Enhancing Grid Resilience Through Renewable Energy Integration: A Hybrid Antlion-Social Spider Optimization Appraoch In Distribution Power System

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ABSTRACT

Objectives: This study addresses the need for reliable and efficient electricity generation in remote locations through the incorporation of renewable energy systems (RES), specifically hybrid wind and solar systems.

Contributions: The research aims to optimize the placement and sizing of photovoltaic panels (PVs) and wind turbines (WTs) within a distribution network to minimize losses and enhance reliability. It introduces the Hybrid Ant Lion-Social Spider Optimization (ALO-SSO) technique to analyze reliability indices and system costs effectively.

Methodology: The ALO-SSO technique is employed for optimizing the location and capacity of RES components based on technical and financial considerations. The optimization algorithm offers unique benefits including enhanced reliability, multi-objective optimization capability and superior compared to traditional methods.

Analysis: The study utilizes MATLAB/Simulink for implementation and simulation. The reliability of the hybrid RES system is assessed through metrics such as Expected Interruption Cost (ECOST) and Expected Energy Not Supplied (EENS).

Results: Implementation of the optimized RES configuration resulted in significant improvements, achieving a reduction in ECOST to 23.36 and EENS to 30.21MWh/yr. These outcomes underscore the enhanced reliability and cost-effectiveness of the developed methodology.

Findings: The study highlights that strategically locating and sizing PVs and WTs in distribution networks substantially enhance system reliability while minimizing operational costs.

Novelty: This research contributes by integrating advanced optimization techniques (ALO-SSO) for enhancing the flexibility of distribution networks against various disturbances and maximize reliability metrics. It provides a comprehensive framework for decision-making in deploying hybrid RES systems in remote areas, emphasizing both technical and financial viability.

Keywords: HRES, Reliability, Distribution network, Hybrid Ant Lion-Social Spider optimization, Ecost, Eens, Matlab.

I. INTRODUCTION

Environmental and financial problems are among many that arise from the increasing use of electricity, which is mostly generated by burning fossil fuels. Nevertheless, big power plants generate close to 15% of all active power [1-3].Reliability analysis in distribution systems is fundamental for ensuring uninterrupted and stable electricity supply to consumers. It involves assessing the system's capability to deliver power consistently under varying conditions, including equipment failures, weather-related disturbances, and fluctuations in consumer demand. This analysis becomes increasingly complex with the addition of renewable energy sources like PV and wind into the grid. [4-8].Integrating RES such as PV and wind poses unique challenges to reliability analysis. These sources are characterized by their variability and intermittency, influenced by factors such as weather patterns and daily solar radiation. Consequently, accurate forecasting of renewable energy output becomes critical to maintain grid stability and reliability. Grid management practices must adapt to accommodate the unpredictable nature of renewable generation, ensuring that voltage stability and frequency regulation are effectively manage [9-12]. Nonetheless, the ideal placement and size of DGs ensures significant effects on the efficiency and control of the power system in addition to preventing any negative consequences. Exploiting distribution

