A Structured Review of Grid Connected Micro Grid for PV Energy Management Systems

Ayat Hussien and Ahmed Obiad

January 13, 2024

A structured review of Grid connected Micro grid for PV energy Management Systems

Ayat.H.Saleh [1,a)] , Ahmed Obaid Aftan [1,b)]
[1,] *Electrical Engineering Techniques Department, Technical College /Al-Mussaib, Al-Furat Al-Awsat Technical University Najaf, Iraq*

Author Emails
Corresponding author : E-Mail : ayathussien562@gmail.com
:Ayat.hussien.tcm.23@student.atu.edu.iq
b) E-Mail : ahmed5@atu.edu.iq

Abstract. The incorporation of photovoltaic systems into micro grids has garnered noteworthy interest as an eco-friendly approach to distributing energy production; this review research aims to investigate the attributes of the grid-connected micro grid while putting a particular emphasis on photovoltaic energy management. Determining the photovoltaic system's ideal capacity within the micro grid aims to improve energy efficiency, lessen reliance on the primary grid, and encourage using renewable energy sources. Advanced modeling and simulation techniques are employed in suggested optimization framework assess the dynamic interactions between photovoltic panels, power storage systems, and the primary grid, which make up the micro grid. The optimization approach considers essential variables such as load demand patterns, grid electricity costs, and fluctuation in solar irradiation. The goal is to find a balance between maximizing powered by green energy and lowering total energy expenses. To assess the influence that different micro grid sizes have on the system's efficiency as a whole, that research looks via a number of situations. The ideal photovoltaic system size established using techno-economic criteria and scenario-based simulations. This considers variables like payback duration, the return on investment, and overall system dependability. With an emphasis on photovoltaic energy management, the results of the study offer significant perspectives on the planning and carrying out, grid-connected micro grids. The ideal micro grid size acts as a standard for upcoming green energy initiatives, giving stakeholders, legislators, and decision-makers a framework to make well-informed decisions as they move towards more environmentally friendly and resilient electricity systems.

Keywords: battery energy storage system, energy management, photovoltaic micro grid, renewable energy resource

1. INTRODUCTION

Electronic devices known as solar panels have the ability to produce electricity from strong sunshine. It is made up of a number of tiny components known as solar cells. Associated together to be the solar panel, and these materials can be manufactured from semiconductor materials such as silicon material so that they produce voltage when exposed to light and cause a current to flow. The usage of solar panels and "Sunlight Electricity Generation Technology" is growing throughout much of the world. Since diesel generators and other energy sources squander non-renewable resources and harm the environment, it is a great substitute for them. Solar Energy is also environmentally friendly and accessible because it is boundless. sunlight that renews daily, small power grids' represent compact energy grids that integrate demand, control, and management systems for energy with renewable energy sources (RES) like wind and photovoltaic (PV) electricity to enable them to function separately from the primary transmission and distribution network, the development and deployment of solar systems are still best by significant hurdles because of how expensive photovoltaic materials, the low conversion efficiency of PV modules is another barrier preventing a big usage of solar energy [1]. Variation the load and generation within a micro grid raises significant concerns about the safety and stability of the electrical grid [2]. Recently, as energy demand, fuel prices, environmental concerns, and the depletion of fossil fuels have increased, hybrid energy systems based on renewable sources have gained popularity [3]. The absence of harmful gas emissions makes renewable energy resources (RESs) like Wind and photovoltaic systems eco-friendly and an excellent substitute for fossil fuels [4]. Annual growth has been observed in the quantity of grid-connected renewable energy systems installed. These systems offer a number of benefits, but they also have certain drawbacks, such as intermittent, which may cause grid issues with managing schedules, frequencies, and voltages [5]-[6]. There are many methods to calculate the ideal (BESS) stands for battery energy storage system, and photovoltaic (PV) size in the grid connected micro grid (MG), minimizing energy costs was chosen as the goal function, a hybrid grey wolf utilizing the cuckoo search optimization algorithm used to achieve an ideal sizing of the proposed grid-connected MG, using a new energy management technique and the particle swarm optimization (PSO) algorithm, one of these ideal BESS and PV sizes is identified in order to minimize overall cost, in order to assess the robustness of the proposed method, the results are compared to those obtained using Grey Wolf Optimization (GWO), whereas the GWCSO technique yielded less total component parts than the GWO procedure. Annual cost, total Net Present Cost (NPC), and Levelized Cost of Energy (LCOE), the GWCSO algorithm also had the lowest variation, suggesting that it is more reliable and accurate than the GWO algorithm [7]. In the MG system, PVs and BESSes have many benefits, but they also have certain drawbacks, cost and size are becoming more significant since high capacity drives up costs and size, despite this, the modest capacity might not be enough to meet load demands and prevent unforeseen power outages ,as a result, BESS size needs to be precisely computed to ascertain the ideal size for a particular system [8]. Therefore, in order to create an effective, dependable, and the cost effective MG system, system designers must determine the ideal BESS size for the particular system [9]. BESS sizing is carried out using a variety of techniques based on the system parameters; some of these techniques can be applied to any size system Mathematically-based optimization techniques further employed to solve sizing issues, two examples of these techniques are Dynamic programming (DP) and Linear programming (LP) When it comes to large-scale systems, though, there are a few issues. Consequently, LP and DP inadequate instruments for intricate systems [10] .Large-scale systems are challenging to apply DP to, hence LP optimization is used as a more straightforward approach, additionally, studies have demonstrated that BESS operate best when appropriately sized for current loads [11].

