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Application of MOPSO to the Optimisation of an Off-Grid Photovoltaic System in a Rural Fruit Farm

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ABSTRACT

An off-grid PV energy system's performance is primarily determined by the Total Net Present Cost (TNPC), which is utilized as a metric to measure the off-grid PV scheme's profitability, and the Loss of Power Supply Probability (LPSP) and Surplus Energy proportion (SEP), which are used to assess the Suggestion system's reliability. that provide enough electricity to a fruit orchard situated on 60 acres new city of Borg El Arab, Alexandria, Egypt multi-objective improvement of an optimum off-grid PV power framework was implemented. Dribble water system and artesian wells are utilized on the site. Apple trees and grapevines cover 40 acres of the farm's land, with another 20 acres planted in grapes. The output power of an off-grid photovoltaic power framework was estimated utilization mathematical models, which were presented. This study's findings revealed the optimal amount of battery banks and PV panels, the system's TNPC, and the price of kWh delivered by the proposed framework, as well as the Surplus Energy Percentage (SEP).

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1. Introduction

Electricity is at the core of contemporary civilization, providing energy to institutions such as healthcare, industry, education, convenience, and entertainment. According to the Stated Policies Scenario, global power demand is projected to increase by 2.1 percent per year by 2040, almost doubling the amount of primary energy supply. This strategy raises the percentage of electricity in total final energy consumption from 19 percent in 2018 to 24 percent in 2040. Power plays a bigger role in the Sustainable Development Scenario, accounting for 31% of total power consumption [1].

Renewables, especially wind and solar PV, have provided three-quarters of the growth in energy production in recent years, owing to government support and lower development costs. Renewable energy production will increase from 26 percent to 44 percent by 2040, with solar photovoltaic and wind combined rising from 7 percent to 24 percent of total power output. Renewable energy systems may be set up to run on or off the grid. Multiple energy sources are typically utilized to overcome the issue posed by the unpredictable idea of environmentally of renewable power resources, which is exacerbated by the fact that these resources are entirely reliant on unpredictable weather conditions, which do not always produce energy with the precision that is required. Wind and solar energy are often complimentary, furthermore, a more steady power source, like biomass energy, may be utilized to improve the consistency and security of the energy delivered by this hybrid collection [2]–[13].

The process of sizing hybrid renewable energy systems (HRES) is complex due to the unpredictable supply of renewable resources, and a reasonable balance between economic and dependability considerations should be achieved. As a consequence, various patterns (algorithms) and programming apparatuses have been developed and are being utilized to improve HRES designs, with more being developed on a regular basis. A portion of the product apparatuses used in the literature are IHOGA TRYNS and Hybrid Optimization of Multiple Energy Resources (HOMER) [14]–[20].

In [21] and [22], the authors used HOMER Pro software to integrate specialized, natural, and monetary factors in order to provide a leader system that is efficient in the arranging and appraisal of hybrid renewable energy-based micro grid (HRE-MG) frameworks. When assessing the optimal mix of various sub frameworks dependent on their specialized, natural, and monetary exhibitions to make the HRE-MG, the net present value (NPV) was found to be the most trustworthy measure. Then, the systems' configurations were evaluated according to their absolute life cycle price (too known as net present value), and the configuration with the lowest overall life cycle price was chosen as the best. Homer software has also been used to evaluate technically viable and ecologically acceptable distributed power framework designs based on total yearly expenses Beside levelized cost of energy (LCOE) in [23] and [24].

When the authors of [25] looked at the techno-economic of a hybrid PV-Wind- Battery framework, they centered on the impact of a system's loss of power supply probability (LPSP) on the cost of energy generation (COE). Meanwhile, the authors in [26] optimized the storage of batteries in a wind-photovoltaic-battery off-grid framework, that took into account the impact that the saturation factor of solar and wind energy had on the economics and dependability of the system as well as the unwavering quality of the framework.

The main point of this study is to decide the best numeral and composition of components for a hybrid off-grid framework. In this review, MOPSO strategy was utilized to analyze three objective functions: TNPC which is utilized as a metric to measure the profitability of the off-grid PV scheme, and LPSP and SEP, which are utilized to assess the unwavering quality of the Suggestion framework.