networks by making the best use of the distributed generation sources inside the network has been the subject of numerous research[13-14]. The approaches that have been put out in this control include analytical, meta-exploratory, and classical approaches. Classical methods are those find the best answer in a brief amount of time, but they become unable to do so as the problem's dimensions increase. Analysis techniques are those that need for extra calculations and might not be able to reach perfectly ideal points [15-16]. The issues of distribution network utilization have recently been resolved by the application of meta-heuristic techniques. By leveraging the optimization algorithms, researchers systematically identify placements that enhance grid efficiency, reduce operational costs, and bolster the resilience of power supply networks, making it a versatile tool in modern electrical infrastructure planning [17-19].
The most popular method for resolving the problem under consideration is the Genetic Algorithm (GA), which is utilized to regulate an optimal locations and sizes of DG units in distribution networks, which balances multiple objectives such as minimizing losses and15% reduction in lower power losses[20-22]. The main disadvantage of GA, which is often used to optimize issue solving, is that it prematurely converges to the local optimization zone [23-24]. In [25-26], the Firefly algorithm (FA) is applied to explore search space and adjusts the positions of DG units to enhance network performance, which achieves loss reduction in 12% in the distribution network. In order to diminish losses and improve voltage stability [27] uses the Ant Lion Optimizer (ALO) algorithm [28], a single objective optimization with a goal of minimizing power losses is developed for the best location of WTs in the distribution network. The location of WTs and PVs is suggested in [29-30] to use the PSO algorithm, which efficiently explores the solution space and converges towards near optimal solutions by adjusting DG configuration iteratively with5% of improving voltage stability. The majority of prior research has indicated that, using the weight coefficients technique, the positioning problem is given as a 1 or 2 objective optimizationareenhancing voltage profile rythm to identify the ideal installation location and DG size depending on renewable resources [31-32].The position of distributed generation has to be seen as a multi-objective problem in order to attain more realistic and accurate distribution network exploitation. Finding the optimal solution using Pareto levels is one of the greatest methods for handling multi objective difficulties [33-34].However, less research has been done on how to deploy renewable resources while taking network failure rate and energy not supplied considers and reliability into consideration. These factors has to be consider for enhancing the overall system resilience and DG reduce dependencyon centralized generation, thereby mitigating the impact of network failures [35-37].This study presents the effects of solving single and multi-objective problems on distribution loss and dependability. Additionally, when solving a problem, the effect of renewable sources' size dispersion is assessed by adopting the Hybrid Ant lion-Social Spider Optimization techniques. It combines ALO's broad search capability with SSO's refined solution improvement, enhancing robustness in optimizing DG placement by mitigating the issues like premature convergence seen in GA. This adapts well to complex optimization challenges, ensuring more accurate and reliable outcomes by upholding a balance between exploration and exploitation throughout the process.

2. RECENT RESEARCH WORKS; A BRIEF REVIEW

Martin János Mayer et al (2020)[38]have developed Multi objective optimization of a domestic hybrid RES using GA with consideration to the environment and economy. Multi-objective optimization has shown to be a useful technique for enhancing the reliability. Nevertheless, at the cost of longer calculating periods it increased computation time, which leads to power losses.
T. Adefarati et al (2019)[39]have proposed the reliability, financial as well as ecological advantages of RES in a microgrid system. This study's methodology offers a valuable insights for managerial decision-making and applied to address numerous socioeconomic issues pertaining to microgrid engineering design. But the seasonal fluctuations in wind and solar energy as well as the reliance of wind and photovoltaic systems on the environment, have been a significant obstacle for the utilities, thus the optimization approaches needs to be introduced in future studies forimproving the flexibility of distribution networks against various conflicts.
Om Krishan et al (2018) [40]the techno-economic studyis carried out utilizing two distinct platforms which leads to the proposal of a grid-independent wind/photovoltaic/battery based HRES. Regardless of changes in solar irradiation, wind speed, or connected load, the developed system keeps the supply and demand in active power balance. Nevertheless, the system accomplishes the intended goal, but it not mention of the ideal dimensions for the many components that it uses, which leads to high cost.
Abolfazl Ghaffari et al (2020) [41] have presentedaCSA for a hybrid system that includes photovoltaic, a diesel engine, a fuel cell, an electrolyzer as well as hydrogen tank by seeing the aspects of renewable energy and reliability. The expansion of CSA to efficiently address the issue of hybrid system size Power

management. However, the component size optimization are crucial for a dependable and economical energy system in hybrid systems.
Iram akhtar et al (2021) [42] have focused on improving power system dependability by utilizing fuzzy system, which considers the effects of addingPV as well as wind energy sources. Additionally, the data demonstrates that integrating solar and wind energy systems into the grid improvesreliabilityof power system. The methods that are suggested are diverse and need less computing power for improving the voltage stability.

Background of the recent research works
The effect of hybrid RES sources in the electrical system is reviewed in the above mentioned literature reviews. Techno-economic study carried out by utilizing two distinct platforms, leads to the proposal of a grid-independent wind/photovoltaic/battery based HRES.The suggested system keeps the supply and demand in active power balance. Nevertheless, the system accomplishes the intended goal, but it fails to mention the ideal dimensions for many components that it uses. The reliability, financial as well asecological advantages of RES in a micro grid system is analyzed. It offers valuable insights for managerial decision-making and applied to address numerous socio economic issues pertaining to micro grid engineering design. But the seasonal fluctuations in wind and solar energy as well as the reliance of wind and photovoltaic systems on the environment, have been a significant obstacle for the utilities. Henceforth, the Multi objective optimization of a household hybrid RES using GA with consideration to the environment and economy is developed, which shown to be a useful technique for examining the trade-offs between the two opposing objectives. Nevertheless, at the cost of longer calculating periods, which increased computation time. To overcome the abovestated issues, this proposed work incorporated with the Reliability evaluation in Distribution Power System with HRES using metaheuristic optimization techniques.The developed optimization technique ability to handle complex, multi-objective optimization problems efficiently significantly contribute to optimizing component dimensions, minimizing power losses, and improving overall system performance.The objectives for the novel proposed techniques are stated as below,