Frequency regulation using PSO technique was used a disconnected micro grid to assess the ideal BESS size and economic processes, the PSO algorithm determines the perfect battery size and the lowest cost for a grid connected home system with an available PV system [12]. Likewise, PSO chooses an island-mode micro grid's efficient battery construction and optimization of battery capacity considering the reliability index, the PSO is used to size wind, photovoltaic, and tidal energy sources as primary and batteries as auxiliary sources as efficiently as possible [13]

The current article views an extensive analysis of the energy management strategy of micro grids and summarizes the benefits and drawbacks of stated techniques and correlation tables for optimization algorithms. This work provides an introduction in the first section, and the second section consists of three categorizations for the system configuration, the third section classifies EMS, control strategy, and constraints, the optimization methods in the fourth section.

2. SYSTEM CONFIGURATION

Figure (1) demonstrates the structure of the micro grid-connected , which includes the grid, loads, photovoltaic cells, AC bus, and BESS, connected to the grid by an AC bus , DC/DC converters connect the PV and battery to the DC bus , so that the PV can continuously charge the storm along the DC bus, the energy management system of the DC and AC buses observes the battery energy levels, available PV power, load demand, and battery charge/discharge status, it also determines when to request electricity from the grid temperature, aging, shade, pollution, and sunlight affect how well solar PV modules function [1]

Maintaining the power balance in the micro grids requires the involvement of storage devices through charging and discharging, on the other hand, a low battery capacity results in inadequate power, which causes instability or raises the expense of using conventional fuel, however, the price would rise due to an excess of battery capacity, consequently, avoiding micro grid dispatch issues and maximizing operating expenses depend on determining the ideal capacity or size for storage units [15, 16].

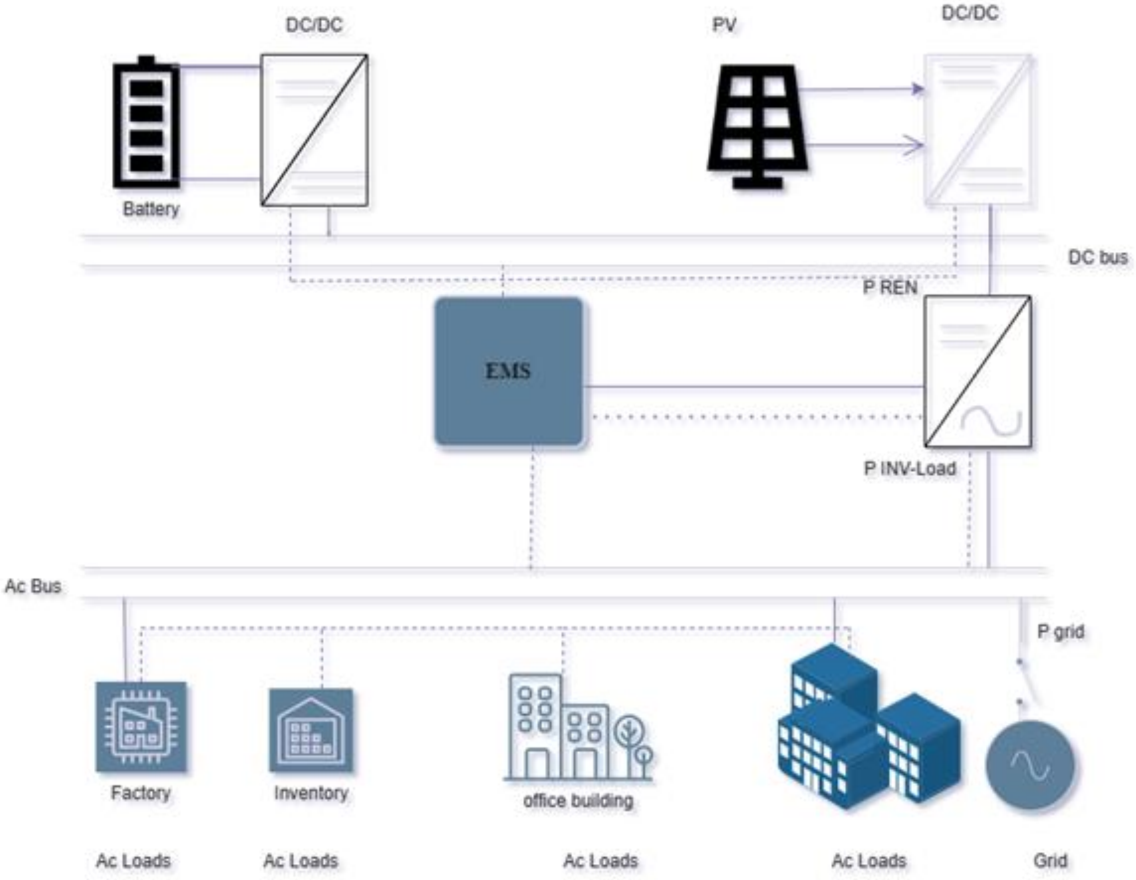

Figure (1) The structure of the micro grid connected [4]

These energy-storage devices can store excess electricity from eco-friendly energy sources when demand is not at its peak or add supplementary power to the grid during blackouts, further more smart control of energy consumption techniques strive for determine an ideal battery size while lowering amount of traditional gasoline used as well as whole operational expenses [17]

MGs have two operating modes: radial (ring) and AC/DC[18]. And, should there be a lack of Energy from the utility grid, sell or buy Energy [19].Micro grids can function as freestanding power systems using local resources or as grid-connected systems linked to the traditional utility grid, regardless of the design of the micro grids, they have been successful in lowering CO2 levels and energy expenses[20, 21] But because renewable energy sources like photovoltaic (PV) units fluctuate and are sporadic, using storage devices in micro grids has become essential [22].