2. Methodology

The following part will explain the methodology took on to track down an answer for ideally estimating an off-grid power generation plan. This segment will likewise incorporate data with respect to required sources of info, the goal work, enhancement calculations, constraints, dispatch procedure, etc.

There are several suspicions which are thought of while planning the calculation:

The PV off-grid system runs 24 hours a day and thus, the equipment breakdowns, the scheduled

- repairs, etc. are not expressly considered, because of the continuous electrification process.
- The technology utilized at the start of project preparation are expected to be usable for the entire duration of the project.
- The load profile, solar radiation, and ambient temperature are accepted to stay consistent over the course of the project.
- The task life is design to be 25 years, the interest proportion is 9.5 %, and the inflation rate is 8.33% [27].

2.1 Solar Recourses

The farm is situated at 29°35' E longitude and 30°49' N latitude, which is in Egypt. The hourly information on sunlight based radiation and temperature for the research region was obtained by using the Copernicus Atmosphere Monitoring Service (CAMS) irradiation Service v3.0 all-sky radiation data from the Copernicus Atmosphere Monitoring Service (CAMS) (as inferred from satellite information) [28].

Figure 1 depicts the average daily solar radiation received by the investigated region on a daily basis. During the research period, the months with the greatest solar radiation (more than 5.0 kWh/m2/day) are March to September, whereas those with the lowest solar radiation (less than or equal to 5.0 kWh/m2/day) are November to February. 5.58 kWh/m2/day is the yearly mean value of solar radiation over the whole globe.

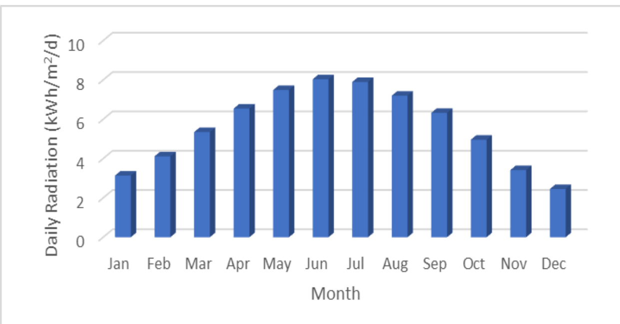

Figure 1 Monthly medium everyday sunlight-based irradiation for the study region.

2.2 Load Profile of the Study Area

Our study area is in Alexandria, Egypt's new city of Borg El Arab. Dribble water system and artesian wells, which are the most effective methods of water supply that are used to provide the water required by farms, are used on the property. As a result, water pumping is the primary cause of electrical load demand. Since the possibilities for utilizing renewable energy technology in this area are encouraging, this research focuses on the components of off-grid renewable energy systems that are actually feasible such as photovoltaic (PV), and battery banks.

It is critical for an optimized system design to accurately predict the load request in the location. The load request is produced by water pumping and water system operations, which account for the majority of the total load demand in the targeted 60-acre farm.

The hypothetical energy required for pumping water is named water horsepower (WHP) and can be Determine from the equation [29]:

$$WHP = Q \times H/3960 \quad (1)$$

Due to the efficiency of the engine, the energy plant's capacity should be greater than the water horsepower. thereupon study, a pump effectiveness of 50% is utilized.

The brake horsepower (BHP), is determined by

$$BHP = \frac{WHP}{(pumping\ plant\ efficiency)} \quad (2)$$

We computed indicative rates for the irrigation water requirements for the apple and grape trees, taking into account the farm's specific characteristics, including soil type and irrigation water source, as well as the origin of the water and the planted species. Additionally, the irrigation system's necessary power demand for each month is computed and recorded. Assuming that the irrigation is on for 24 hours each day.

In this study, we utilize a 3.5 kW water pump with a head of 140 m to power the system. Figure 2 illustrates the seasonal load profile of the water system load, which has a medium of 393 kWh/d and a peak of 111 kW.