- To optimize the placement and sizing of PV and WTs within distribution network, the hybrid ALO-SSO is developed, which aims to minimize transmission losses, enhance system reliability metrics and optimize system costs effectively.
- To assess the reliability and cost effectiveness of the optimized hybrid RES and to quantify the improvements in reliability achieved through optimization approach compared to the traditional methods.
- To estimate the effectiveness of the ALO-SSO in achieving the reliability enhancement and cost reduction, emphasizing technical and financial viability.

This paper is organized as follows, In section II, the proposed system modelling is discussed and the subsection (a) modelling of DG, (b) PV, (c) WTs, (d) Reliability Indices and (e) optimization techniques are discussed. In section III. The results and discussion part is analyzed and in section IV, the conclusion of the proposed work is discussed.

3. PROPOSED SYSTEM MODELLING
The Hybrid RES is integrated into PV and Wind energy system in this research work, by adopting the proposed Hybrid Antlion-Social Spider Optimization technique the reliability is achieved, which analyze the ECOST and EENS respectively. The foremostobjective of this work is to meet system requirements while lowering the cost of the power outage distribution system. The Schematic diagram for the proposed topology is illustrated in Figure 1.
The integration of RES, such as PV and WTs, into the distribution system highlights the growing trend towards incorporating sustainable and clean energy solutions. The figure includes an energy storage system, which is an essential role in balancing fluctuations in power generation and demand. This storage system helps to store additional energy produced from renewable sources and release it when needed, ensuring a more stable and reliable power supply. The optimization techniques employed in the system, namely ALO-SSO, are aimed at enhancing the overall performance and efficiency of the DG system. These techniques used to optimize the placement and operation of the DG components, such as the PV panels, WTs and energy storage systems, to achieve the best possible reliability and cost-effectiveness. Also, the two key reliability indices, EENS and ECOST are employed to calculate the reliability and performance of the DG system. These indices provide valuable insights into the system's ability to meet the energy demand and the associated costs of potential interruptions or outages.

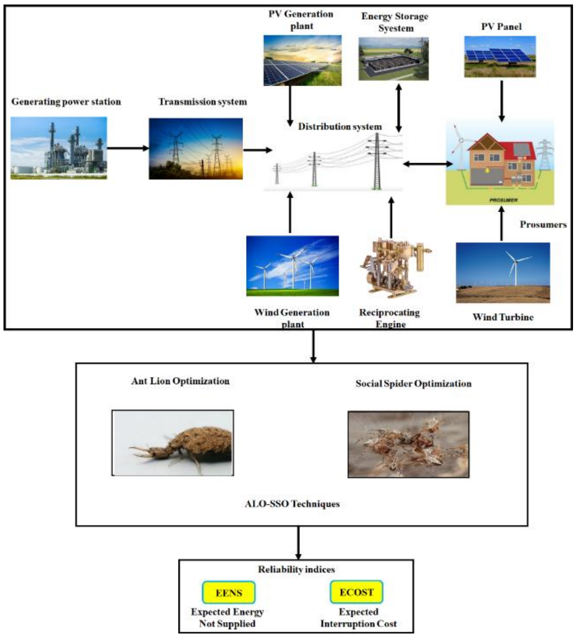

Figure 1: Flow diagram of the proposed work

A) MODELLING OF DG TECHNOLOGIES

DG technologies are so affordable in relation to the load necessities of customers, which are vital to the availability of power supplies. The modeling of DG technologies, including PV and WTG, is briefly discussed in the below section.