Table 1 presents a concise overview of prior research on energy management systems, including the system type employed, objectives pursued, control mechanisms employed, and elements that have an impact on these systems.

Table.1 summary of energy management in grid tied micro grids

Hybrid energy system	PV, wind, fuel cell, micro turbine, diesel generator, battery, super capacitor, water storage
Objectives	Save money, reduce emissions, reduce peak demand, stabilize the grid, prevent central EMS collapse, improve grid quality, eliminate overvoltage, and increase financial benefits.
Factors considered	Renewable energy resource stochasticity, battery degradation, prediction mistake, demand uncertainty, real-time electricity market price changes
Control strategy	Centralized, decentralized, hierarchical, demand response, online/real time

3. CLASSIFICATION OF EMS

The main grid's power-type connection, the strategy of control, configuration, solving methods, and the parameter selection methods are the factors that may be used to categorize the EMS in MGs, the categorization of popular energy management systems in literature is displayed in Fig(2)[23].

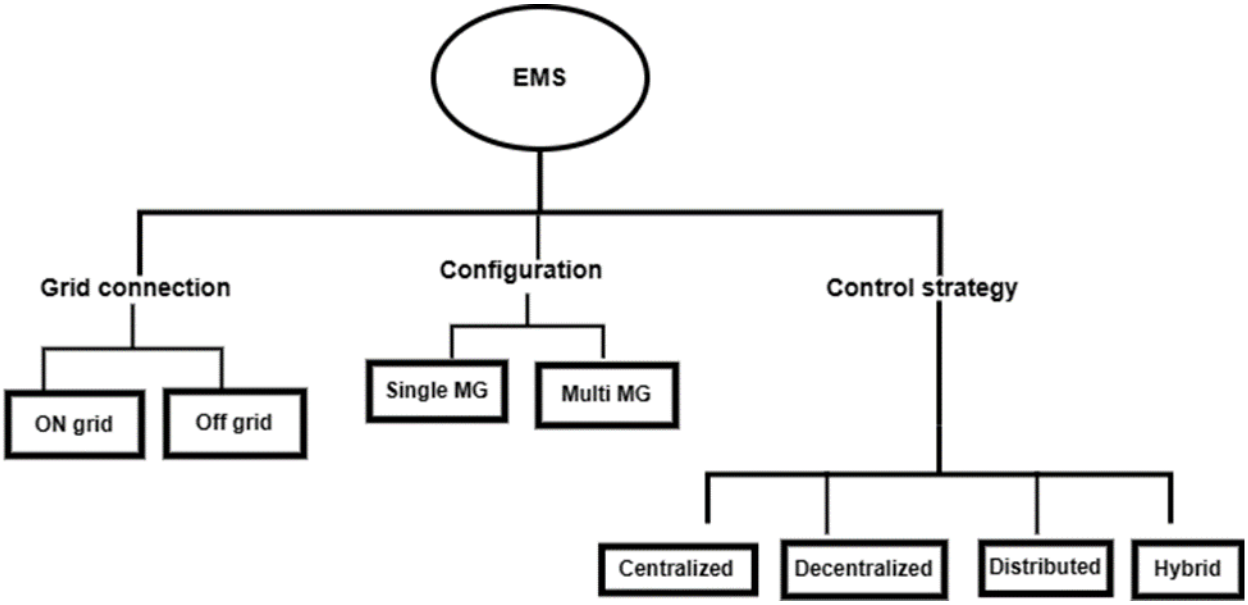

Figure (2) Classification of energy management [23]

3.1 TECHNIQUES OF CONTROL

MGs require extra control algorithms or energy management systems to provide the best possible power flow among all MG components in order to produce a steady and economical functioning because they contain a variety of dispersed generator units and stochastic-character loads, for the purpose determine each unit in the MG's operating point and oversee the coordination and movement of Energy among the different departments for an effective, dependable, and cost effective operation that results in demand supply balance, the energy management system (EMS) is required inside a distributed generation (DG) systems with multiple sources and storage devices, References in [24] [25] [26].

