A Review Article of Analysis Optimal sizing of a standalone microgrid system

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***Abstract*: This paper focuses on the minimization of the overall cost (installation plus annual maintenance cost) of the hybrid standalone system using the advantages of bio-inspired optimization techniques and mathematical modelling of considered energy sources (Photovoltaic, wind, battery, and diesel generator) of the system. The system operation is managed in such a way that the system can harvest the maximum amount of energy from renewable sources and the diesel generators are utilized in the case when renewable sources are failed to meet the load demand. The analysis is carried out by considering Gaussian distributed hourly load demand. The monte-Carlo simulation is carried out to verify the system robustness with the derived optimal number of renewable sources considering the uncertainties of wind speed and solar irradiation over the period. Finally, a plot of the probability of failure vs unmet load is generated using the software MATLAB to support the results of the Monte-Carlo simulation.**

***Keywords*: Mathematical modeling, bio-inspired optimization, Monte-Carlo simulation, probability of failure.**

1. INTRODUCTION

World electricity demand is rising steadily at twice the rate of overall energy usage. The challenge is to meet the rising demand with decelerating fossil fuels and rising fuel prices. As reported by the World Energy Council, the world primary energy demand increased about 26% in the past decade and the electricity demand alone is predicted to rise about 81% with 40000 TWh of electric energy by 2040. About 70% of this growing energy demand will be from the developing countries like India and China.

For future generations, energy has become one of the most important necessities. Coal, fuel, and gas are currently used, but because of over-dependence, these resources have become costly and decreasing, as well as emitting greenhouse gases that are harmful to human health. As a result, renewable energy sources such as solar and wind energy were developed to alleviate the difficulties[1] for future generations. Renewable energy sources used in hybrid systems with energy storage and diesel generators are the least cost and more effective than a single-source system. Wind and solar energy are examples of renewable energy sources that need installation, acquisition, and management. These tasks have a cost attached to them, which can be reduced via optimization strategies. An optimization called genetic algorithm is used in this work, to optimize the cost function and reduce overall cost.

All these factors have urged the world governments to look for alternative sources of energy to meet future demands and combat environmental degradation. Many government policy measures and financial motivations are being provided to drive down the investment and operation costs of renewable. Thermal power generation using coal is a major contributor to carbon-di-oxide and other greenhouse gas emissions which contribute to global warming and ozone depletion. Nuclear power provides about 11% of the world's electricity and is also proclaimed to be a benign source of electricity with cheaper operating costs.

Abundant availability of renewable sources in India enables to strengthen its energy portfolio by reducing the dependence on imported fossil fuels. Hydro, Solar and Wind are the three prime pillars of renewable energy generation in the world today