B) MODELLING OF PV SYSTEM

The photovoltaic is also termed as solar cells, which is a clean energy that absorb sunlight and produce electricity. Here, the solar-photovoltaic system's mathematical modelling is discussed as below, an ideal solar cell equivalent circuit has a current source and a diode connected in parallel. The load is connected to the circuit's output terminals. The ideal formula for solar cell's voltage and current is provided by the following equation (1),

$$I_{PV} = I_{Ph} - I\left(e^{qV_{PV}/KT} - 1\right) \quad (1)$$

Here, k denotes the Boltzmann constant, T refers the cell temperature and I_{Ph} indicates the photocurrent. The output power of PV cell is specifiedin equation (2),

$$P_{PV} = V_{PV} I_{PV} \quad (2)$$

Where, V_{PV} is the solar cell working voltage, I_{PV} specifies output current of solar cell and P_{PV} denotes output power of solar cell.Additionally, solar radiation serves as the PV system's input energy. On an inclined surface, total solar radiation is predicted as expressed in equation (3)

$$I_T = I_b R_b + I_d R_d + (I_d + I_b) R_r \quad (3)$$

Where,R_b,R_d and R_r denotes tilt factors for the beam, diffuse as well as reflected parts of solar radiations, and I_b and I_d are the direct normal and diffuse sun radiations.

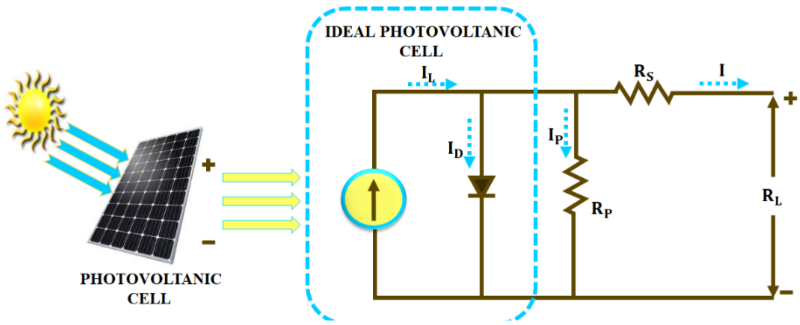

Figure 2. Circuit of PV system.

C) MODELLING OF WT SYSTEM

A wind turbine is the main mechanical system that converts the kinetic energy of the wind into the rotational mechanical energy.The gear system transmits the mechanical energy from the turbine shaft to the generator as represented in Figure 3, which changes the mechanical energy into electrical energy.

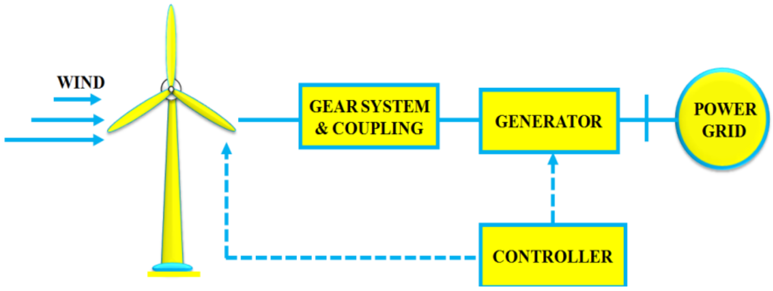

Figure 3: Diagram of Wind Turbine system

The wind power equation shown here is used to predict wind power production from turbine as follows. The non-dimensional performance of WT is defined by the tip speed ratio. A wind turbine's mechanical power outputis expressed in below equation (4),

$$P_t = \frac{-(C_P \lambda \rho A V^3)}{2} \quad (4)$$

The wind turbine's torque is represented in below equation (5),

$$T_t = \frac{P_t}{\omega m} (5)$$

Where ρ the air density in kg/m3 is, λspecifies tip speed ratio,$C_P$represents power co-efficient, $T_t$indicates torque produced by the wind turbine, and $P_t$denotes output power. VIs the wind speed, and Aspecifies wind turbine's frontal area and ω represents turbine rotor speed.

D) RELIABILITY INDICES

In normal operating conditions, reliability implies the probability that a power system will run as intended without experiencing any failures within a certain period of time. Using the following dependability indices, one can examine how Distributed Generation (DG) technologies affect a power system.