In general, centralized, decentralized, distributed, and hybrid control are four types of control systems utilized in MG EM, under centralized management, breakers and local control units that are assigned to specific units receive command signals for protection and control from a central control unit (CCU),the CCU uses requirements-based algorithms to determine the best operating point while taking into considering a multitude of factors, including cost, emissions, grid availability, resilience, and dependability since only local data is available when taking extended MGs into account , a hierarchical approach is preferable since the decentralized method necessitates a great deal of coordination, which is troublesome when dealing with extensive MGs and the limited availability of local data is recommended rather than a wholly centralized or entirely decentralized one, these controls may be categorized as either primary, secondary, or tertiary: the primary control includes things like droop control, islanding detection, and power electronic converter control, secondary control is responsible for ensuring EM operates in MGs in a dependable, secure, and cost effective manner tertiary management oversees the coordination of numerous MGs[27]. Because hybrid EM is more flexible than centralized control and less expensive to operate than decentralized control, it combines the best features of both approaches [28]. Benefiting from privacy protection, less computing effort and simplicity of expansion, decentralized control necessitates fewer information systems and important details of different units [29]. Decentralized control lacks this, meaning that the controller cannot execute it, in contrast, the command and control entity of the dispersed management system gathers materials and communicates the optimal results from scattered agents [30]

Table 1 provides a concise summary of the distinctions between centralized and decentralized control approaches.

Table.2 Overview of centralized and decentralized methodologies.

Centralized	**Decentralized**
A bulk data-handling central controller makes decisions depending on data availability from controller-MG component communication [31]	Each unit has its own controller and data. which self-schedules by interacting[33],[34]
Provides ideal voltage, current, and minimum needs for optimization method, although poor data connection between the management unit and control unit might reduce efficiency and delay[32]	The advantages include robustness, reliability, reduced computational time, enhanced data correctness in information interchange, preservation of data privacy, and improved network security.[35]

3.2 GRID CONNECTION

An economical storage management system that makes timely use of the ESS capacity in a grid-tied MG for both variable and fixed time, independent loads by participating in the electricity market [36].

The primary distinction in relation to primary the MG and the grid, although engaged in primary grid, the generation units and load are able to viewed the unique organization for economic distribution, despite the fact that load is unpredictable and that only the generator side can consider optimal scheduling [37].

The inclusion of the MG shouldn't have any impact on the primary grid's stability, fuel costs, emissions of greenhouse gases(GHG), power outages, and emissions of greenhouse gases must all be decreased through MG optimization [38].

3.3 THE GRID CONSTRAINTS

The constraints: which are stated as a part of the optimization problem dictate the operating ranges of the variables.

3.3.1 Limitations of Distributed Generation (DG) Restraints:

Each unit's distributed generators' output operation should fall between the following maximum and minimum bounds [39]

$$PMT,\min \; \le \; PMT\,,t \; \le \; PMT\,,\max \tag{1}$$
$$P\,FC,min \; \le \; P\,FC \;\;,t \; \le \; PFC\,,\max \tag{2}$$
$$PPV,min \; \le \; PPV,t \; \le \; PPV,max \tag{3}$$
$$PWT,min \; \le \; P\,WT,t \; \le \; P\,WT \;\;,\max \tag{4}$$

Where:

PMT, min	minimum producible power of the micro turbine
PFC, min	minimum producible power of the fuel cell.
P pv, min	minimum producible power of the photovoltaic.
PWT, min	minimum producible power of the wind turbine.
And P MT, max	maximum producing power of the micro turbine.
PPV, max	maximum producible power of the photovoltaic.
PFC, min	maximum producing power of the fuel cell.
PWT, max	maximum producing power of the wind turbine.

3.3.2 Limitations of the Grid

The maximum and lowest restrictions for power coming from the utility grid should be met in each time step [40]

$$Pgrid,min \; \le \; P\,grid,t \; \le \; P\,grid,max \qquad t=1,\ldots.,T \tag{5}$$

Where Pgrid, max , Pgrid, min: Maximum /minimum limits of power production utility, respectively (KW)

Pgrid,t : power of utility in (KW)

3.3.3 Limitations of Power Storage in Batteries (BES)

The actions of charging and discharging batteries are described as follows, respectively [35]:

$$E\,bat(t)[E\,PV(t) - E\,Load(t)/\eta\,inv\,] \;\times\; \eta\,Bch \tag{6}$$
$$E\,bat(t)\;[E\,Load(t)/\eta\,inv - E\,PV(t)] \;\times\; \eta\,B\,dch \tag{7}$$

In this context, EPV(t) denotes the energy that was created and E Load(t) stands for the load demand at time interval t. η Bch, η Bdch, and η inv the stand for inverter, battery charging efficiency, and discharging efficiency, respectively.

Equations (8) and (9), respectively, express the boundary limitations of BES power in the charging and discharging modes[17]

$$P\,BES,min \; \le \; P\,BES \;\;,t \; \le \;\; PBES\,,max \qquad t=1,\ldots\ldots.,T \tag{8}$$
$$P\,BES \;\;,min \; \le \; PBES\,,t \; \le \; PBES\,,max \qquad t=1,\ldots\ldots,T \tag{9}$$

4. OPTIMIZATION METHODS IN MICRO GRIDS

Various models that incorporate determinism, analysis, heuristics, stochastics, and hybrids are among the optimization strategies utilized in MGs, lagrange relaxation, greedy algorithms, linear programming with mixed integers (MILP), dynamic programming, non-linear simulations, and solving problems using linear programming (LP) [41] and interactive programming are techniques employed in the using a predetermined strategy [42].

PSO (particle swarm optimization), AI-powered flower pollination algorithms, search for cuckoo, explosive blast method, algorithms for optimizing whales, moth swarms, and harmony searches, and optimizing electromagnetic fields [43].The heuristic, metaheuristic method encompasses all of them, natural processes that continually iterate to obtain the ideal value are the basis for the metaheuristic algorithms [44].

