A Review on Optimization of Microgrid for Rural Electrification

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Abstract— Microgrids are a good technique for applying clean and renewable energy by 2030. Goal 7 of the Sustainable Development Goals calls for the improvement of energy operations. Since the majority of people in rural areas lack access to power, rural electrification is extremely difficult. Currently, more than two billion people lack access to energy, which affects their living conditions. A billion people throughout the globe still do not have access to power, making economic progress impossible. Many individuals live in remote, rural areas that are not connected to the national grid. Optimization techniques by offering an analytical framework may play a crucial part in this advancement. Achieve a wide range of economic, social, and environmental goals that are bound by budget, resources, local population statistics, and other considerations. This paper has been divided into basically two subsections. In section one, we begin by compiling. It gives an overview of the microgrid concept and its properties and presents important reviews of the literature on common microgrids and their remote operation localization of electricity in section second we compile various optimization methods of a microgrid. After that, we compile combining intelligent optimization algorithms with adaptive techniques Each issue type is discussed in detail, with a categorization system based on the problem's goal, suggested solution approach, components, size, and area. Finally, we identify upcoming research issues for microgrid improvement.

Keywords: — optimization, rural electrification, system structure, Intelligent algorithms, Adaptive techniques**.**

I. INTRODUCTION

The entire microgrid is a state-of-the-art distributed energy system using sustainable local energy sources designed with various smart-grid systems. It also provides power protection to the local community as it can be used without the presence of a broad-use grid. Microgrid technology generally represents three key social values such as honesty (physical, cyber), sustainability (environmental considerations), and economics (cost improvement, efficiency). The term distributed generation refers to the generation of electricity available at or near the point of operation. Compared to the “middle generation”, the DG can eliminate costs of generation, transfer, and distribution while increasing efficiency by eliminating complex and interdependent features. A more detailed explanation is provided by [1] referring to the small grid as a locally made locus electricity generation collection, energy conservation, tools for energy conversion, monitoring, and control, as well as load management that may run on time linked to a conventional main grid or independently. Figure 1 [2] depicts the basic construction of a microgrid. The term "power sources" refers to a group of resources that includes both renewable and non-renewable resources. Below are a few of the wind, solar photovoltaic and micro hydropower

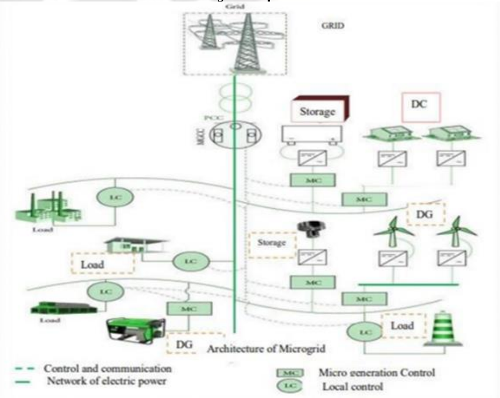

Figure-1 Microgrid Architecture

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 September 2023*

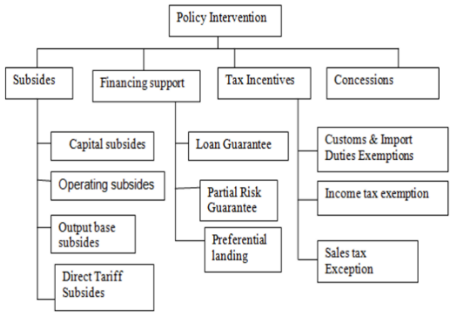

Figure-2 Investing in strategy to support Private [4]

examples of renewable energy sources. Examples of renewable energy sources include single-phase and three-phase induction generators, synchronous generators powered by IC engines, synchronous generators powered by IC engines, diesel fuel cells, diesel fuel cells, three-phase and single-phase induction generators, and diesel fuel cells. Furthermore, the advantages of microgrids have resulted in a rise in policy delivery as well as regulatory stimulants for microgrid development and deployment. [3].

Grants, tax relief, financial assistance, and contracts are all examples of these. Figure 2 taken from [4] illustrates this.