Expectation energy not supplied

The total energy which is not provided at system load locations is known as EENS. Once the load demand surpasses the obtain able causing capacity, the energy emergency predicted by the EENS occurs. It is a significant metric that utilities the use to evaluate a power system's reliability. Using the EENS index, the capacity of the unfulfilled load demand for a given time period can be calculated in MW/ hr. The following mathematical formulas is anticipated to establish the EENS of a power supply system as,

$$EENS = P_i U_i (MW/hr/yr) \; (6)$$

$$\sum_{i=0}^{n} \lambda_i r_i L_i (7)$$

$$= \lambda_a r_a L_a + (\lambda_a r_a + \lambda_b r_b) L_b + (\lambda_a r_a + \lambda_b r_b + \lambda_c r_c) L_c (8)$$

$$= (L_a + L_b + L_c)\lambda_a r_a + (L_a + L_b)\lambda_b r_b + L_c \lambda_c r_c (9)$$

$$= PF_a \lambda_a r_a + PF_b \lambda_b r_b + PF_c \lambda_c r_c (10)$$

$$= \sum_{i=0}^{n} \lambda_i r_i PF_i (11)$$

Where$\lambda_i$denotes the average failure rate at load point i, $n$specifies number of outages at load point i, r_i indicates failure duration at load point i, and $U_i$represents yearly outage duration at load point$i$ as well asPF_a, PF_b, PF_crepresent the power flow in the line sections a, b, and c, correspondingly.

Expectation Interruption cost

The ECOST index measures the cost of neglecting to serve load points' consumers due to a power outage brought on by faulty elements in a power system. Thefeatures of the consumer determine ECOST.

$$ECOST = P_i \sum N_e f_{r,j} \lambda_i (k"\$"/yr) \quad (12)$$

$$= P_a N_e f_{a,j} \lambda_a + P_b N_e f_{b,j} \lambda_b + P_c N_e f_{c,j} \lambda_c \; (13)$$

Where$P_i$specifies the average load (MW), $N_e$denotes a number of constituents on which faults will disturb load point i, and $f_{r,j}$are the costs of interruption customer damaged function (CCDF).

E) MODELLING OF ANTLION OPTIMIZATION TECHNIQUES

The output of PV and wind systems are predicted based on weather conditions and other relevant factors. These predictions are vital for assessing reliability of the RES in meeting demand. Next, optimization algorithms inspired by Antlion and social spider behaviors are employed to maximize the reliability indices. These algorithms help in determining the optimal sizing and placement of PV arrays as well asWTs within the power system infrastructure. By considering factors such as energy availability, demand patterns and system constraints, the framework aims to minimize EENS and ECOST, thereby boosting the overall reliability and performance of the renewable energy integration.Antlion-social spider algorithms in Distribution Generation system optimization simulate the collective behaviors of Antlion's and social spiders to solve complex optimization problems. Antlion's use pit-trap strategies to capture prey, while social spiders cooperate to build webs for efficient prey capture. In algorithmic terms, this translates to using a population-based approach where potential solutions (representing distribution configurations) evolve over iterations. Antlion behaviors guide the exploration of diverse solution spaces, ensuring thorough coverage for optimal configurations. Social spider behaviors encourage collaboration among solution candidates to refine and improve distribution designs iteratively. By combining these strategies, the algorithms effectively balance exploration and exploitation, leading to enhanced performance in optimizing Distribution Generation systems with more effectiveness.

The predatory insect species,Antlion is a member of the Myrmeleontidae family. During their 2.5–3 year larval stage, they mostly consume ants. An Antlion uses its jaws to make a cone-shaped hole. After that, it waits while hiding in the cone's bottom an ant starts tossing sand in the direction of the trap when it sees a hole in the ground, hoping to bury its meal. Antlionthrow the leftover prey outside the trap once they have caught and consumed it.