Avariety of variants or modifications of the aforementioned algorithms are used to tackle power optimization challenges in optimal power flow and energy management concerns [45] [46] [47]. Any combination of the two techniques is used by a hybrid system [42], however, it has a disadvantage of taking longer to compute, which parallelism can solve[48].

The benefits and drawbacks of popular optimization methods, such as PSO strength, are While the drawback makes it impractical for real-time applications and makes it challenging to determine the ideal design parameters, it is simple to code, less sensitive to the nature of the goal function and initial points, and has a quick computation time[49]. Multi-objective optimization generates a group of optimal values rather than a single optimum while meeting numerous equality and inequality requirements issues involving multiple on the same conflicting purposeful operations [50]. Comparisons between existing studies and are given in Table (1).

A close examination of Table (2) provides an idea of the difference between the different algorithms , Numerous research have employed various optimization techniques to achieve the goal of cost minimization in energy management systems. The table below lists the advantages and disadvantages of some optimization algorithms and approaches that are commonly employed (3)

Table 3. The comparison of the existing studies

Ref	The optimization algorithm(s)	The number of Opt. Criteria	The operation mode	Type of RES	EMS	The objective function	The purpose of the ESS
[51]	PSO	More	Grid-connected	PV, BESS	Yes	Optimize the system's cost-profitability.	energy efficiency
[52]	DP	Less	Grid-connected	PV,BESS	No	Finding the best charging and discharging path for ESSs while minimizing operating costs	energy efficiency
[53]	LP	Less	Grid - connected	PV ,Wind , BESS	No	MG operating expenses as low as possible and BESS sizing optimization	highest shaving point
[54]	MILP	Less	Grid connected	PV,BESS	Yes	Reduction of an overall yearly expenses Energy and costs related to battery deterioration included)	energy efficiency
[55]	MCDP	Less is better in terms of efficacy.	Grid connected	BESS (storage plant)	Yes	Calculated the storage power references that yield the highest profit	Energy sustainability and energy arbitrage
[56]	ABC	Average	Grid connected	Wind, Hydro ,BESS	No	Maximizing income	Energy efficiency and energy arbitrage

Table.4 The exploration of popular optimization methods

Algorithms	Fortitude	Feebleness
LP	Fastness and dependability of computation	The majority of problems in the actual world are nonlinear, and developing a linear model for them can lead to significant losses[57]
DP	The solution to the problem can be used to deduce the sensitivity analysis [58]	For situations where there are a plenty of functions increase,the quantity of factors increases exponentially, needing more memory space. [57]
Nonlinear programming	Because the model accurately captures the nonlinear properties of the system being studied, the results are more dependable.	If the computing functions are not differentiable, then optimal solutions cannot be obtained. Need for a workable initial point to achieve worldwide optimum [57]
Heuristic approach	The ideal solution was found while maintaining the nonlinear properties and requiring a manageable amount of memory and processing time.[57]	Instead of the global optima, a hidden solution might produce local optima [59]
ABCA	Versatile,adaptable,minimal chance of early convergence, and the outcomes represent worldwide optimal values[60]	greater computational cost and demand for more time and memory[60]

5. CONCLUSION

This paper focus on the review for energy management, which classified to grid connection type, control strategy and configuration in this research topic. A detailed literature review of various optimization algorithms is offered with specific factors taken in account, furthermore energy managements ,to achieve stable economic operation .The benefits and drawbacks of various optimization algorithms are also examined and listed in tables .In summary, the optimization of grid-connected micro grid size for PV energy management represents a significant step towards achieving a more resilient, cost-effective, and environmentally friendly energy landscape. The knowledge generated by this research can empower stakeholders to make informed decisions, ultimately contributing to the advancement of renewable energy technologies and the realization of a cleaner and more sustainable energy ecosystem.