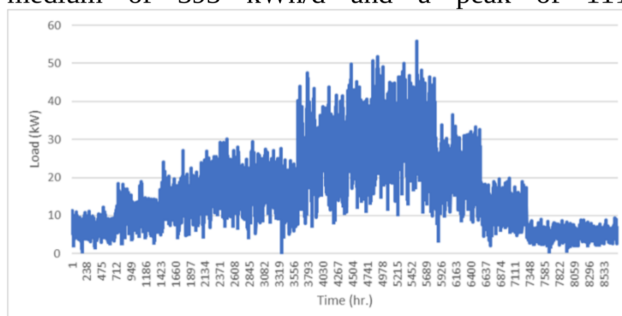

Figure 2: The seasonal load profile of the water system load.

Every hour load profile for a time of one year was combined measurably utilizing the medium everyday load desired. The load profile was created by utilizing Hybrid Optimization of Multiple Energy Resources (Homer®) software tool [30]. As a result, HOMER has synthesized load data by introducing some randomness in accordance with the values given for the daily changeability and the time step to time step inconstancy, which in this research have been calculated to be 15% and 20% of the total load data, respectively.

2.3 Proposed Off- Grid System Configuration

As shown in Figure 3 comprises for the most part of PV boards with MPPT, battery banks, and an inverter.

When it comes to providing electricity to the system, the PV system takes precedence. Exceeding demand results in excess energy being utilized to freightage the battery banks depending on the situation when it becomes accessible for usage. After that, the stored power in the battery banks is utilized to meet load needs at times when the off-grid system does not provide enough energy. overabundance power left over in the wake of charging the battery bank is referred to as lost power, and it would be used to power a Dump load. A dump load is a kind of electrical resistance heater that is utilized to accept the whole system's produced power to prevent the battery from overcharging and damaging itself [31]. From all possible combinations, it is selected the one that supplies the load at the least cost.

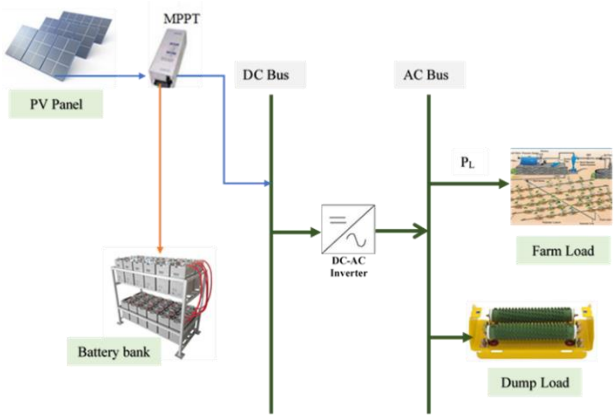

Figure 3 General block diagram of the proposed off-Grid system.

3. Problem formulation

The suggested system is sized to satisfy the expected load at the lowest possible expense. The suggested system features batteries for energy storage to maintain supply reliability throughout the day and night, including on cloudy days. This was accomplished by maximizing the capacities of solar PV panels and battery banks, which are regarded as the primary decision variables in the issue. The objective function, operating approach of the framework, and a short outline of the suggested improvement algorithm are introduced in this section.

The fundamental target of current review is to suggest an optimized off-grid IRES which can give continuous power supply to a 60-acre fruit farm. The multi-objective function proposed involves three objective functions: TNPC, SEP and LPSP.

For this situation, two nonstop choice factors of N_{PV} and N_{bat} ought to be ideally changed.

TNPC is the total net present cost of the framework which is made out of the NPC of battery banks and the PV.

$$TNPC = \sum_{n=0}^{N_{proj}} \left(C_I(n) + C_R(n) + C_{O\&M}(n)\right) \times \frac{1}{(1+I_r)^n} \quad (3)$$

$$C_I = \sum N_{PV} C_{I_{PV}} + N_{bat} C_{I_{bat}} \quad (4)$$

$$C_R = \sum N_{PV} C_{R_{PV}} + N_{bat} C_{R_{bat}} \quad (5)$$

$$C_{O\&M} = \sum N_{PV} C_{O\&M_{PV}} + N_{bat} C_{O\&M_{bat}} \quad (6)$$

The LPSP for a certain time T may be computed using the following formula:

$$LPSP = \frac{\sum_{t=1}^{T} P_{deficit}(t)\,.\,\Delta t}{\sum_{t=1}^{T} P_{demand}(t)\,.\,\Delta t} \quad , T = 8760 \; and \;\; \Delta t = 1. \quad (7)$$