Using a random walk in the following manner, the stochastic movement of ants in the search space is modelled:

$$X(t) = [0, cum\ sum(2r(t_1) - 1), cum\ sum(2r(t_2) - 1 \ldots, cum\ sum(2r(t_n) - 1)] \quad (14)$$

Here, $t$denotes the current iteration, $r(t)$ specifies stochastic function, $X(t)$ indicates the ant random walk and n represents the maximum number of iteration.

$$r(t) = \begin{cases} 1 & rand > 0.5 \\ 0 & otherwise \end{cases} (15)$$

Where, $rand$ denotes the random number and the antlions position is written by the below equations (16)

$$M_{antlion} = \begin{matrix} AL_{1,1} & A_{L1,2} & \ldots & \ldots & AL_{1,d} \\ AL_{2,1} & AL_{2,2} & \ldots & \ldots & AL_{2,d} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ AL_{n,1} & AL_{n,2} & \ldots & \ldots & AL_{n,d} \end{matrix} \quad (16)$$

Here, $M_{antlion}$ specifies the matrix which saves the Antlion's position and to simulate the actions of Antlion's in their trap, the subsequent formulas are presented.

$$c^t{}_i = Antlion^t{}_i + c^t (17)$$

$$d^t{}_i = Antlion^t{}_i + d^t (18)$$

$$c^t = \frac{c^t}{I} (19)$$

$$d^t = \frac{d^t}{I} (20)$$

Here,c^t and d^trepresent minimum and maximum of all variables at the t-th iteration, correspondingly and $c^t{}_i$j, $d^t{}_i$represents minimum and maximum of all variables for the i-th ant, Antlion$j$ displays the position of the j-th antlion at the t-th iteration.

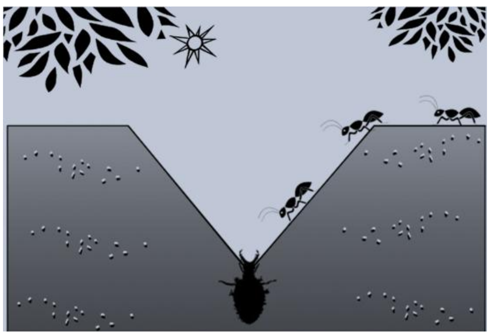

Figure 4: Antlion's hunting strategy

To simulate the last phase of hunting—pulling the ant into the sand and eating it. After that, the antlions updates its location based on the subsequent equation:

$$Antlion^t{}_i = Ant^t{}_i \quad if \quad (Ant^t{}_i) < Antlion^t{}_i \qquad (21)$$

F) MODELLING OF SOCIAL SPIDER OPTIMIZATION

The natural cooperative behavior of the social spider in its colony serves as the model for this population-based Swarm intelligent system. Two primary components of spider colonies are the communal web and spiders. While problem solutions are symbolized by insects, the web is symbolized by the domain of the search box. SSO examines both male and female search agents, andspiders. The first generation of the standard SSO algorithm is randomly distributed over the search space at the beginning. Every person is addressed by a gender. The population matrix addresses the initial agents (spiders) as feminine and the remaining agents as masculine. Weighing the spider is the initial step in the search loop calculation, this computation using Equation (22), which is given as follows,

$$w_i = 1 - \frac{FS_i - FS_{best}}{FS_{worest} - FS_{best}} \quad (22)$$

Where$w_i$denotes the ith spider's weight, FS_ispecify its objective function value, population's FS_{best} denotes the best objective value, and FS_{worest} is the lowest objective value attained.

After all males and females have been moved across a web, final operator represents the mating behavior, in which only leading males will take part. The code will determine whether any female is present nearer a leading male than the radius of mating. Equation (23) provides the radius of mating.

$$rm = \frac{\sum_{d-1}^{d}(p^{h}{}_d - P^l{}_d)}{2D} (23)$$

Where D is the issue dimension and $p^{h}{}_d$ and $P^l{}_d$represent upper as well as lower bounds for a certain dimension, respectively. By using roulette approach, men and females that are below mating radius produce new applicant spiders. Every potential spider is assessed inside the objective function, and the outcome is subsequently put to the test against every member of the population.

The fitness function in the method considers the number of selected features and is based on the rough sets dependence degree. A population of spiders is randomly initialized by the procedure. After that, each person is transformed into a binary vector of length N using the next Equation (24)

$$x^j{}_i(t+1) = \begin{cases} 0 & , if x^j{}_i(t) > € \\ 1 & , otherwise \end{cases} (24)$$

Where$x^j{}_i(t)$ denotes the spider value at the iteration t

G) MODELLING OFTHE PROPOSED HYBRID ANTLION-SOCIAL SPIDER OPTIMIZATON

Combining ALO and SSO in optimization leverages their complementary strengths: ALO's ability to explore diverse solution spaces and SSO's effectiveness in refining promising solutions. ALO's random exploration helps discover new potential solutions, while SSO's focus on exploiting known good solutions enhances their quality.