Current Status of Microgrids Research

Numerous academics who study distributed generation, energy systems, sustainable electricity, and remote installation have been interested in the microgrid. The research of an isolated community microgrid included participants from the United States, Japan, China, Canada, and the United Kingdom, and several studies on the topic were published [4]. The editing capabilities of the remote microgrid are the topic of this article. The history, present, and future of China's microgrid state are explored. Microgrids, according to the author, will be an essential feature of the future smart grid, providing control flexibility, enhanced dependability, and improved energy quality. Highlights these as well Microgrids are crucial to the creation of intelligent grids, according to research results. However, it was determined that more research was needed on how to find the island's more reliable and faster response than the development of a standard simulation tool that could aid in further research on the effectiveness of temporary durability, protection, and control strategies as well as improve microgrid design guidelines [5].

Demand Side Management (DSM) Overview

Demand-side management is a model that proposes consumers' active participation in energy use. Demand-side management is the term used by the Department of Energy in the United States for variations in end-to-end customer consumption patterns in response to changes in electricity over time or incentive payments designed to promote low electricity consumption during pricing peak sales prices in the market or where the reliability of the system is compromised at DSM, all means reducing demand, a review on optimization of microgrid for rural electrification are possible and continuous costs, electricity supply and consumption are in balance. The demand response reflects the effect of the electrical consumer response on the stimulus as well as includes patterns of usage pattern. Its health value in the community is based on the result of accumulation throughout the electrical system. These two ideas should be a consideration when measuring and evaluating the response to demand and specifying limitations round. The problem's solution can be used at any stage of the management of the electrical system, as shown in the figure

Demand response can be applied at any point throughout the management of the power system, as shown in the diagram. Customers might adjust their consumption habits as a result of the adoption of DSM programs, reducing the requirement for an increased generation [6]. The benefits of DSM may be divided into three categories: economic, environmental, and dependability.

The following are some of them:

- Cost-cutting [7]
- The number of blackouts is being reduced
- Improves system dependability
- Delays expenditures in generating, transmission, and
- Distribution network capacity development [6]

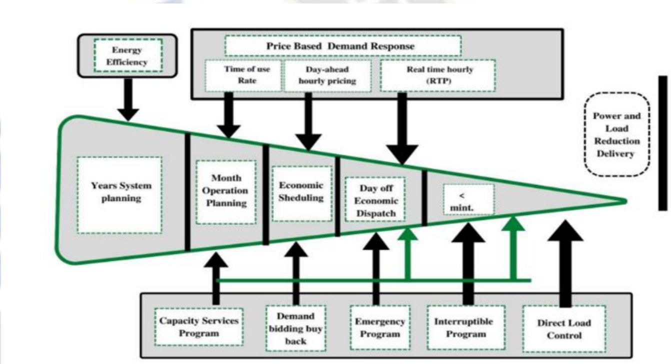

Figure 3 –Demand actions roles in the planning and operation of the electric system

Microgrid Design

Microgrid design contains several microgrid features such as the generation model, load modeling, storage option, and control determinations. When constructing a microgrid, system dependability and affordability are important considerations. It is done on microgrids given in an overview of the many difficulties in micro and the significance of research investigations. Microgrid learning areas are included Distributed production,
microgrid benefits, energy consumption, economic problems, operation and control of the small grid, small collections, and protection as good communication. Research on small-town design and economic feasibility was introduced [8]. Five steps to building a village grid are provided which include; estimated annual requirement and local climate

1.2.1 Selection of integrated temperature and energy (CHP), ground floor, and renewable energy resources.
1.2.2 Improvement of a selected area
1.2.3 Analysis of system performance stability and
1.2.4 The economic analysis takes into account both fixed and variable costs.

It's necessary to keep in mind that a microgrid may be either AC or DC when designing one. Consider a dc load rating

while selecting whether to use AC or DC Microgrids. When this rate changes, the overall cost changes as well. If the size is reduced, an AC microgrid will be deemed cost-effective.

