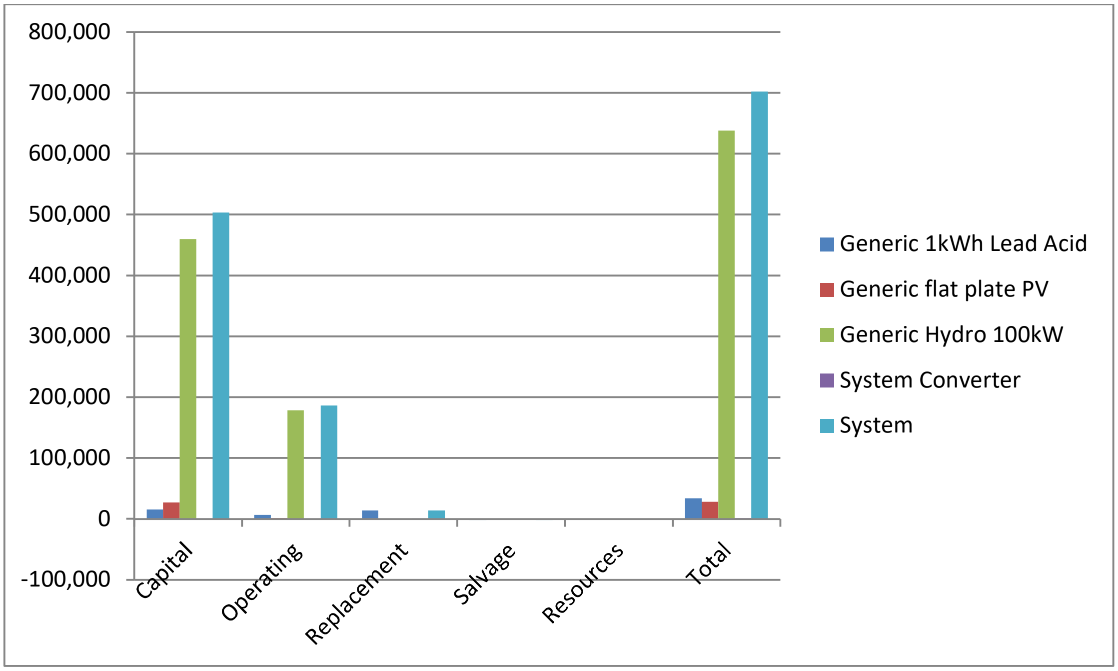

Figure 5 Total NPC of MG-01 System

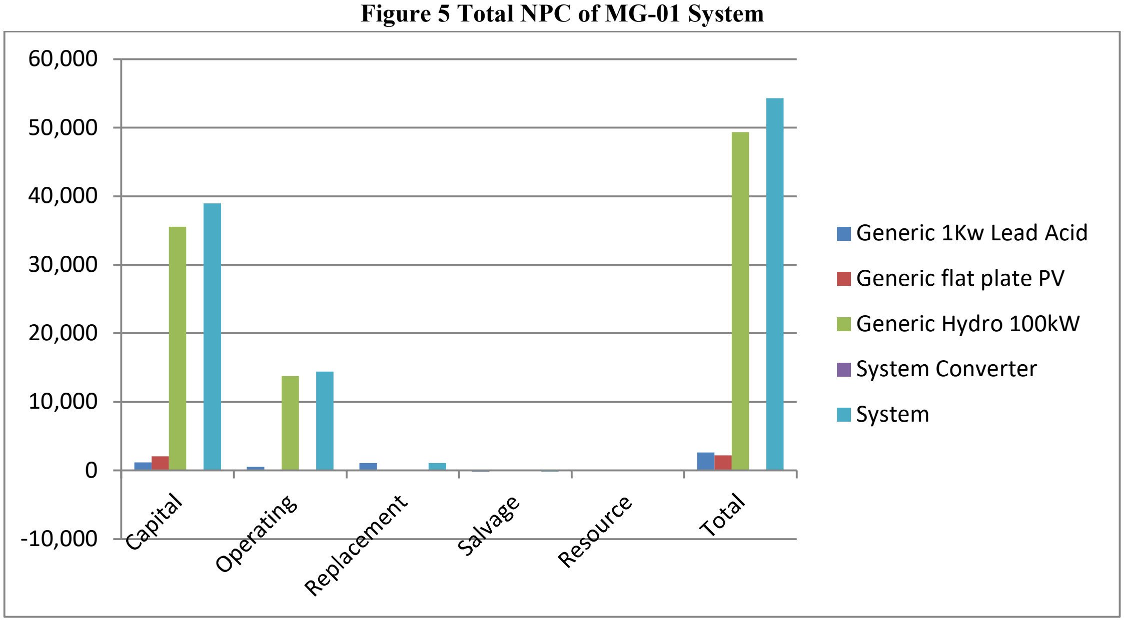

Figure 6 Total Annualized Costs of MG-01 system

5.2 Optimized Cost analysis of Microgridsystem (PV/Diesel)

The microgrid system comprises a hydro generator, PV panels, LA battery, converter, DC bus, AC bus, and load. To meet the year-round load demand, a thoroughly optimized microgrid system is proposed for the site, based on insights from the survey report [8,9]. Optimization is conducted using HOMER, and Table 4.8 presents the electricity production and capacity of the microgrid system independently for the remote area. Additionally, the overall cost-optimized results are detailed in Tables 11 and 12. Figures 