SEP, on the other hand, is characterized as the amount of squandered energy partitioned by the aggregate amount of renewable power delivered by the off-grid system [32]. In order for the SEP to be valid, it must satisfy the constraint $0 \le SEP \le 1$.

$$SEP = \frac{\sum wasted\ energy}{\sum E_{PV}} \quad (8)$$

The following is an expression for the objective function for this multi-objective optimization problem:

$$minimize: \begin{cases} F_1 = TNPC \\ F_2 = LPSP \\ F_3 = SEP \end{cases} \quad (9)$$

$$subjct\ to: \begin{cases} N_{PV}^{min} \le N_{PV} \le N_{PV}^{max} \\ N_{bat}^{min} \le N_{bat} \le N_{bat}^{max} \\ 0 \le LPSP \le LPSP_{max} \,, LPSP_{max} = 5\% \\ 0 \le SEP \le SEP_{max} \,, SEP_{max} = 40\% \end{cases} \quad (10$$

3.1 The Power Management Technique of the Suggestion System

The proposed methodology seeks the optimum combination of PV energy frameworks and battery banks that minimizes the cost of the specified LPSP as per the simulated scenario. In this suggested framework, we basically have three scenarios that may occur:

scenario 1: whether the energy produced by the PV generators is equivalent to the necessary requirement, the battery bank will not be utilized.

scenario 2: As the energy created by the PV generators exceeds the requirement, the surplus energy is deposited in the batteries. If there is some electricity leftover after charging the batteries, it would be absorbed in a dump load.

scenario 3: The energy produced by the PV generators is insufficient to satisfy demand: The storage battery bank is used to cover the shortfall.

3.2 multi-objective particle swarm optimization algorithm (MOPSO)

MOPSO strategy had been utilized in this work to handle the power management dilemma.

Consequently, the MOPSO method is used to get the Pareto front of the improvement issue. For this study, the MOPSO method was modified from [33] and [34].

It is possible to determine the initial capital expenses based on the information provided in Table 1.

Parameter	Unit	Value
PV panels		
Rated power	kW	0.305
Lifetime	years	25
Initial cost	$	550
O&M cost	$	5
Flooded Lead Acid Battery (Trojan 100AH 48VDC)		
Capacity	kWh	4.8
Lifetime	years	10
Initial cost	$	672
O&M cost	$	10

TABLE 2: EXPENSES AND DIFFERENT PARAMETERS FOR MONETARY EXAMINATION.

4. Results and discussions

It was decided to develop a MATLAB program to decide the optimal quantity of PV panels and battery banks that reduce the total net present cost, LPSP, and SEP as much as possible. This program's input data consists of the following items:

Hourly solar radiation and ambient temperature.

Characteristic of PV module, and the Flooded Lead Acid battery.

Hourly load demand.

The outputs of this program are:

The optimum numeral of PV panels, and the battery banks

The TNPC of the system and the cost of kWh generated from the proposed system,

The Surplus Energy Percentage (SEP).

The Annual life-cycle expense of the suggested hybrid power framework is processed dependent on principal, operating, and M&O expenses of various power parts. These costs of framework parts are listed in Table 1.

The optimal goals given in this work are to reduce TNPC, SEP, and LPSP, where the TNPC is utilized to evaluate hybrid framework economies, the LPSP is used to assess hybrid system dependability, and the SEP is used to investigate hybrid framework Ease of use and effectiveness. The complete number battery banks and PV is one of the optimization factors to consider.

A representation of the MOPSO algorithm's Pareto front estimate is shown in Figure 4.

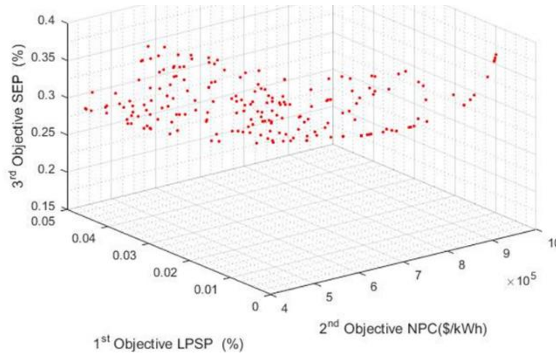

Figure 4. The three objective functions of the Pareto front.