Microgrid Energy Storage

Energy conservation is as important as a microgrid as any of the production equipment used in a medium microgrid in the environment e.g. the sun and the wind. This enables a microgrid to keep its power supply stable. Even when no descendant generation is in use. In addition, a microgrid can work in island mode without the main grid so it is the necessary placement of the placement [9] [10] [11] [12]. For electrical power, several forms of storage technologies are present, and numerous authors have focused their studies on them. The following are examples of technology:

1.2.1 An electrical power source
1.2.2 Storage of energy via compressed air
1.2.3 A magnetic energy storage structure called a super capacitor.[16]
1.2.4 Energy storage with flywheels

When planning a microgrid, it's critical to consider the storage alternatives and size for that particular store. One of the most prevalent energy storage options in solar PV and/or renewable power systems is battery storage A study on the best size of energy storage for microgrids was published in [52]. The study focused on lithium-ion (Li-ion) batteries, and it performed a cost-benefit analysis to establish the economic feasibility of battery storage in both grid-connected and island modes. In general, the cost of an energy storage option is an important consideration when determining which form of storage to utilize. Lazard [53] conducted and published a detailed analysis of the economics of different storage methods. The following is a summary of the findings

i. Even if certain energy storage technologies have proven attractive for a variety of unique grid applications, they are still costly and not as cheap as some renewable energy proponents had planned.
ii. Within the next five years, costs are predicted to drop dramatically owing to an increase in the usage of renewable and the implementation of government laws that encourage energy storage. the need for a decrease in fossil fuel consumption, as well as the various changes that are predicted to occur as the electricity infrastructure advances.

Renewable Energy

A word used to describe energy sources that are both naturally occurring and self-renewing is "renewable energy." Because these resources are naturally scattered, we may create energy in far locations without having to invest in big transportation networks [54]. [55] Is an example of a nontraditional resource?

i. Biomass, Hydropower, Geothermal, Wind, Solar, Tidal Energy
ii. Aside from the capacity to create energy in distant regions, renewable have numerous additional benefits, including:
iii. Because of their minimal or near-zero carbon and greenhouse emission, they are clean (nonpolluting).
iv. They are both inexhaustible and long-lasting.When compared to typical generators, renewable energy plants may be less costly to maintain.
v. Renewable energy sources may be a dependable supply of energy with correct planning and infrastructure. Renewable energy sources provide the much-needed flexibility in power production, reducing reliance on fossil fuels. [15]

II. Rural Electrification Problem

2.1 A detailed analysis of the study informs us that we have proposed the division of power supply in rural areas into four types of problems:

i. Complete system setup and unit size,
ii. Comprehensive power supply plan,
iii. Sound technical selection, and
iv. High-quality network design

The first step in the entire system setup and unit measurement challenge is to choose the kinds of power sources and balance the power system's components. Second, the problem of high power transmission strategy is focused on planning efficient operations; Power generation and power transfer between components are included third, based on a set of goal functions, the issue of suitable technology selection chooses the production of different technologies and kinds of electrical installation technology (grid, off the grid, embedded). Fourth, models for optimum network design try to develop local network configurations that satisfy the objective requirements unique to each scenario. Importantly, to achieve the varied electrification targets in rural regions, the capacity of these four sorts of issues to address SDG7's various components, including affordability, reliability, and sustainability. To increase the environmental sustainability of rural electrification, a high-tech technology model may be devised to decrease carbon emissions in the system. Finally, as a sensitive and serious topic of rural electrification, the construction of the right network model may incorporate reliability by modeling flexible power and the hazards of power outages dependent on the distance from newly found transformers[17].

Optimal System Configuration & Unit Sizing

We examine publications that concentrate on comprehensive system setup and the unit measurement unit for rural electrification in this part. The choice of energy sources is critical before the implementation of mixed-use programs in rural regions to deliver power. Power planners must measure system components to attain optimal efficiency, particularly when considering renewable energy sources from time to time. We describe the amended articles in Table 1 in terms of performance, circumstances, system design, and historical data on local area improvement. Classical development techniques are very popular in the construction of a mixed renewable energy system with system configuration problems. Other examples of ancient development methods used in the revised studies include linear programming (LP) [30, 31], mixed integer linear programming (MILP) [39], and stochastic efficiency (ISO) [35]. Aside from these traditional approaches,

