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REVIEW: NEED OF HYBRID SYSTEM FOR OFF GRID RURAL ELECTRIFICATION

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Abstract:
Hybrid power is the result of combining different technologies to produce energy. The term 'hybrid' in power engineering refers to a power and energy storage system that is integrated. Typically, hybrid systems involve the integration of renewable energy technologies, such as wind turbines and solar photovoltaic (PV) cells. These systems offer a high level of energy security by combining multiple modes of electricity generation, and often incorporate energy storage systems like batteries or fuel cells, as well as fossil-fueled generators to ensure a reliable and secure power supply. This review paper delves into a comprehensive analysis of over 40 research papers, extracting their strengths, weaknesses, and common findings. The results highlight the pressing need for hybrid systems in India.

Keywords: Hybrid, Off Grid, Rural, Electrification

Literature Review:

The common findings extracted from the review of research papers are presented in point form which are as follows:

- Most of the researchers have been used Homer Software for analysis and optimization.
- A total installed capacity of 838 MW was found for biomass-based power generation, including bagasse and non-bagasse cogeneration and biomass gasifiers. Bagasse fired boilers account for the majority of this capacity at 692.3 MW.
- Biomass-based power plants are a better investment and operational cost option compared to centralized power stations if they operate with a plant load factor of at least 70% in whole year.

- Biomass-based power plants with a plant load factor of over 70% and year-round operation demonstrate comparable performance to centralized power stations with respect to investment and operational costs.
- Annually, India generates 686 million tonnes of gross crop residue biomass, out of which an estimated surplus of 234 million tonnes (34% of gross) is available for energy generation.
- Remote villages in India are consistently supplied with electricity for lighting for 4-5 hours by renewable isolated power plants with a capacity of 1-20 kW.
- The cost of generating electricity from Small Wind Electric Generation (SWEG) projects with a capacity of 3.2 kW at locations with an annual mean wind speed of 6-10 m/s is estimated to be in the range of Rs. 12.77-27.96/kWh.
- Micro hydropower (MHP) is a renewable energy technology that is widely regarded as one of the most viable and promising solutions for rural electrification in Nepal. This is because MHP is relatively easy to manage and operate, and it is cost-effective, making it an attractive option for many communities in Nepal. Additionally, there are several other renewable energy technologies (RETs) available, but MHP is a popular choice due to its simplicity and cost-effectiveness.
- Nepal has a significant potential for electricity generation, with an installed capacity of 1786 MW and over 6000 MW of undeveloped hydropower potential. However, access to electricity in rural areas is limited, with only 2.2% of the population having access, and 78% of the population living in poverty.
- Hybrid energy systems are capable of utilizing a combination of energy sources to provide reliable electricity in off-grid situations, which can significantly reduce the total life cycle cost of stand-alone power supplies. This means that rather than relying on a single energy source, a hybrid energy system can use multiple sources, such as solar, wind, and diesel generators, to provide a more consistent and reliable power supply. By using a combination of energy sources, the hybrid system can also optimize energy production based on the availability of each energy source and the specific energy needs of the location. Ultimately, hybrid energy systems offer a cost-effective and sustainable solution to providing reliable electricity in off-grid locations.
- Analysis indicates that the levelized cost of electricity from diesel and photovoltaic sources is $0.62/kWh and $0.33/kWh, respectively, which is higher than the amount Liberians are willing to pay.
- According to the analysis, the cost of generating electricity from diesel and photovoltaic sources is $0.62/kWh and $0.33/kWh, respectively. However, these costs are higher than what Liberians are willing to pay.

2.3 Comparative Analysis of Research Work Reviewed

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Various authors have considered precision, recall, and accuracy as the performance evaluation parameters. This section presents the solutions and methodologies used by the researchers for each issue, along with the results displayed in Table 2.3 below.