REFERENCES

1. A. R. Hameed, A. O. Aftan, and N. A. Kudher, "A structured review of MPPT techniques for photovoltaic systems," presented at the The Fourth Scientific Conference for Electrical Engineering Techniques Research (Eetr2022), 2023.
2. T. T. Teo, T. Logenthiran, and W. L. Woo, "Forecasting of photovoltaic power using extreme learning machine," in *2015 IEEE Innovative Smart Grid Technologies - Asia (ISGT ASIA)*, 3-6 Nov. 2015 2015, pp. 1-6, doi: 10.1109/ISGT-Asia.2015.7387113.
3. B. N. Alhasnawi, B. H. Jasim, P. Siano, and J. M. Guerrero, "A novel real-time electricity scheduling for home energy management system using the internet of energy," *Energies,* vol. 14, no. 11, p. 3191, 2021, doi: https://doi.org/10.3390/en14113191.
4. S. Garip and S. Ozdemir, "Optimization of PV and battery energy storage size in grid-connected microgrid," *Applied Sciences,* vol. 12, no. 16, p. 8247, 2022.
5. T. Zhang, H. B. Gooi, S. Chen, and T. Goh, "Cost-effectiveness studies of the BESSs participating in frequency regulation," in *2015 IEEE Innovative Smart Grid Technologies - Asia (ISGT ASIA)*, 3-6 Nov. 2015 2015, pp. 1-6, doi: 10.1109/ISGT-Asia.2015.7387077.
6. J. J. Kelly and P. G. Leahy, "Sizing Battery Energy Storage Systems: Using Multi-Objective Optimization to Overcome the Investment Scale Problem of Annual Worth," *IEEE Transactions on Sustainable Energy,* vol. 11, no. 4, pp. 2305-2314, 2020, doi: 10.1109/TSTE.2019.2954673.
7 C. U. o. T. Giorgos Georgiou, "A novel grid-connected microgrid energy management system with optimal sizing using hybrid grey wolf and cuckoo search optimization algorithm," *frontiers* 2022.
8. T. Kerdphol, Y. Qudaih, and Y. Mitani, "Battery energy storage system size optimization in microgrid using particle swarm optimization," 2014: IEEE, pp. 1-6, doi: 10.1109/ISGTEurope.2014.7028895.
9. K. S. El-Bidairi, H. D. Nguyen, S. D. G. Jayasinghe, T. S. Mahmoud, and I. Penesis, "A hybrid energy management and battery size optimization for standalone microgrids: A case study for Flinders Island, Australia," *Energy conversion and management,* vol. 175, pp. 192-212, 2018, doi: https://doi.org/10.1016/j.enconman.2018.08.076.
10. Y. Yang, S. Bremner, C. Menictas, and M. Kay, "Battery energy storage system size determination in renewable energy systems: A review," *Renewable and Sustainable Energy Reviews,* vol. 91, pp. 109-125, 2018/08/01/ 2018, doi: https://doi.org/10.1016/j.rser.2018.03.047.
11. J. Fedjaev, S.-A. Amamra, and B. Francois, "Linear programming based optimization tool for day ahead energy management of a lithium-ion battery for an industrial microgrid," 2016: IEEE, pp. 406-411, doi: 10.1109/EPEPEMC.2016.7752032.
12. T. Kerdphol, K. Fuji, Y. Mitani, M. Watanabe, and Y. Qudaih, "Optimization of a battery energy storage system using particle swarm optimization for stand-alone microgrids," *International Journal of Electrical Power & Energy Systems,* vol. 81, pp. 32-39, 2016/10/01/ 2016, doi: https://doi.org/10.1016/j.ijepes.2016.02.006.

13. M. Moghimi, R. Garmabdari, S. Stegen, and J. Lu, "Battery energy storage cost and capacity optimization for university research center," 2018: IEEE, pp. 1-8, doi: 10.1109/ICPS.2018.8369968.
14. S. Chen, T. Zhang, H. B. Gooi, R. D. Masiello, and W. Katzenstein, "Penetration Rate and Effectiveness Studies of Aggregated BESS for Frequency Regulation," *IEEE Transactions on Smart Grid,* vol. 7, no. 1, pp. 167-177, 2016, doi: 10.1109/TSG.2015.2426017.
15. M. D. A. Al-Falahi and M. Z. C. Wanik, "Modeling and performance analysis of hybrid power system for residential application," 2015: IEEE, pp. 1-6.
16. Z. W. Geem and Y. Yoon, "Harmony search optimization of renewable energy charging with energy storage system," *International Journal of Electrical Power & Energy Systems,* vol. 86, pp. 120-126, 2017.
17. K. S. Nimma, M. D. A. Al-Falahi, H. D. Nguyen, S. D. G. Jayasinghe, T. S. Mahmoud, and M. Negnevitsky, "Grey Wolf Optimization-Based Optimum Energy-Management and Battery-Sizing Method for Grid-Connected Microgrids," *Energies,* vol. 11, no. 4, p. 847, 2018. [Online]. Available: https://www.mdpi.com/1996-1073/11/4/847.
18. R. Mohanty and A. Pradhan, "Protection of DC and hybrid AC-DC microgrids with ring configuration," in *2017 7th International Conference on Power Systems (ICPS)*, 2017: IEEE, pp. 607-612.
19. F. Katiraei, R. Iravani, N. Hatziargyriou, and A. Dimeas, "Microgrids management," *IEEE power and energy magazine,* vol. 6, no. 3, pp. 54-65, 2008.
20. S. M. Nosratabadi, R.-A. Hooshmand, and E. Gholipour, "A comprehensive review on microgrid and virtual power plant concepts employed for distributed energy resources scheduling in power systems," *Renewable and Sustainable Energy Reviews,* vol. 67, pp. 341-363, 2017.
21. M. D. A. Al-falahi, S. D. G. Jayasinghe, and H. Enshaei, "A review on recent size optimization methodologies for standalone solar and wind hybrid renewable energy system," *Energy Conversion and Management,* vol. 143, pp. 252-274, 2017/07/01/ 2017, doi: https://doi.org/10.1016/j.enconman.2017.04.019.
22. B. Bahmani-Firouzi and R. Azizipanah-Abarghooee, "Optimal sizing of battery energy storage for micro-grid operation management using a new improved bat algorithm," *International Journal of Electrical Power & Energy Systems,* vol. 56, pp. 42-54, 2014/03/01/ 2014, doi: https://doi.org/10.1016/j.ijepes.2013.10.019.
23. R. G. Allwyn, A. Al-Hinai, and V. Margaret, "A comprehensive review on energy management strategy of microgrids," *Energy Reports,* vol. 9, pp. 5565-5591, 2023, doi: 10.1016/j.egyr.2023.04.360.
24. B. Zhou *et al.*, "Smart home energy management systems: Concept, configurations, and scheduling strategies," *Renewable and Sustainable Energy Reviews,* vol. 61, pp. 30-40, 2016.
25. M. W. Khan, J. Wang, M. Ma, L. Xiong, P. Li, and F. Wu, "Optimal energy management and control aspects of distributed microgrid using multi-agent systems," *Sustainable Cities and Society,* vol. 44, pp. 855-870, 2019.
26. X. He, X. Fang, and J. Yu, "Distributed energy management strategy for reaching cost-driven optimal operation integrated with wind forecasting in multimicrogrids system," *IEEE Transactions on Systems, Man, and Cybernetics: Systems,* vol. 49, no. 8, pp. 1643-1651, 2019.
27. D. E. Olivares *et al.*, "Trends in microgrid control," *IEEE Transactions on smartGridd,* vol. 5, no. 4, pp. 1905-1919, 2014.
28. N. Wu and H. Wang, "Deep learning adaptive dynamic programming for real time energy management and control strategy of micro-grid," *Journal of cleaner production,* vol. 204, pp. 1169-1177, 2018.

