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Study Social Characteristics of Estimate Electrical Load

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Abstract: Over 1.5 billion people in the world today are still without access to electricity with many of them living in rural and remote areas that are far away from the national main grid. First, an examination of the issues surrounding microgrids for rural electrification is carried out with a major focus on the sustainability challenges. Informed by this examination, the important factors to consider when evaluating sustainability are presented and an easy-to-use sustainability evaluation tool kit is proposed and tested against three microgrid projects. This approach utilizes "Mixed Integer Linear Programming (MILP)" to optimally size the PV microgrid and the "Density Based Spatial Clustering of Applications with Noise (DBSCAN)" algorithm to aggregate load and meteorological data. MATLAB software is used to execute the optimization algorithm. The critical elements that have to be considered when designing microgrids for rural communities are addressed with the aim of reducing the overall cost of electricity.

Keywords: Social, Electrical Load, Microgrids, Electricity, Power

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INTRODUCTION

Microgrid is an emerging power system which consists of different types of interconnected DERs such as photovoltaic (PV), wind, fuel cell, battery energy storage (BES) systems etc. It has shown a paradigm shift from conventional power system to this emerging technology with less pollution or carbon footprints reducing the consumption of fossil fuels which will be exhausted in near future. In the evolution of this technology, it has been observed that maintenance of power quality is a fundamental challenge to microgrid systems. The alternating current (AC) microgrid system is proficient to integrate with conventional utility grid in combination with different types of DERs in fulfilment of most preferable AC loads. AC microgrid system has implicated its role in the existing AC power system to redesign the overall AC network as per international standards for voltage, harmonics, frequency, unbalancing, power factor etc. Several DERs generate direct current (DC) power while few of them generate AC power which creates major challenges for their integration, synchronisation and power quality. To overcome these challenges, effective operation and control topologies should be implemented in order to overcome these challenges through microgrid central controller (MGCC).

The demand for energy keeps increasing, which is no longer fulfilled by fossil fuels shortly, so it is necessary to move towards a smart grid. Smart grid reduces pollution by integrating renewable resources, decentralization, digitalization, and many more benefits. A smart grid provides a dual data and power flow for efficient energy transmission, fault tolerance, cost optimization, peak demand curtailment, improved security, and better handling of customer-centric power generation. Along with that, better handling of blackout or brownout situations to satisfy customer demand with better reliability.

Smart grid is the most promising topic around the world. Smart appliances are started manufacturing all around the world. Multiple researchers are working on this topic around the world. Various researchers use numerous technologies to resolve the issues that arise on the path of deployment of smart grids (Elgenedy et al., 2015). Along with deploying renewable resources at production and consumer levels, automation goes hand in hand. Automation is applied on the transmission and distribution side to enhance the credibility of the smart grid (Yoldas et al., 2017). The problem discussed in the smart grid is different for different countries. South Africa has increased its use of renewable generation, de-carboning electricity generation, and improved network reliability and availability. For Asian countries, smart grid efforts are related to generation expansion, transmission expansion, and reducing emissions.

REVIEW OF LITERATURE

Chambon, C. L., Karia, T., Sandwell, P., & Hallett, J. P. (2020) Solar and biomass energy assets were used to develop a standalone hybrid energy-producing strategy for Ethiopia's remote villages. The primary constraints to economic and human progress in Myanmar's energy poverty were studied. The electrical system is centered in lowland metropolitan regions, limiting access to remote settlements, even though 66 percent of the rural population lives in these areas. One solution to decrease renewable energy prices has been discovered as renewable hybrid systems. Many algorithms were utilized to find the optimal result for the PV/biomass HRES off-grid issue. Green energy that is self- contained is becoming more cost-effective as a method of distributing electricity to the billions of people who do not have access to the grid. Solar energy costs decrease, while government laws lower agri - waste emissions. The configured hybrid rooftop solar PV/biomass plants were modelled and simulated for rural electricity in Rajasthan for residential, streetlight, and school loads with negligible unfulfilled loads.

Rehmani, A. M., & Akhter, P. (2019) To diminish greenhouse gas (GHG) emissions, the economic and environmental assessment. The proposed hybrid systems focused on optimizing biomass feedstock combinations for optimal production through the neural network tools kit of Matlab-10. Over 70% of India's population lives in remote areas, unable to access the grid's essential electricity. In the Indian state of Haryana, hybrid energy is used to reduce diesel generator greenhouse gas emissions. To meet rural needs, an economical and integrated solution for energy generation employing a hybrid PV/biomass system was presented. In rural Bangladesh, the efficiency of conventional plants was compared to that of a sustainable hybrid solar biomass system. The modelling of three possible configurations were explored for power generation in Bangladesh, with varying solar, biomass, diesel, and battery storage combinations. The optimum energy usage has been figured out to provide electricity to the village of Lumshnong, Meghalaya using HOMER software.