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
Article Received: *25 July 2023* ***Revised:*** *12 September 2023* ***Accepted:*** *30 September 2023*

heuristic or metaheuristic methods may be highly useful in finding limited solutions for significant events in a short amount of time. These methods are particularly suitable for dealing with non-convex or chronic problems where Due to the problem's intricate nature, traditional approaches are ineffective. One of the most frequently employed techniques for resolving system-setting problems is the Genetic Algorithm (GA). [20,21, 30]The Natural Selection Process, which includes cross-over and genetic modification operators, forms the foundation of how the Genetic Algorithm functions. Incomplete system design and unit measurement investigations are often employed with this strategy [22, 50]. Each particle represents a potential solution in this optimization process. The result is obtained by reviewing generations for each duplicate. Particle Swarm Optimization does not need crossover and mutation operators for subsequent generations, in contrast to the Genetic Algorithm. Another way for locating the whole system configuration and unit measurement is Harmony Search (HS) [64]. The improvement of musical instrument harmony affected this process. The Artificial Bee Colony Algorithm (ABC) is a technique for optimizing a system setup that simulates the intelligent behavior of beekeepers when seeking honey. [64]. similarly, [64] employs the Firefly Algorithm (FA) for signal transmission, the flashing pattern of fireflies inspired this design

Optimal Power Dispatch

Problem Rural electrification's economic feasibility, particularly in terms of varied renewable energy systems, depends largely on operating costs from day-to-day operations during power generation. In addition, the distribution of energy resources and the flow of energy between production locations and end-users have a substantial influence on the dependability of a system that combines many energy sources. Therefore, Rural electrification requires planning efforts and determining an

effective energy distribution strategy to provide inexpensive and dependable electricity to rural customers We've compiled a list of articles that concentrate on developing related techniques for control, which include organizing energy flow and power generation in systems. Classical development techniques have been widely used to improve the performance of mixed-use renewable energy systems. According to [25], more than 60% of the research examined in this area employs linear regression to determine the best implementation technique. Some studies suggest a flexible planning approach and the design of mixedline systems [19] solve this problem. As well as genetic algorithms, evolutionary algorithms have been frequently employed in this phase of the challenge [20, 21], uncontrolled genetic algorithm- II, and particle efficiency [23].

Table-1 Summary of the optimization frameworks that have been proposed in the peer-reviewed literature

Methods of Optimization	Techniques of Optimization	Advantage of techniques Solution Methodology	References
Optimization Model	Linear programming	Linear programming improves the quality of decision making.	[13] ,[18],[19], [32], [33], [34], [35]
	MILP	MILP solver method is the solution accuracy	[26],[27],[28],[36],[37]
		it can obtain both local and total optimal solution.	[67],
	Dynamic Programming	Optimal control problem with inequality path constraints	
	Non-linear Programming		[5]

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
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	Genetic Algorithm	Find solutions to problems that are difficult or impossible to solve using traditional methods	
		Fewer parameters to tune, limited acceptance	[19] [20], [41-43],[47], [30], [48] [22],[24],[29],[50], [44] [46]
Met heuristics		Easier to implement, less parameter tuning, and faster convergence.	
	Particle Swarm Optimization		[50],[51] [59],[60],[61]
	Harmony Search		[51][56],[57],[58],[62][63]

Table 2: A list of the optimization frameworks that have been suggested in the peer reviewed literature

Approach		**Issue**			**Techniques and Methods for Optimization**	**Proposed**	**Reference No**
Multi optimization	**Single objective**	**Uncertainty optimization**	**Power flow optimization**	**Design optimization**	Fuzzy Logic Controller , PID for converters, PI, and Multi-Objective Particle Swarm Optimization for battery charging and discharging	MOPSO for converter FLC for battery	[26]
Yes	No	No	No	No	Using Particle Swarm Optimization PSO, one can cut down on energy costs and emissions	PSO	[37]

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
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Yes	No	No	Yes	Yes	stable optimization Using the distributional robust optimization and adaptive robust optimization models,	DRO model	[40]
Yes	No	No	Yes	No	Economic dispatch is carried out using the MultiObjective Spotted Hyena and Emperor Penguin Optimizer approach.	MOSHEPO	[38]
Yes	No	No	Yes	Yes	Utilization of HOMER software to lower energy costs and emissions from hybrid microgrids for the targeted load	SAME	[36]
Yes	No	No	Yes	No	Improved Memetic Algorithm , Memetic Algorithm	IMA	[25]
No	Yes	Yes	No	Yes	Regression using stochastic swarm optimization for inexpensive, ideal sizing	SAME	[50]

It is different from previous evolutionary algorithms, and introduces a framework for preparation using an internal point method to address a major non-line development problem.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 September 2023*

Optimal Network Design Problem

Table-3 Methodology to optimization, techniques and methods used and suggested approach