The Pareto front permits the leader to pick an ideal arrangement dependent on assumptions for lower SEP, COE, or LPSP from the ideal arrangement's assortment.

According to the objective function restriction, the MOPSO algorithm was designed to run for 200 iterations with the maximum LPSP set to 5 percent and the maximum SEP set to 40 percent.

As part of this research, a dynamic methodology is used in order to completely show the accessibility of the enhancement process and to allow the leader to more thoroughly Evaluation the capabilities of the hybrid technique [35]. every point on the Pareto front is represented as a tridimensional vector [TNPC(i), LPSP(i), SEP (i)] in this study, and the Euclidean

space between each three-point is computed. The point on the front of Pareto's diagram with the smallest distance between other points is selected and designated as the ultimate optimal solution [36].

$$Optimal\ Sol. = min \sum_{k=1}^{N_p} \sqrt{\begin{matrix}(TNPC(i) - TNPC(k))^2 + (LPSP(i) - LPSP(k))^2 \\ +(SEP(i) - SEP(k))^2 \quad i \in [1, N_p]\end{matrix}} \qquad (11)$$

Where,

$[TNPC(i) - TNPC(k)], [LPSP(i) - LPSP(k)], and$ $[SEP(i) - SEP(k)]$ indicates three random points on the Pareto front and N_p is the complete numeral of points of the Pareto front.

The best configuration includes 374 PV panels (114.07 kW) and 174 battery banks with an LPSP of 2.15% and a SEP of 31.97% with a TNPC of 577,736 $ and an energy expense of 0.298 $/kWh.

Because the planned framework is for a farm, small LPSP framework would be prohibitively expensive. Furthermore, a too generous LPSP system would have a negative impact on on-farm activities. A minimum TNPC of $420,041 is calculated for the system at an LPSP of 4.6 percent and a SEP of 31.33 percent. However, the maximum TNPC calculated for the system is $ 909,067, which represents a 216.4 percent increase in the system cost at a zero percent LPSP and a SEP of 31.33 percent.

5. Conclusion

The most important objective of this paper is the design of an optimum off-grid PV power framework is to estimate the power demand of an irrigation load on a fruit farm in Egypt by using the sun powered assets available in the study area. The system uses (MOPSO) technique to see as the ideal system size. TNPC, LPSP, and Surplus Energy Percentage (SEP) comprise the multi-objective function utilized in this study. A PV off-grid system was designed for a 60-acre fruit orchard near Alexandria, Egypt's new city of Borg El Arab. On the land, there is dribble water system and artesian wells. Specifically, three scenarios are presented in this article to process the multi-objective sizing problem that arises from the connection between the off-grid PV energy system and the electricity demand. According to the first scenario, the power generated by the PV dynamo is equivalent to the demand; as per the second situation, the energy delivered by the PV dynamo is more than the demand; but according to the third scenario, the energy delivered by the PV generators is incomplete to meet demand.

6. References

[1] “World Energy Outlook 2019,” Int. Energy Agency, 2019.

[2] M. Ferrara et al., “Design optimization of renewable energy systems for NZEBs based on deep residual learning,” Renew. Energy, vol. 176, pp. 590–605, 2021, doi: https://doi.org/10.1016/j.renene.2021.05.044.

[3] M. M. Samy, M. I. Mossad, M. F. El-Naggar, and S. Barakat, “Reliability Support of Undependable Grid Using Green Energy Systems; Economic Study,” IEEE Access, vol. 9, pp. 14528–14539, 2021.

[4] M. M. Samy, H. H. Sarhan, S. Barakat, and S. A. Al-Ghamdi, “A Hybrid PV-Biomass Generation Based Micro-Grid for the Irrigation System of a Major Land Reclamation Project in Kingdom of Saudi Arabia (KSA)-Case Study of Albaha Area,” in 2018 IEEE International Conference on Environment and Electrical Engineering and 2018 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), 2018, pp. 1–8.