7 and 8 illustrate the Net Present Cost (NPC) and annual cost analysis specifically for the Tendua Site microgrid system. It is noted that the NPC stands at 63,850 Rs, with an annual cost of 4,939 Rs.

Table 11- Optimized Net Present Costs of MG-02 in Rs.

Name	Capital	Operating	Replacement	Salvage	Resource	Total
Generic 1 KWH lead acid	Rs 16,800	Rs 7,239	Rs 14,842	-Rs 2,012	Rs 0.00	Rs 36,869
Generic flat plate PV	Rs 24,577	Rs 1,271	Rs 0.00	Rs 0.00	Rs 0.00	Rs25,848
System converter	Rs 843.31	Rs 0.00	Rs 357.79	- Rs 67.34	Rs 0.00	Rs 1,134
System	Rs 42,220	Rs 8,510	Rs 15,200	-Rs 2,080	Rs 0.00	Rs 63,850

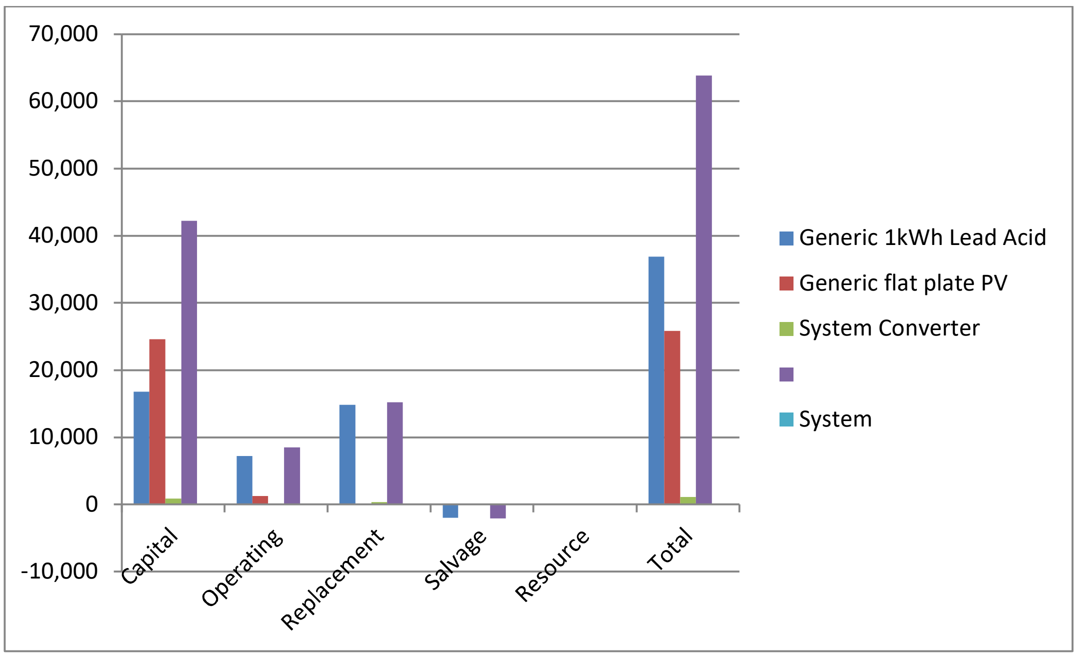

Figure 7 Total NPC of MG-02 System

Table 12- Annualized Costs of MG-02 in Rs.