Banacloche Santacruz et al. (2020) described that electricity consumption in the MENA (the Middle East and North Africa) area is increasing at a 6–8% annual pace. By 2020 it'll have doubled, and by 2030, it'll be tripled. Climate protection and energy security are ensured by renewable energy. This paper examines the long-term viability of CSP-biomass hybridization in Tunisia. The environmental impact was calculated using the Life Cycle Analysis method. A Multiregional Input-Output (MRIO) approach was utilized to examine product and service output, value addition, and job development for socioeconomic effects.

According to the results, the system emits 22g CO2 eq per kWh. Due to biomass transportation, the gasifier system is an essential component in terms of emissions. The results of the socioeconomic analysis demonstrate that the O&M phase has a significant influence on job generation in Tunisia.

Sethi V.P. et al. (2020) developed a solar-biomass-based greenhouse crop drier that runs continuously for 24 hours at a constant drying temperature of 62°C using solar energy and biomass heat. For latitudes of 30°, 35°, 40°, 45°, and 50°N, the vertical space (clearance) between the two following trays has been increased. To forecast solar radiation availability and chamber air temperature, global solar radiation and thermal models are employed.

A. Khosravi et al. (2021) suggested a 100 MWe hybrid system connected to a multi-effect distillation unit, which provided energy and economic assessment. According to the findings, utilizing a solar thermal collector to offset rising boiler temperatures might be a realistic option. It decreases the year-round Levelized energy cost by reducing the fuel consumed.

RESEARCH METHODOLOGY

DBSCAN Clustering Algorithm

Clustering is a method for grouping data items into smaller groups called clusters based on how similar they are to one another. The density, which groups together items that are physically near together, is one way to quantify similarity.

Sensitivity Analysis

a) Effect of consolidation factor (m%) to the microgrid sizing Consolidation values of5%,10%,20%, and 30% shall use to size the microgrid.

b) Effect of subsidy on the Cost of energyin order to make power cheap, some rural towns that have implemented microgrids have sought subsidies from the government. A total of two thousand, equal UGX is the LCE that will calculate.

c) Effect of lower Lifetime of the system componentsOne aspect that impacts the total cost of the microgrid is the calibre of the maintenance. Lack of technical knowledge and ineffective management techniques may lead to rural microgrids being unmaintained for extended periods of time. A number of variables, including environmental considerations and a lack of maintenance, could shorten the expected lifespan of the microgrid system's components.

d) Effect of a higher load demandComputing the LLP for the microgrid under the assumption of a 5% increase in load demand allowed us to examine the impact of load demand on dependability.

Design Considerations

Research on whether factors significantly impact the cost-effectiveness of rural community microgrids

- **Battery choice and parameters**

During the times when the sun is shining, the battery bank in a PV microgrid system saves energy. When the sun doesn't shine bright enough, the battery bank steps in to supply the demand for electricity. The microgrid's total running expenses over time are heavily influenced by the cost of the batteries.

- **Availability of anchor customers**

Households make up the bulk of microgrid users in more remote places. These homes have low power consumption rates, with peak demand occurring in the morning and evening and very little use throughout the day. There will be a great deal of daytime energy excess in a microgrid that serves just residential consumers.

- **Gender and community characteristics**

For power services to remain affordable, community participation in microgrid design, maintenance, and operation is essential. Estimating present and future power needs as well as the anticipated system dependability may be facilitated with the help of community engagement throughout the planning stage.

DATA ANALYSIS

Using Social Characteristics of an Area to Estimate Electrical Load

This case study intends to show how social characteristics of an area can be used in the estimation of the electrical load. It assumes a village, village_1, that has been electrified. Its energy and socioeconomic data is to be used in the electrification process for Village_2. The following are the assumed results of the energy survey in the electrified village:

i) The data for actual energy consumption in [81] has been used as the daily load. The consumption categories in [89] have been adopted namely: Low: < 140, Medium: 140-450, and High: > 450Wh. The households with Low consumption belong to Group 1, those with medium to Group 2 and those with high consumption to Group 3.

ii) It's been assumed that household usage pattern is equally distributed between Profile1(has a large evening peak and a small morning bump), Profile3(has continuous growth during the day and an evening peak) and Profile4(has an evening peak and continuous night consumption) defined in [89].

iii) The assumed transition probabilities for WAP, WAPA and NA from the socioeconomic survey as well as between High, Medium and Low.