[5] S. Barakat, H. Ibrahim, and A. A. Elbaset, “Multi-Objective Optimization of Grid-Connected PV-Wind Hybrid System Considering Reliability, Cost, and Environmental Aspects,” Sustain. Cities Soc., p. 102178, 2020.

[6] S. Barakat, M. M. Samy, M. B. Eteiba, and W. I. Wahba, “Viability study of grid connected PV/Wind/Biomass hybrid energy system for a small village in Egypt,” in Power Systems Conference (MEPCON), 2016 Eighteenth International Middle East, 2016, pp. 46–51.

[7] A. M. Ghaithan, A. Al-Hanbali, A. Mohammed, A. M. Attia, H. Saleh, and O. Alsawafy, “Optimization of a solar-wind-grid powered desalination system in Saudi Arabia,” Renew. Energy, vol. 178, pp. 295–306, 2021, doi: https://doi.org/10.1016/j.renene.2021.06.060.

[8] M. Jafari and Z. Malekjamshidi, “Optimal energy management of a residential-based hybrid renewable energy system using rule-based real-time control and 2D dynamic programming optimization method,” Renew. Energy, vol. 146, pp. 254–266, Feb. 2020, doi: 10.1016/j.renene.2019.06.123.

[9] A. F. Tazay, M. M. Samy, and S. Barakat, “A Techno-Economic Feasibility Analysis of an Autonomous Hybrid Renewable Energy Sources for University Building at Saudi Arabia,” J. Electr. Eng. Technol., 2020.

[10] K. Hori, J. Kim, R. Kawase, M. Kimura, T. Matsui, and T. Machimura, “Local energy system design support using a renewable energy mix multi-objective optimization model and a co-creative optimization process,” Renew. Energy, vol. 156, pp. 1278–1291, 2020, doi: https://doi.org/10.1016/j.renene.2019.11.089.

[11] M. M. Samy and S. Barakat, “Hybrid Invasive Weed Optimization-Particle Swarm Optimization Algorithm for Biomass/PV Micro-grid Power System,” in 2019 21st International Middle East Power Systems Conference (MEPCON), 2019, pp. 377–382.

[12] R. Shi, S. Li, P. Zhang, and K. Y. Lee, “Integration of renewable energy sources and electric vehicles in V2G network with adjustable robust optimization,” Renew. Energy, vol. 153, pp. 1067–1080, 2020, doi: https://doi.org/10.1016/j.renene.2020.02.027.

[13] M. M. Samy, H. I. Elkhouly, and S. Barakat, “Multi-objective optimization of hybrid renewable energy system based on biomass and fuel cells,” Int. J. Energy Res., vol. 45, no. 6, pp. 8214–8230, 2021.

[14] M. Morad, M. Nayel, A. A. Elbaset, and A. I. A. Galal, “Sizing and Analysis of Grid-Connected Microgrid System for Assiut University Using HOMER Software,” in 2018 Twentieth International Middle East Power Systems Conference (MEPCON), 2018, pp. 694–699.

[15] J. Kumari, P. Subathra, J. E. Moses, and D. Shruthi, “Economic analysis of hybrid energy system for rural electrification using HOMER,” in 2017 International Conference on Innovations in Electrical, Electronics, Instrumentation and Media Technology (ICEEIMT), 2017, pp. 151–156.

[16] V. Khare, S. Nema, and P. Baredar, "Optimization of hydrogen based hybrid renewable energy system using HOMER, BB-BC and GAMBIT," Int. J. Hydrogen Energy, vol. 41, no. 38, pp. 16743–16751, 2016, doi: 10.1016/j.ijhydene.2016.06.228.

[17] V. Khare, S. Nema, and P. Baredar, "Optimisation of the hybrid renewable energy system by HOMER, PSO and CPSO for the study area," Int. J. Sustain. Energy, vol. 36, no. 4, pp. 326–343, 2017.

[18] S. Goyal, S. Mishra, and A. Bhatia, "A comparative approach between different optimize result in hybrid energy system using HOMER," Int. J. Electr. Comput. Eng., vol. 9, no. 1, p. 141, 2019.