Article	Heuristics and Metaheuristics	Model	Objective	PV	Wind	Diesel	Battery	Country	Scale
[69]	Genetic Algorithm		cost	√	-	√	√	Bangladesh	Village
[64]	Genetic algorithm		Cost, LPSP	√	√	-	√	Senegal	Village
[70]	Evolutionary Algorithm with a Stable State		GHG Emissions, Cost	√	√	-	-	Sri Lanka	Village
[71]		MILP	Cost	√	√	-	-	Peru	Village
[20]	MOEA, GA		Cost	√	-	√	√	Central Africa n Republic	Village
[72]	Genetic algorithm		Cost	√	√	√	√	Spain	Village
[73]	Genetic algorithm		Cost	√	-	√	√	Nigeria	Village
[50]	Discrete HS		Cost	√	√	-	-	India	Village
[11]		MILP	Cost	√	-	√	-	India	Village
[32]	LP		Cost	√	√	√	√	Colombia	Village
[65]	GA		Cost	√	√			China	Village
[68]	MFO	-	Cost LPSP	√	√	√	√	India	Village

The best ways to build, manage, and operate power distribution networks at the lowest possible cost, as well as how to develop grid-based networks, are examined in this section's [14] studies for rural energy planners. Two frequent topics covered in this study are the centralized grid and mini-grid design. Table 2 shows the result. Demand points and production facilities are anticipated to be closely connected in this architecture, which is known as the star configuration topology. These articles include case studies from developing and no developing resources to create a proper distribution network for end used-users All branches of the radial distribution are depleted to the value between the lowest limit and the voltage reduction drop in these investigations. The voltage drop must be calculated by looking at the power flow between the network's required locations. As a result, Ferrer-Mart et al. [48], Ranaboldo et al. [49], and Triado'-Aymerich et al. These decisionmaking factors also influence node interaction, resulting in a final network that accounts for the flow of power between any two places in space. While technological restrictions improve the correctness of suggested networks, they also limit the extent of the issue and force editors to concentrate on narrower regions. Some studies, on the other hand, attempt to let editors undertake a quick evaluation of the cost of electrification projects [39, 50, 66, 67]. These studies disregard or "liberate" other technology limitations and offer advice on how to utilize heuristics to create editorial guidelines using bigger data sets than a program that gives all the specifics. A site that runs in a separate solution region and has a set of predetermined locations for producing points or transformers was developed after extensive research. Some structures provide a site for designing a two-tier network and transformer placements in the Euclidean area, according to Kocaman et al. [39] and Fobi et al.

Optimization Techniques Regarding Power Flow Utilizing cutting-edge algorithms, microgrid performance is taught and enhanced to provide optimum energy flow with the ultimate goal of lowering costs and losses. The authors of [31] suggest using the local pricing approach to verify the hybrid microgrid's economic benefits. Energy balance is done by this procedure, which boosts revenue. The authors of this model [28] use fuzzy logic to meet charge demand, monitor battery charging and discharging, and optimize operating costs taking into account the high penetration of renewable energy resources in the hybrid grid. This model has many benefits, including the ability to increase income and decrease operating costs. To address the power imbalance in the three-phase hybrid microgrid originating from huge integration and independent operation of the sub-grids, the authors of [35] suggest a new optimization model based on the multi leader and multi follower game theory. 2.7 Development Strategies for Design and Topology The thorough planning and configuration of a power system are its most crucial components. The best technique or a mix of programs from all system designs and machine characteristics is chosen for the power system design. And examines the performance of the system, diverse resources, and natural barriers. Table 3 below provides an overview of my most recent research in this area.

III. CONCLUSION

The present condition of development strategies that have been devised and executed in the rural electrification dilemma is reviewed in this study. We found 106 scholarly publications that propose a novel mathematical, heuristic, or metaheuristic model address different elements of rural electrification difficulties By providing a list of best practices (see Table 1) that researchers in the field of rural electrification should follow, we hope to draw the attention of researchers to specific issues in this review study. A potential extension of the study undertaken has been noted in this publication, which might be investigated to advance the research. The following are some of them:

- Metrics for Sustainability Development
- Other Microgrid Components Lessons Field Studies to Learn More About Load
- Measurement Demand Management and Demand Response

Acknowledgement

The authors would like to acknowledge Integral University, Lucknow, for providing the MCN "IU/RED/2022-MCN0001760" The statements made herein is solely the responsibility of authors.

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