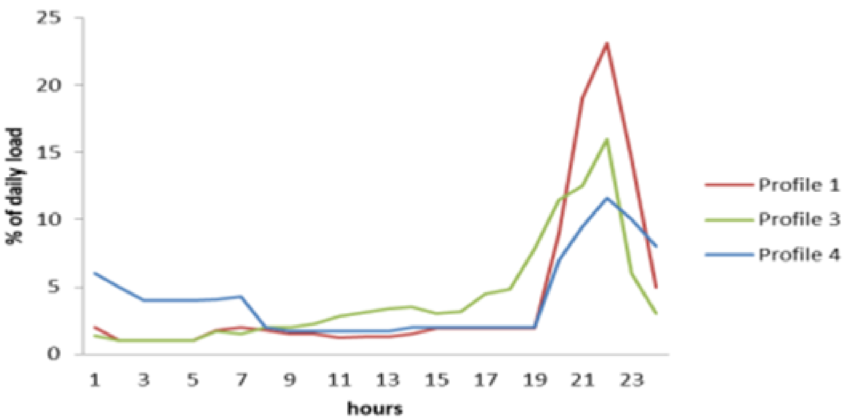

Figure 1: Household Load Profiles

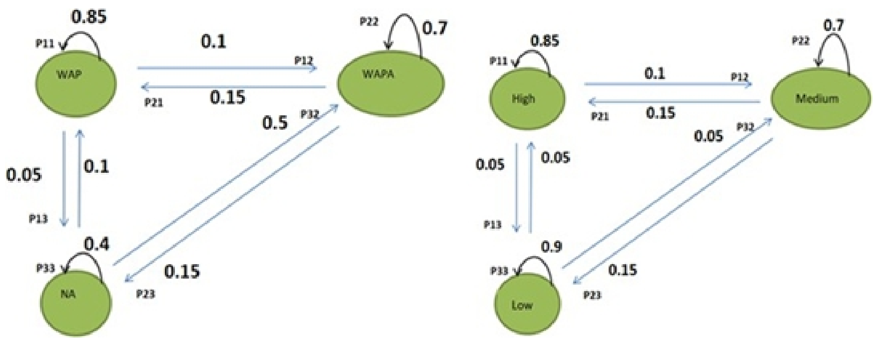

Figure 2: Transition for WAP, WAPA, NA and High, Medium and Low

The following are the assumed results of the energy survey in the unelectrified village:

i) Using the households' current energy use, their economic state, wellbeing and future appliance wish list, the households are classified into groups 1, 2 and 3 as in Table 1. An average daily load is assigned.

Table 1: Household Distribution in the Unelectrified Village

Group	No. of households
Group 1:	65
Group 2:	25
Group3:	10

$$\begin{bmatrix} High_0 \\ Medium_0 \\ Low_0 \end{bmatrix} = \begin{bmatrix} 0.1 \\ 0.25 \\ 0.65 \end{bmatrix} \quad (4.21)$$

$$\begin{bmatrix} High_n \\ Medium_n \\ Low_n \end{bmatrix} = \begin{bmatrix} 0.85 & 0.15 & 0.05 \\ 0.1 & 0.7 & 0.05 \\ 0.05 & 0.15 & 0.9 \end{bmatrix} \begin{bmatrix} High_{n-1} \\ Medium_{n-1} \\ Low_{n-1} \end{bmatrix} \quad (4.22)$$

ii) Assuming that all households are to be electrified and the microgrid is designed for a load of 5 years. The average daily load is 22.1kWh and the peak is 5 kWh.

$$\begin{bmatrix} High_5 \\ Medium_5 \\ Low_5 \end{bmatrix} = \begin{bmatrix} 0.27 \\ 0.18 \\ 0.55 \end{bmatrix} \quad (4.23)$$