Table: Comparison on the basis of Literature Review

S. No	Author Name and year	Type of system	Input							Output				
			Tools	Location	Latitude(N) & Longitude (E)	Resources				MHP	SPV	Wind	Biomass	Cost of energy
						MHP	SPV	Wind	Biomass	MWh /yr	MWh/ yr	MWh /yr	MWh /yr	($/kW h)
1	K.R. Jyothy 2017	Hybrid	Homer	--	--	--	Y	--	--	--	3700-5000	--	--	--
2	J. A. Weber 2016	Hybrid	Homer	--	--	--	Y	Y	--	--	1825	1759	--	0.47
3	B. J. Saharia 2015	Hybrid	Homer	Guwahati	26.13 N & 91.66 E	--	Y	Y	--	--	8760	2372	--	0.53
4	H. E.Khashab 2015	Hybrid	Homer	Yanbu, Saudi Arabia	24.02 N & 38.19 E	--	Y	Y	--	--	6261	2726	--	0.44
4	M.S. Adaramola 2014	Hybrid	Homer	Nigeria	9.52 N & 8.54 E	--	Y	--	--	--	685	--	--	0.41
5	H. Borthanazad 2013	Hybrid	--	Malaysia	4.21 N & 101.97 E	Y	Y	Y	--	2091	1509	1414	--	0.52
6	S. Mahapatra 2012	Decent ralized	Homer	South Asia	2.21 S & 115.66 E	N	Y	--	Y	--	565787	--	83790	0.44
7	S. Singh 2013	Decent ralized	--	Rural area of N-W	--	--	--	Y	Y	--	--	17000	5000	0.55
8	R. Sen 2013	Off grid	Homer	Chhattisgarh	21.29 N & 81.82 E	Y	Y	--	Y	106649	34439	--	25294	0.49
9	M. Ranjeva 2012	Hybrid	HYPO RA	Rural area	--	--	Y	Y	Y	--	1625	849.8	402	0.61
10	S.C. Bhattacharya 2011	Hybrid	Homer	--	--	Y	Y	Y	--	5	25.5	10	50	0.45
11	A.L. Hossain 2010	Decent ralized	Nasa & Homer	Dinajpur	25.3 N & 91.9 E	Na	Y	Y	--	--	23413	18323	--	0.47
12	S.K. Nandi 2010	Hybrid	Homer	Bangladesh	21.51 N & 92.85 E	--	Y	Y	N	--	53317	89151	--	0.46
13	K. voorspools 2009	On Grid	Homer	--	--	--	--	Y	--	--	--	1000	--	0.67
14	S.K. Nandi 2009	Hybrid	Homer	Kutubdia Island	21.81 N & 91.85 E	--	Y	Y	--	--	1275	1060	--	--
15	R.B. Hiremath 2008	Decent ralized	Lindo	Karnataka	15.31 N & 75.71 E	--	Y	Y	Y	--	14000	50	1900	0.5
16	A.K. Akella 2005	Off grid	Lingo	Uttrakhand	29.38N & 79.29E	Y	Y	Y	Y	293040	12859	8890	198556	0.38
17	S. Rana 1997	Off Grid	--	Madhya Pradesh	22.97 N & 78.65 E	--	Y	Y	--	--	7891	2678	--	0.47

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Strengths and Weaknesses of the reviewed area:

After, the review of more than 40 research papers the strengths and weaknesses of various solution approaches of various methods used by different authors were listed as:

Strengths

- The cost of the energy of the model using LINDO software was decreased to 0.65Rs/kWh compared to the cost of energy using HOMER software. (6)
- The most cost-effective and reliable system was found to be scenario 4 (MHP-Biomass-Biogas-Energy Plantation-Wind-SPV). (5)
- Utilizing the full potential of biogas and meeting the remaining demand with biomass or PV technologies results in a lower per unit electricity cost. (27)
- Biomass-based power plants with plant load factors exceeding 70% operating year-round can perform comparably to centralized power stations in terms of investment and operational costs.
- Solar PV power, despite not providing enough electricity for cooking or machinery, was found to increase worker presence in health clinics and schools and is a promising potential solution for rural electrification due to several reasons, including its current technology and cost.
- Wind penetration improves the system voltage profile in distribution system but power increases due to grid code requirements in large scale wind farm.
- The Micro Hydro Power (MHP) scheme is one of the most promising indigenous technologies to bring electricity to rural areas in Nepal, thanks to its simplicity, cost-effectiveness, and ease of management and operation. Other renewable energy technologies (RETs) also show potential.
- The Renewable Energy Fund (REF) has benefited from increased financing and private sector involvement in rural electricity supply systems, thanks to liberalization and a supportive legal framework.
- Hybrid energy systems can offer a cost-effective and reliable solution for stand-alone power supplies in off-grid situations by combining different energy sources.
- A successful approach to rural electrification in some areas has been to develop local grids first and then integrate them, using appropriate small-scale systems that can be upgraded or connected to create a regional network, thus creating demand.