Name	Capital	Operating	Replacement	Salvage	Resource	Total
Generic 1 KWH lead acid	Rs 1,300	Rs 560.00	Rs 1,148	- Rs 155.66	Rs 0.00	Rs 2,852
Generic flat plate PV	Rs 1,901	Rs 98.31	Rs 0.00	Rs 0.00	Rs 0.00	Rs 1,999
System converter	Rs 65.23	Rs 0.00	Rs 27.68	- Rs 5.21	Rs 0.00	Rs 87.70

system	Rs 3,266	Rs 658.31	Rs 1,176	Rs 160.87	Rs 0.00	Rs 4,939

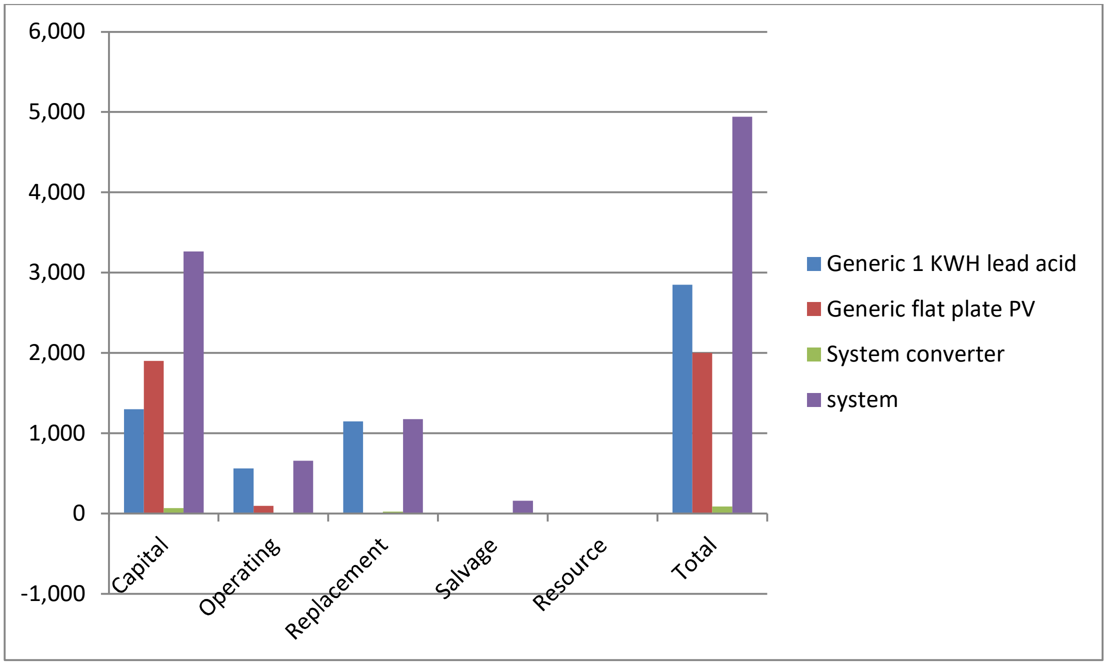

Figure 8 Total Annualized Costs of MG-02 system

5.3. Comparative Economic Analysis:

The primary source of power generation in Chhattisgarh is currently reliant on thermal units, but even this established solution faces growing concerns. With the availability of coal and the resulting CO2 emissions posing significant threats to the power sector, there is an urgent need to adopt alternative energy solutions. The country's economy is heavily impacted by electricity crises and energy resource limitations. To reduce dependency on conventional sources and decentralize the power system, Renewable Energy Technologies (RET) could play a crucial role. There are numerous locations and opportunities to establish Renewable Energy Source (RES) based power plants, which could effectively address India's major electricity challenges.

In this study, through analysis and development, an autonomous microgrid renewable energy system power plant is proposed as a better solution for developing sustainable energy solutions in rural India. An economic feasibility analysis of all three proposed systems is conducted using HOMER Pro for the Thrishuli site to meet the electricity demand of the rural area. The system best suited to meet the electricity requirement of Tendua village is recommended. A comparative cost analysis is performed, as depicted in Figure 10, where the Net Present Cost (NPC), Cost of Energy (COE), operating cost, initial investment, and fuel expenses are individually compared for all three proposed systems in the rural area (Tendua). The overall cost of the microgrid system (PV/Hydro) falls between that of the standalone PV system and the PV/Diesel System, approximately amounting to 1,111,832 Rs. Based on production capacity and overall cost, the PV/Hydro microgrid system emerges as the most feasible option for Tendua village.

Table 13- Compare Economics Payback of Proposed System

Parameters	PV/Hydro (Microgrid-01)	PV/Diesel (Microgrid-02)
IRR (%)	13.5	NA
Discounted payback (yr)	9.59	5
Simple payback (yr)	9.28	5.3