Table 1: Parameters of ALO and SSO algorithm

ALO parameters	**SSO parameters**
Number of ant lions (population size): 20	Number of social spiders (population size): 30
Maximum number of iterations: 50	Maximum number of iterations:50
Initial pheromone trails: Random initialization within a defined range	Neighborhood size for social interaction: 5
Levy flight parameters: Step size, scale factor, and probability distribution parameters	Spider movement parameters: Step size, exploration rate, and influence of best solution found so far

This hybridization is expected to improve reliability indices like ECOST and EENS by balancing exploration and exploitation more effectively, leading to better overall optimization performance compared to single-method approaches. It is common knowledge that in real-world optimization situations, standalone methods may not always be sufficiently effective to handle uncertainty. Improved solutions to new issues like unit commitment and economical load dispatch is found through hybridization of algorithms. Hybrid algorithms also avoid the drawbacks of multiple distinct algorithms while retaining the benefits of each. Henceforth, the hybridization of ALO and SSO is implemented in this study to examine the reliability indices. ALO, while efficient in exploration, sometimes struggle with exploitation of found solutions. SSO, with its cooperative strategies, excels in exploitation but may have

limitations in exploration. By hybridizing these methods, their complementary strengths are leveraged: ALO's strong exploration capabilities ensure thorough coverage of the search space, while SSO's exploitation strengths refine promising solutions efficiently. It is anticipated that the population's utilization rate will rise when the SSO system is integrated with ALO. A faster convergence is achieved by refining the ALO solutions with SSO, which can further lessen the probability of becoming trapped in local optima.Figure 5 depicts this ALO and SSO hybridization system.
The Hybrid ALO-SSO technique represents a deliberate choice based on its potential to address the identified gaps in the literature by optimizing both exploration and exploitation phases. This methodological decision is expected to contribute significantly to achieving our research objectives of improve reliability indices like ECOST and EENS.

4. RESULTS AND DISCUSSION

In this research work, the Hybrid Antlion- Social Spider optimization techniques are incorporated for analyzing the reliability indices like ECOST, HRES system cost and EENS. In addition, the overall proposed work is implemented in MATLB/Simulink and comparative analysis is made over with the existing technique to exhibit the ability of the developed work. As a consequence, the proposed hybrid optimization topology provide the excellent performance based on cost reduction and reliability. The parameter of PV panel is illustrating in Table 2 below,

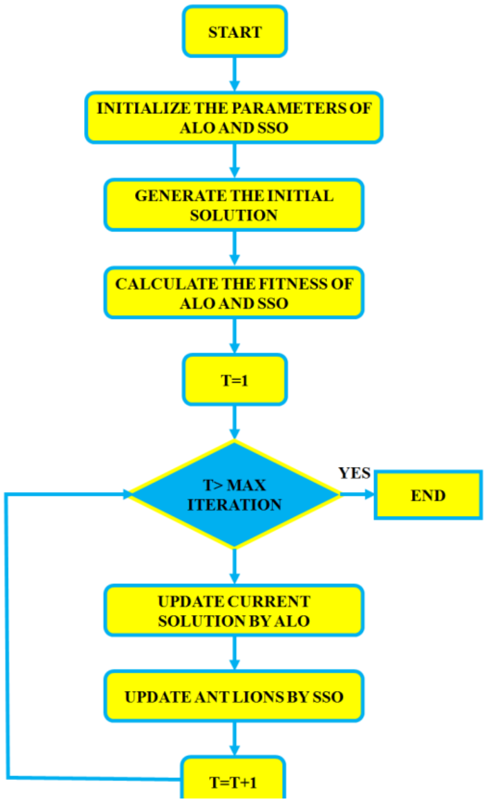

Figure 5: Flowchart for the proposed Hybrid ALO-SSO optimization

Table 2: PV panel parameter

Parameter	**Description**
Solar PV System	
Open circuit Voltage	37.25V
Short circuit Current	8.95A
Maximum Voltage	29.95V
Maximum Current	8.35A