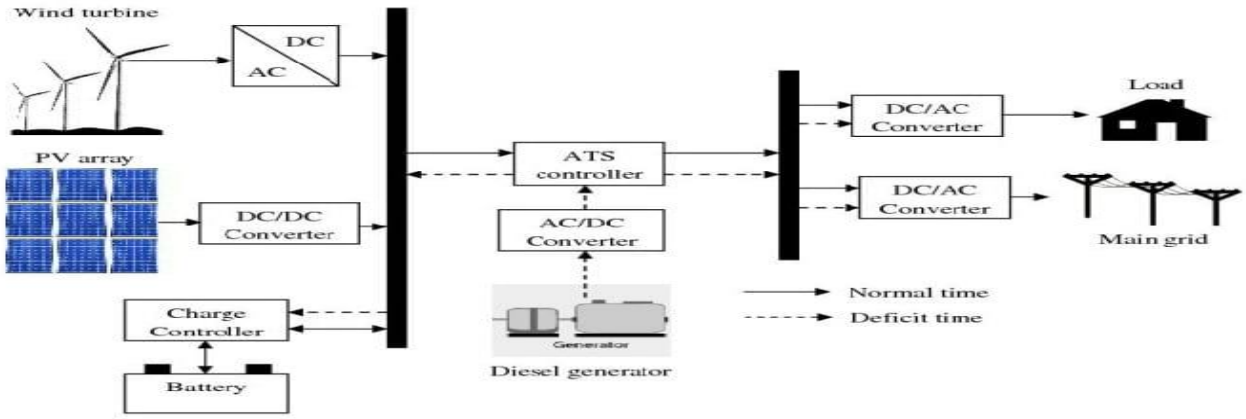

FIG.1 standalone micro grid system

2. GENETIC ALGORITHM

Natural selection is the inspiration for genetic algorithms, which are a subset of evolutionary algorithms. Crossover, mutations, and selection are all common uses for genetic algorithms. This algorithm is inspired by Charles Darwin's theory of evolution, which follows the survival of the fittest reproduction process to generate the next generation of off spring.

The offspring are chosen from the available population throughout the selection phase. If the present generation is physically fitter than the previous generation, it will have a higher chance of survival. This process continues until the fittest candidate emerges. We consider the best solution from a huge group of solutions in this genetic method.

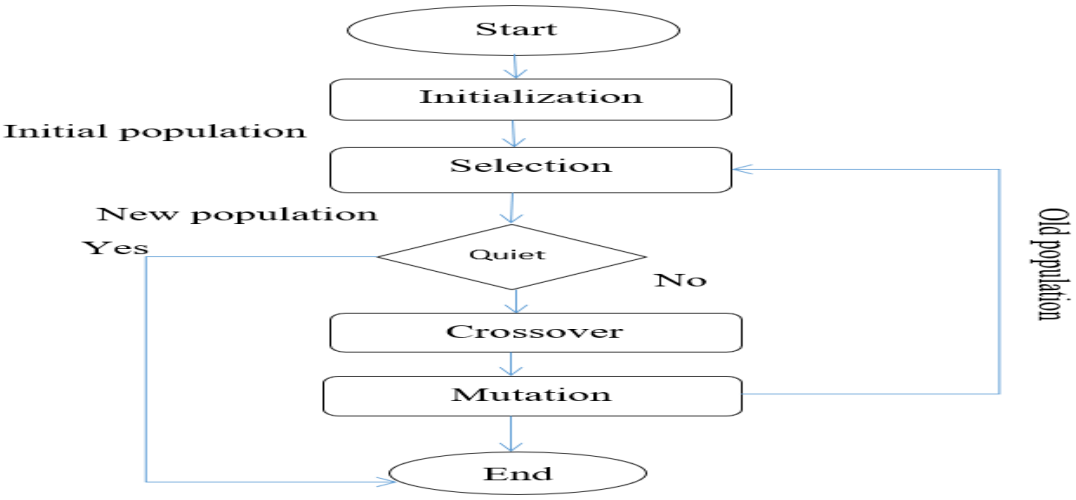

FIG.2 THE GENETIC ALGORITHM CONSISTS OF FIVE STAGES[13]

3. INITIAL POPULATION

Each individual is a solution to the problem, and the population is nothing more than a collection of individuals. A string is used to represent the collection of genes in this genetic process. These strings are represented by binary values, and the genes in a chromosome will be encoded. Renewable energy sources used in hybrid systems with energy storage and diesel generators are the least cost and more effective than a single-source system.

i. Fitness function:

This function describes an individual's ability to collaborate with others. This yields a fitness score, which indicates the likelihood that this person will be chosen for reproduction.

ii. Selection:

The fittest individuals will be chosen, and their genes will be passed down to future generations. The fitness score will be used to determine which pair will be used for reproduction. As a result, individuals with a high score have a better chance of being chosen for reproduction.

iii. Mutation:

With a low random probability, the genes of new offspring will be vulnerable to mutation. The bits in a bit string can be inverted in this case. As a result, the mutation will occur to maintain the population's variety and prevent premature convergence.

iv. Monte Carlo simulation:

Monte Carlo simulation is a mathematical methodology for quantitative risk analysis and decision making that may be implemented in software. This simulation shows the odds and probable consequences of a given action. Surprisingly, scientists working on the atomic bomb were the first to employ this simulation.