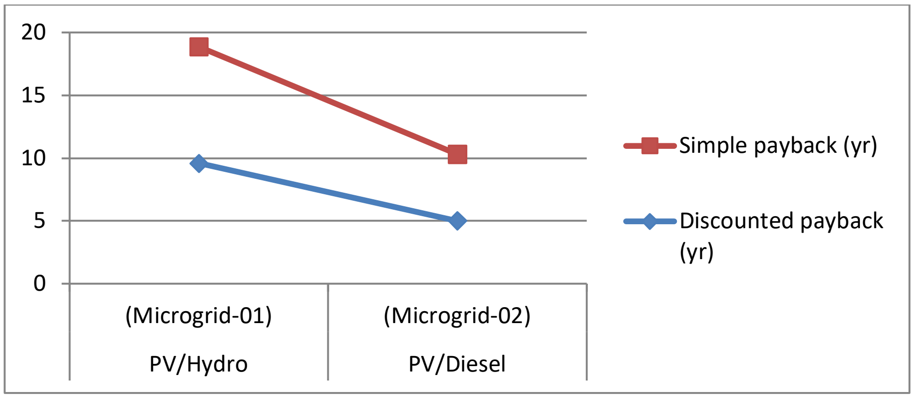

Figure 9 Payback Period of Proposed System

Table 14- Economic Comparison of Proposed Systems in Rs.

MG system/Parameter		Net Present Cost	CAPEX	OPEX	LCOE (per kWh)	CO2 Emitted (kg/yr)	Fuel Consumption (L/yr)
PV/Hydro (MG-01)	Base Case	705,658	505,408	17,563	12.52	0	0
	Current Case	703,839	509,392	16,639	13.35	0	0
PV/Hydro (MG-02)	Base Case	1,700,000	41,000	118,326	24.39	207,076	80,935
	Current Case	69,508	42,560	1,356	1.03	0	0

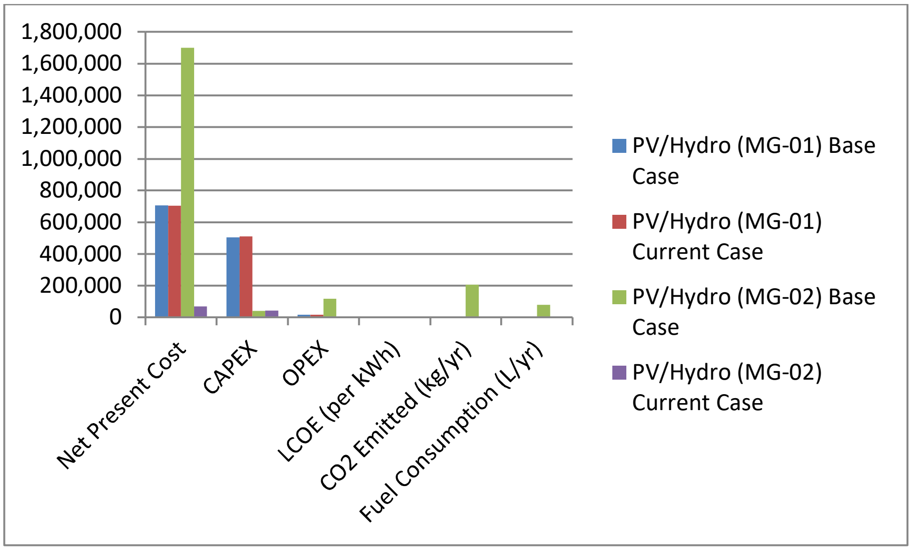

Figure: 10 Optimized comparative cost analysis of proposed system

4. *Conclusion*

In this study, simulation, modeling, and optimization were employed to devise a microgrid off-grid power system tailored to meet the electric demands of Thrishuli village, aligning with the available resources. The microgrid power system encompasses two power generation units: a standalone solar PV system for the proposed site (PV alone), as well as PV-hydro and PV-diesel systems integrated with batteries and inverters. Input data regarding primary loads, solar resources at both sites, technology options, component costs, constraints, and controls were gathered through surveys. Simulation and optimization analyses were conducted to evaluate the performance and cost-effectiveness of the proposed microgrid system. The findings indicate that the standalone solar PV system adequately caters to the household requirements at the Tendua site. Meanwhile, the solar PV/hydro generator/battery/inverter power system satisfies the annual electrical demand of the selected 95 houses. Among the proposed configurations, the PV/hydro, battery/inverter microgrid system emerges as the optimal choice for power generation when compared to the PV/diesel/inverter, generator/battery/inverter, and generator-only setups. This option exhibits the highest penetration of renewable resources (with a renewable fraction of 100%), the lowest levelized cost of energy (1,111,832 Rs.), and zero carbon dioxide emissions.

The monthly average electric production of the photovoltaic and hydro components totals 35% and 70%, respectively, contributing to the overall net present cost (NPC), capital cost, and cost of energy for the system. Notably, the total net present cost of the PV/hydro system is lower compared to alternatives, amounting to 703,856 Rs. in the base case and 701,938 Rs. in the current system. Based on the optimized results obtained across all three systems for the proposed site, the PV/hydro microgrid system emerges as the most viable solution for fulfilling electricity demands in remote areas, with a lower total NPC.

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