29. X. Xing, L. Xie, and H. Meng, "Cooperative energy management optimization based on distributed MPC in grid-connected microgrids community," *International Journal of Electrical Power & Energy Systems,* vol. 107, pp. 186-199, 2019.
30. H. Fontenot and B. Dong, "Modeling and control of building-integrated microgrids for optimal energy management–a review," *Applied Energy,* vol. 254, p. 113689, 2019.
31. Olivares, D.E., Mehrizi-Sani, A., Etemadi, A.H., Cañizares, C.A., Iravani, R., Kazerani, M., et al., 2014. Trends in microgrid control. IEEE Trans. Smart Grid 5, 1905–1919
32. Agnoletto, E.J., De Castro, D.S., Neves, R.V., Machado, R.Q., Oliveira, V.A., 2019. An optimal energy management technique using the ϵ-constraint method for grid-tied and stand-alone battery-based microgrids. IEEE Access 7, 165928–165942
33. Ilic-Spong, M., Christensen, J., Eichorn, K., 1988. Secondary voltage control using pilot point information. IEEE Trans. Power Syst. 3, 660–668.
34. Li, J., Liu, Y., Wu, L., 2016. Optimal operation for community-based multi-party microgrid in grid-connected and islanded modes. IEEE Trans. Smart Grid 9, 756–765.
35. Rahim, S., Javaid, N., Khan, R.D., Nawaz, N., Iqbal, M., 2019. A convex optimization based decentralized real-time energy management model with the optimal integration of microgrid in smart grid. J. Clean. Prod. 236, 117688.
36. C. K. Nayak, K. Kasturi, and M. R. Nayak, "Economical management of microgrid for optimal participation in electricity market," Journal of Energy Storage, vol. 21, pp. 657-664, 2019.
37. M. A. Husted, B. Suthar, G. H. Goodall, A. M. Newman, and P. A. Kohl, "Coordinating microgrid procurement decisions with a dispatch strategy featuring a concentration gradient," Applied Energy, vol. 219, pp. 394-407, 2018.

38. M. Petrollese, L. Valverde, D. Cocco, G. Cau, and J. Guerra, "Real-time integration of optimal generation scheduling with MPC for the energy management of a renewable hydrogen-based microgrid," *Applied Energy,* vol. 166, pp. 96-106, 2016.
39. A. A. Moghaddam, A. Seifi, and T. Niknam, "Multi-operation management of a typical micro-grids using Particle Swarm Optimization: A comparative study," *Renewable and Sustainable Energy Reviews,* vol. 16, no. 2, pp. 1268-1281, 2012/02/01/ 2012, doi: https://doi.org/10.1016/j.rser.2011.10.002.
40. A. Hassan, Y. M. Al-Abdeli, M. Masek, and O. Bass, "Optimal sizing and energy scheduling of grid-supplemented solar PV systems with battery storage: Sensitivity of reliability and financial constraints," *Energy,* vol. 238, p. 121780, 2022/01/01/ 2022, doi: https://doi.org/10.1016/j.energy.2021.121780.
41. J. Ahmad, M. Tahir, and S. K. Mazumder, "Dynamic economic dispatch and transient control of distributed generators in a microgrid," *IEEE Systems Journal,* vol. 13, no. 1, pp. 802-812, 2018.
42. S. Leonori, M. Paschero, F. M. Frattale Mascioli, and A. Rizzi, "Optimization strategies for Microgrid energy management systems by Genetic Algorithms," *Applied Soft Computing,* vol. 86, p. 105903, 2020/01/01/ 2020, doi: https://doi.org/10.1016/j.asoc.2019.105903.
43. J. Zhao, H. S. Ramadan, and M. Becherif, "Metaheuristic-based energy management strategies for fuel cell emergency power unit in electrical aircraft," *International Journal of Hydrogen Energy,* vol. 44, no. 4, pp. 2390-2406, 2019.
44. M. A. Shaheen, H. M. Hasanien, R. A. Turky, M. Ćalasan, A. F. Zobaa, and S. H. Abdel Aleem, "Opf of modern power systems comprising renewable energy sources using improved chgs optimization algorithm," *Energies,* vol. 14, no. 21, p. 6962, 2021.
45. C. G. Marcelino, J. V. C. Avancini, C. A. D. M. Delgado, E. F. Wanner, S. Jiménez-Fernández, and S. Salcedo-Sanz, "Dynamic Electric Dispatch for Wind Power Plants: A New Automatic Controller

System Using Evolutionary Algorithms," *Sustainability,* vol. 13, no. 21, p. 11924, 2021. [Online]. Available: https://www.mdpi.com/2071-1050/13/21/11924.