4. LITERATURE REVIEW

Some of the recent studies that are base to this research are

Title of the paper	Author	The base for this research
Optimal sizing of a wind/solar/battery hybrid grid-connected microgrid system	Umer Akram et. al[8]	The algorithm proposed consists of two key essentials: maximum reliability and minimum cost
Optimal Sizing of PV/wind/diesel hybrid microgrid system using multi-objective selfadaptive differential evolution algorithm	Makbul A.M. Ramli et. al[9]	optimal sizing of a PV/wind/diesel HMS with battery storage is conducted using the Multi-Objective Self-Adaptive Differential Evolution (MOSaDE) algorithm
Optimal sizing of an autonomous photovoltaic/wind/battery/diesel generator microgrid using grasshopper optimization algorithm	Abba Lawan Bukar et. al[10]	Based on the deficiency of power supply probability (DPSP) and energy cost, the proposed grass hopper algorithm is applied to an autonomous microgrid system to determine the optimal system configuration that will reliably supply energy demand.

In [1] sizing model of a standalone PV system is proposed based on integrated programming. Hourly sun radiation and ambient temperature were employed in this study. The model generates batteries and the ideal quantity of PV modules for installation. For PV device installers and policymakers, the model is a helpful sizing technique. When finding the appropriate sizes, the model takes site-specific data into account. The viability of the proposed paradigm is assessed through a case study in Bursary, Nigeria.

In [2] we look at the optimum sizing of grid-connected rooftop photovoltaic systems from the viewpoint of a household. We calculate the profit-maximizing size for over 800 Austrian houses under a variety of electricity tariffs and subsidy schemes, taking into consideration economies of scale in comparison to the investment costs of solar systems with installed capacities ranging from 1 to 20 kW. To estimate size-dependent investment costs, data on solar systems installed in Austria from 2008 to 2013 was examined. From a social cost standpoint, the findings are contrasted to the overall investment costs to add a particular quantity of electricity in suburban regions.

In [3] for a hybrid energy system, an optimized technique for optimum sizing and position is provided. For a remote location, a self-contained photovoltaic battery-diesel system is considered. Technical, economic, social, and environmental factors are all taken into account. Changes in fuel prices, the initial expenses of the hybrid system's PV and batteries, and interest rates are all taken into account.

In [4] it addressed the issue of micro grid device scaling design using the Grasshopper Optimization Tool (GOA), a novel nature-inspired met heuristic optimization algorithm. Based on power supply likelihood and energy cost, the suggested algorithm is used in an autonomous micro grid system to determine the best system configuration for effectively supplying electricity demand. To begin, a powerful rule-based energy management system (EMS) is proposed to coordinate power flow among the micro grid's multiple device components.

In [5] micro grid projects, which mix solar photovoltaic (PV) power and wind energy with diesel generators, are intriguing energy sources that are economically viable for present and future use in light of growing energy demand and depletion of existing sources, according to the article. This research uses the Multi-Objective Self-Adaptive Differential Evolution method to optimize the size of a PV/wind/diesel HMS with battery storage for Yanbu, Saudi Arabia. The multi-objective optimization methodology is used to tackle the priorities concurrently and individually, resulting in a reduction in processing time.

5. CONCLUSION

In this study the total cost of the hybrid standalone system (installation + yearly maintenance) is reduced by using the benefits of bio-inspired optimization approaches and mathematical modelling of the system's energy sources (photovoltaic, wind, battery, and diesel generator). The system is operated in such a manner that it can collect the greatest amount of energy from renewable sources while also using diesel generators in the event when renewable sources fail to fulfil load demand. The research is conducted using a Gaussian distributed hourly load demand model. The Monte Carlo simulation is used to assess the system's resilience with the calculated optimum number of renewable sources, taking into account the uncertainties in wind speed and solar irradiation over time. Finally, to support the Monte-Carlo simulation findings, a plot of the chance of failure vs. unmet load is constructed using the programme MATLAB.