Weaknesses

- The cost of the energy of the model using HOMER software was increased to 2.63Rs/kWh compared to the cost of energy using LINDO software.(6)
- Some hurdles in rural electrification such as Low loads and low capacity utilization, high transmission and distribution losses, CO2 emission etc.
- Providing a reliable electricity service with solar PV power stations poses limitations, especially when compared to fossil fuel-based rural electrification programs.

- In decentralized PV rural electrification, the battery is considered the most expensive component (at 19.5% of the cost) compared to the PV module (at 17.5% of the cost).
- A Constant Power Factor is more suitable than a Constant Voltage target for wind farms as it can optimize network operations, such as power quality.
- It is difficult and unlikely to connect rural areas to the national electricity grid due to various factors such as the geographical remoteness of these areas, scattered consumers, high supply and maintenance costs, low consumption levels, and low household income levels.
- Even though PV hybrid systems are more complicated than using a single energy source, they have the potential to fulfill the electricity requirements of rural areas in a cost-effective manner, despite difficulties such as determining the appropriate system size and incorporating PV energy into the load.

Findings from the review:

- In India, the total installed capacity of biomass-based power generation is 838 MW, which includes bagasse and non-bagasse cogeneration and biomass gasifiers. The majority of this capacity, about 692.3 MW, is through bagasse-fired cogeneration, which has some inefficiencies and CO2 emissions.
- However, biomass-based power plants that operate throughout the year with a plant load factor exceeding 70% are feasible and could perform comparably to centralized power stations in terms of investment and operational costs.
- India produces a large amount of gross crop residue biomass, with an annual output of 686 million metric tons. Out of this, 234 million metric tons, or about 34%, are estimated to be surplus for energy generation.
- Moreover, in remote areas of India, many renewable isolated power plants with capacities of 1-20 kW consistently provide electricity mainly for lighting for 4-5 hours.
- • Small Wind Electric Generation (SWEG) projects which are running on mean wind speed of 6-10 m/s annually with a capacity of 3.2 kW can provide electricity at a levelized cost of Rs. 27.96-12.77/kWh.
- • Micro hydropower (MHP) is a renewable energy technology that is highly promising for rural electrification in Nepal. It is preferred among other renewable energy technologies (RETs) due to its simplicity in management and operation, cost-effectiveness, and ease of use.
- India has the potential to generate a large amount of electricity, with an installed capacity of 1786 MW and undeveloped hydropower potential exceeding 6000 MW. Despite this potential, only less than 3% of rural areas have access to electricity, leaving a large portion of the population, roughly more than 75%, in poverty.
- • Hybrid energy systems are a type of power system that combines multiple energy sources to provide reliable electricity in off-grid locations. By integrating different sources of energy, such as solar and wind, hybrid systems can provide a more stable and cost-effective

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solution compared to traditional stand-alone power supplies. These systems have the potential to reduce the overall life cycle cost of providing electricity in off-grid locations.

- • An analysis has shown that the levelized cost of electricity from diesel and photovoltaic sources is higher than Liberians' willingness to pay, making it challenging to provide affordable electricity using these sources in Liberia.Researchers mostly focused on calculating losses and performance analysis based on geographical location and orientation separately.
- Researchers mostly focused on hypothetical system rather than working on some real installed system. Multiple parametric variations were not applied in the reviewed papers.

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