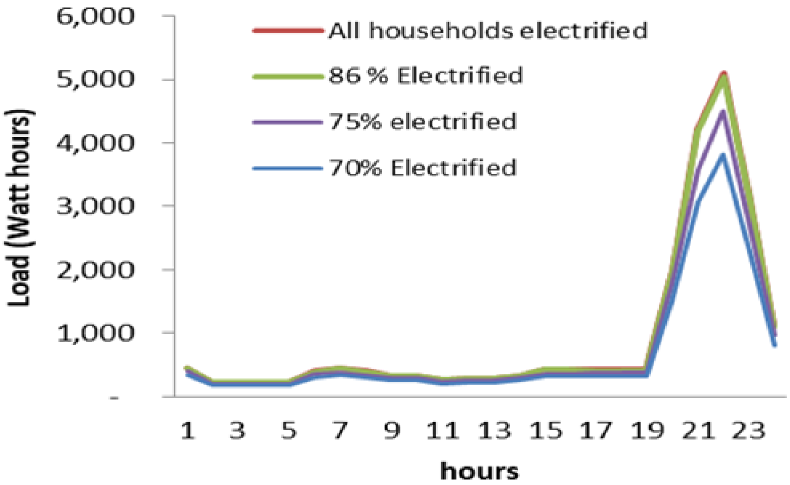

Figure 3: Load profiles for different socioeconomic characteristics

iii) Assuming that 32% are WAP, 48% are WAPA and 20% are NA. If the socioeconomic characteristics in Village_1 and Village_2 are similar, transition probabilities for Village_1 apply to Village_2.

$$\begin{bmatrix} WAP_0 \\ WAPA_0 \\ NA_0 \end{bmatrix} = \begin{bmatrix} 0.32 \\ 0.48 \\ 0.2 \end{bmatrix}$$

$$\begin{bmatrix} WAP_n \\ WAPA_n \\ NA_n \end{bmatrix} = \begin{bmatrix} 0.85 & 0.15 & 0.1 \\ 0.1 & 0.7 & 0.5 \\ 0.05 & 0.15 & 0.4 \end{bmatrix} \begin{bmatrix} WAP_{n-1} \\ WAPA_{n-1} \\ NA_{n-1} \end{bmatrix}$$

$$\begin{bmatrix} WAP_5 \\ WAPA_5 \\ NA_5 \end{bmatrix} = \begin{bmatrix} 0.45 \\ 0.41 \\ 0.14 \end{bmatrix} \qquad (4.26)$$

The results show that by the 5th year, 45% have ability to always pay and 41% will irregularly pay. If the microgrid is designed for those who will regularly and irregularly pay, this is 86% of the households. Basing on the transition between High, Medium and Low, 27% of these connected users will be considered as High users, 18% Medium and 40% Low. The average daily load is 21.9kWh and the peak is 5.1kW.

iv) Assuming the socioeconomic characteristics of Village_1 and Village_2 are different resulting in different total scores for each village. The ratio of total score of village 2 to village 1 in this case study is 70% therefore the electricity adoption rate for Village_2 is assumed to be 30% slower than that of Village_1. The transition probabilities drivers P21, P31 and P32 are reduced by 30% and the probabilities P12, P13 and P23 are increased by 30%.

$$\begin{bmatrix} WAP_n \\ WAPA_n \\ NA_n \end{bmatrix} = \begin{bmatrix} 0.81 & 0.1 & 0.07 \\ 0.13 & 0.7 & 0.35 \\ 0.06 & 0.2 & 0.58 \end{bmatrix} \begin{bmatrix} WAP_{n-1} \\ WAPA_{n-1} \\ NA_{n-1} \end{bmatrix} \qquad (4.27)$$

$$\begin{bmatrix} WAP_5 \\ WAPA_5 \\ NA_5 \end{bmatrix} = \begin{bmatrix} 0.32 \\ 0.43 \\ 0.25 \end{bmatrix}$$

$$\begin{bmatrix} High_5 \\ Medium_5 \\ Low_5 \end{bmatrix} = \begin{bmatrix} 0.18 \\ 0.16 \\ 0.66 \end{bmatrix}$$

Designing for those who will regularly and irregularly pay, means 75% of the houses will be connected. Of these, 18% are High users, 16% Medium and 66% Low. The average daily load is 19.2kWh and the peak load is 4.5 kW.

CONCLUSIONS

The purpose of this PhD research study was to formulate and design an optimum, sustainable and economical solar PV based smart community microgrid solution for purposes of bringing electricity to the over 1.5 billion people who currently have no access to electricity with many of them living in rural and remote areas that are far away from the main grid. This approach also uses the "Density Based Spatial Clustering of Applications with Noise (DBSCAN)" algorithm to aggregate the load and meteorological data so as to achieve both accuracy and faster convergence to the solution. One of the main problems facing design of sustainable microgrids for rural electrification is load estimation. There is need for better load assessment approaches due to the limitations of the existing current load estimation methods Affordability of the rural microgrid is very essential for effective utilisation of the services offered and hence this thesis investigated and presented the critical factors that need to be considered when designing PV microgrids for rural electrification.

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