46. M. Nemati, K. Bennimar, S. Tenbohlen, L. Tao, H. Mueller, and M. Braun, "Optimization of microgrids short term operation based on an enhanced genetic algorithm," in *2015 IEEE Eindhoven PowerTech*, 29 June-2 July 2015 2015, pp. 1-6, doi: 10.1109/PTC.2015.7232801.
47. R.-K. Kim, M. B. Glick, K. R. Olson, and Y.-S. Kim, "MILP-PSO Combined Optimization Algorithm for an Islanded Microgrid Scheduling with Detailed Battery ESS Efficiency Model and Policy Considerations," *Energies,* vol. 13, no. 8, p. 1898, 2020. [Online]. Available: https://www.mdpi.com/1996-1073/13/8/1898.
48. L. Mellouk, M. Ghazi, A. Aaroud, M. Boulmalf, D. Benhaddou, and K. Zine-Dine, "Design and energy management optimization for hybrid renewable energy system- case study: Laayoune region," *Renewable Energy,* vol. 139, pp. 621-634, 2019/08/01/ 2019, doi: https://doi.org/10.1016/j.renene.2019.02.066.
49. K. Y. Lee and J. b. Park, "Application of Particle Swarm Optimization to Economic Dispatch Problem: Advantages and Disadvantages," in *2006 IEEE PES Power Systems Conference and Exposition*, 29 Oct.-1 Nov. 2006 2006, pp. 188-192, doi: 10.1109/PSCE.2006.296295.
50. G. Aghajani and N. Ghadimi, "Multi-objective energy management in a micro-grid," *Energy Reports,* vol. 4, pp. 218-225, 2018/11/01/ 2018, doi: https://doi.org/10.1016/j.egyr.2017.10.002.

51. J. Koskela, A. Rautiainen, and P. Järventausta, "Using electrical energy storage in residential buildings – Sizing of battery and photovoltaic panels based on electricity cost optimization," *Applied Energy,* vol. 239, pp. 1175-1189, 2019/04/01/ 2019, doi: https://doi.org/10.1016/j.apenergy.2019.02.021.
52. C. Yohwan and K. Hongseok, "Optimal scheduling of energy storage system for self-sustainable base station operation considering battery wear-out cost," in *2016 Eighth International Conference on Ubiquitous and Future Networks (ICUFN)*, 5-8 July 2016 2016, pp. 170-172, doi: 10.1109/ICUFN.2016.7537010.
53. M. Moghimi, R. Garmabdari, S. Stegen, and J. Lu, "Battery energy storage cost and capacity optimization for university research center," in *2018 IEEE/IAS 54th Industrial and Commercial Power Systems Technical Conference (I&CPS)*, 7-10 May 2018 2018, pp. 1-8, doi: 10.1109/ICPS.2018.8369968.
54. U. G. K. Mulleriyawage and W. X. Shen, "Optimally sizing of battery energy storage capacity by operational optimization of residential PV-Battery systems: An Australian household case study," *Renewable Energy,* vol. 160, pp. 852-864, 2020/11/01/ 2020, doi: https://doi.org/10.1016/j.renene.2020.07.022.
55. S. Grillo, A. Pievatolo, and E. Tironi, "Optimal Storage Scheduling Using Markov Decision Processes," *IEEE Transactions on Sustainable Energy,* vol. 7, no. 2, pp. 755-764, 2016, doi: 10.1109/TSTE.2015.2497718.
56. N. K. Paliwal, A. K. Singh, N. K. Singh, and P. Kumar, "Optimal sizing and operation of battery storage for economic operation of hybrid power system using artificial bee colony algorithm," *International Transactions on Electrical Energy Systems,* vol. 29, no. 1, p. e2685, 2019.
57. Z. W. Geem, J. H. Kim, and G. V. Loganathan, "A new heuristic optimization algorithm: harmony search," *simulation,* vol. 76, no. 2, pp. 60-68, 2001.
58. L. Urbanucci, "Limits and potentials of Mixed Integer Linear Programming methods for optimization of polygeneration energy systems," *Energy Procedia,* vol. 148, pp. 1199-1205, 2018/08/01/ 2018, doi: https://doi.org/10.1016/j.egypro.2018.08.021.

59. B. R. Mistry and A. Desai, "Privacy preserving heuristic approach for association rule mining in distributed database," in *2015 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS)*, 19-20 March 2015 2015, pp. 1-7, doi: 10.1109/ICIIECS.2015.7192972.
60. E. Gerhardt and H. M. Gomes, "Artificial bee colony (ABC) algorithm for engineering optimization problems," 2012, vol. 11, 4 ed.