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REFERENCES

[1] A. Abdelkader, A. Rabeh, D. Mohamed Ali, and J. Mohamed, "Multi-objective genetic algorithm based sizing optimization of a stand-alone wind/PV power supply system with enhanced battery/supercapacitor hybrid energy storage," *Energy*, vol. 163, pp. 351–363, 2018, doi: 10.1016/j.energy.2018.08.135.

[2] M. Kharrich *et al.*, "Developed approach based on equilibrium optimizer for optimal design of hybrid PV/Wind/Diesel/Battery Microgrid in Dakhla, Morocco," *IEEE Access*, vol. 9, pp. 13655–13670, 2021, doi: 10.1109/ACCESS.2021.3051573.

[3] C. O. Okoye and O. Solyalı, "Optimal sizing of stand-alone photovoltaic systems in residential buildings," *Energy*, vol. 126, pp. 573–584, 2017, doi: 10.1016/j.energy.2017.03.032.

[4] M. Hartner, D. Mayr, A. Kollmann, and R. Haas, "Optimal sizing of residential PV-systems from a household and social cost perspective: A case study in Austria," *Sol. Energy*, vol. 141, pp. 49–58, 2017, doi: 10.1016/j.solener.2016.11.022.

[5] W. Cai *et al.*, "Optimal sizing and location based on economic parameters for an off-grid application of a hybrid system with photovoltaic, battery and diesel technology," *Energy*, vol. 201, p. 117480, 2020, doi: 10.1016/j.energy.2020.117480.

[6] T. A. Jumani, M. W. Mustafa, M. M. Rasid, N. H. Mirjat, Z. H. Leghari, and M. Salman Saeed, "Techno-Economic Optimization of an Off-Grid Solar/Wind/Battery Hybrid System with a Novel Multi-Objective Differential Evolution Algorithm," *Energies*, vol. 11, no. 11, 2018, doi: 10.3390/en11113191.

[7] A. A. Zaki Diab, H. M. Sultan, I. S. Mohamed, N. Kuznetsov Oleg, and T. D. Do, "Application of different optimization algorithms for optimal sizing of pv/wind/diesel/battery storage stand-alone hybrid microgrid," *IEEE Access*, vol. 7, pp. 119223–119245, 2019, doi: 10.1109/ACCESS.2019.2936656.

[8] U. Akram, M. Khalid, and S. Shafiq, "Optimal sizing of a wind/solar/battery hybrid grid-connected microgrid system," *IET Renew. Power Gener.*, vol. 12, no. 1, pp. 72–80, 2018, doi: 10.1049/iet-rpg.2017.0010.

[9] M. A. M. Ramli, H. R. E. H. Bouchekara, and A. S. Alghamdi, "Optimal sizing of PV/wind/diesel hybrid microgrid system using multi-objective self-adaptive differential evolution algorithm," *Renew. Energy*, vol. 121, pp. 400–411, 2018, doi: 10.1016/j.renene.2018.01.058.

[10] A. L. Bukar, C. W. Tan, and K. Y. Lau, "Optimal sizing of an autonomous photovoltaic/wind/battery/diesel generator microgrid using grasshopper optimization algorithm," *Sol. Energy*, vol. 188, no. May, pp. 685–696, 2019, doi: 10.1016/j.solener.2019.06.050.

[11] A. Maheri, "Multi-objective design optimisation of standalone hybrid wind-PV-diesel systems under uncertainties," *Renew. Energy*, vol. 66, pp. 650–661, 2014, doi: 10.1016/j.renene.2014.01.009.

[12] L. Zhang, G. Barakat, and A. Yassine, "Design and optimal sizing of hybrid PV/wind/diesel system with battery storage by using DIRECT search algorithm," *15th Int. Power Electron. Motion Control Conf. Expo. EPE-PEMC 2012 ECCE Eur.*, pp. 1–7, 2012, doi: 10.1109/EPEPEMC.2012.6397335.

[13] S. Katoch, S. S. Chauhan, and V. Kumar, *A review on genetic algorithm: past, present, and future*, vol. 80, no. 05. Multimedia Tools and Applications, 2021.