[19] S. Barakat, M. M. Samy, M. B. Eteiba, and W. I. Wahba, "Viability study of grid connected PV/Wind/Biomass hybrid energy system for a small village in Egypt," 2017. doi: 10.1109/MEPCON.2016.7836870.

[20] M. A. Baseer, A. Alqahtani, and S. Rehman, "Techno-economic design and evaluation of hybrid energy systems for residential communities: Case study of Jubail industrial city," J. Clean. Prod., vol. 237, p. 117806, 2019, doi: https://doi.org/10.1016/j.jclepro.2019.117806.

[21] M. R. Elkadeem, S. Wang, A. M. Azmy, E. G. Atiya, Z. Ullah, and S. W. Sharshir, "A systematic decision-making approach for planning and assessment of hybrid renewable energy-based microgrid with techno-economic optimization: A case study on an urban community in Egypt," Sustain. Cities Soc., vol. 54, no. April 2019, p. 102013, 2020, doi: 10.1016/j.scs.2019.102013.

[22] M. R. Elkadeem, S. Wang, S. W. Sharshir, and E. G. Atia, "Feasibility analysis and techno-economic design of grid-isolated hybrid renewable energy system for electrification of agriculture and irrigation area: A case study in Dongola, Sudan," Energy Convers. Manag., vol. 196, no. August, pp. 1453–1478, 2019, doi: 10.1016/j.enconman.2019.06.085.

[23] O. D. T. Odou, R. Bhandari, and R. Adamou, "Hybrid off-grid renewable power system for sustainable rural electrification in Benin," Renew. Energy, vol. 145, pp. 1266–1279, Jan. 2020, doi: 10.1016/j.renene.2019.06.032.

[24] M. S. Islam, "A techno-economic feasibility analysis of hybrid renewable energy supply options for a grid-connected large office building in southeastern part of France," Sustain. Cities Soc., vol. 38, no. November 2017, pp. 492–508, 2018, doi: 10.1016/j.scs.2018.01.022.

[25] M. S. Javed and T. Ma, "Techno-economic assessment of a hybrid solar-wind-battery system with genetic algorithm," Energy Procedia, vol. 158, pp. 6384–6392, 2019.

[26] T. Ma and M. S. Javed, "Integrated sizing of hybrid PV-wind-battery system for remote island considering the saturation of each renewable energy resource," Energy Convers. Manag., vol. 182, pp. 178–190, 2019.

[27] CBE, "Inflation Rates."

[28] MINES ParisTech, "Copernicus Atmosphere Monitoring Service (CAMS)."

[29] G. Fipps, "Calculating horsepower requirements and sizing irrigation supply pipelines," 1995.

[30] T. Lambert, P. Gilman, and P. Lilienthal, "Micropower system modeling with HOMER," Integr. Altern. sources energy, vol. 1, no. 15, pp. 379–418, 2006.

[31] A. Heydari and A. Askarzadeh, "Optimization of a biomass-based photovoltaic power plant for an off-grid application subject to loss of power supply probability concept," Appl. Energy, vol. 165, pp. 601–611, 2016, doi: 10.1016/j.apenergy.2015.12.095.

[32] S. Diaf, D. Diaf, M. Belhamel, M. Haddadi, and A. Louche, "A methodology for optimal sizing of autonomous hybrid PV/wind system," Energy Policy, vol. 35, no. 11, pp. 5708–5718, 2007.

[33] S. Mostaghim and J. Teich, "Strategies for finding good local guides in multi-objective particle swarm optimization (MOPSO)," in Proceedings of the 2003 IEEE Swarm Intelligence Symposium. SIS'03 (Cat. No. 03EX706), 2003, pp. 26–33

[35] A. R. Starke, J. M. Cardemil, R. Escobar, and S. Colle, "Multi-objective optimization of hybrid CSP+ PV system using genetic algorithm," Energy, vol. 147, pp. 490–503, 2018.

[36] S. Guo, Y. He, H. Pei, and S. Wu, "The multi-objective capacity optimization of wind-photovoltaic-thermal energy storage hybrid power system with electric heater," Sol. Energy, vol. 195, no. August 2019, pp. 138–149, 2020, doi: 10.1016/j.solener.2019.11.063.