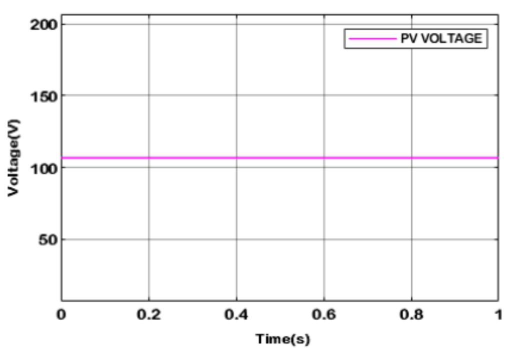

Figure 6: PV voltage waveform

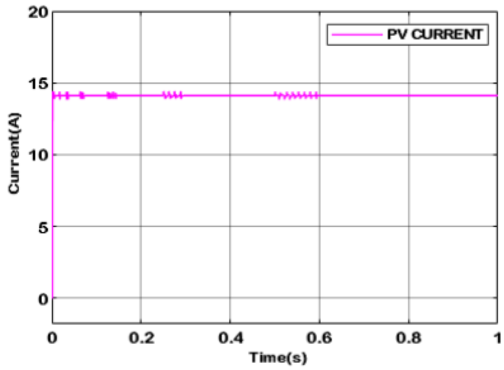

Figure 7: PV current Waveform

The waveform for PV Voltage is demonstrated in figure 6, from the Figure it is observed that the voltage is constantly maintained at 105V respectively.Figure 7 represents the PV current waveform, which is analyzed that initially the current gets fluctuates in certain period of time after 0.6s the current is constantly maintained at 14A without any distortion.

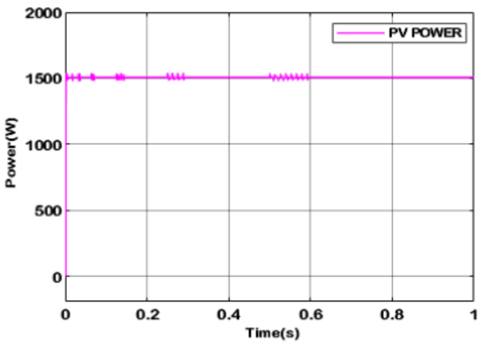

Figure 8: Waveform for PV power

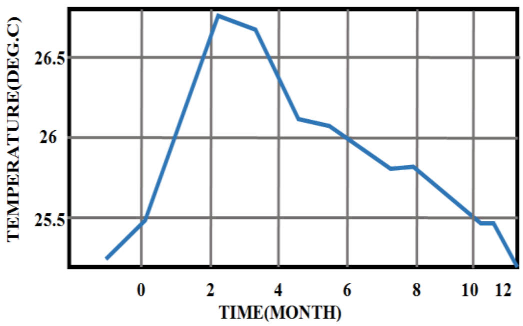

Figure 9: Observation of Monthly average ambient temperature

Waveform for the PV power is specified in figure 8, from the waveform it is observed that power raised suddenly and gets fluctuated. After 0.6s the power started maintained constantly without any fluctuations. Furthermore, the Voltage and current fluctuations affect the stability of the system, potentially causing disruptions in power delivery or compromising equipment lifespan. Power fluctuations can impact the consistency of energy supply, affecting overall system reliability and the ability to meet demand.

The analyzation of monthly average ambient temperature is specified in figure 9, which is stated that the temperature gets raised highly in initial month at 29.9℃. After 4 to 12 month, it gradually decreased at 25℃correspondingly.Ambient temperature changes alter the efficiency of PV panels, affecting their output and overall system performance. Similarly, fluctuations in wind speed can impact cooling mechanisms or wind turbine efficiency in hybrid systems, influencing energy production.

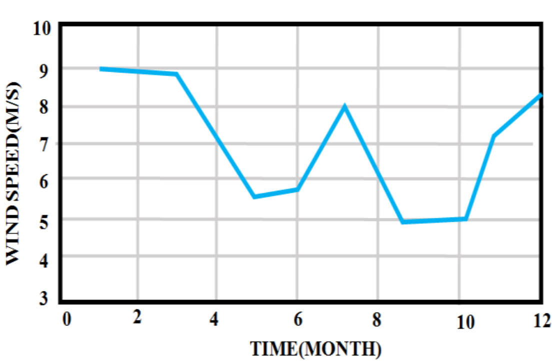

Figure 10: Analyzation of Wind speed per month

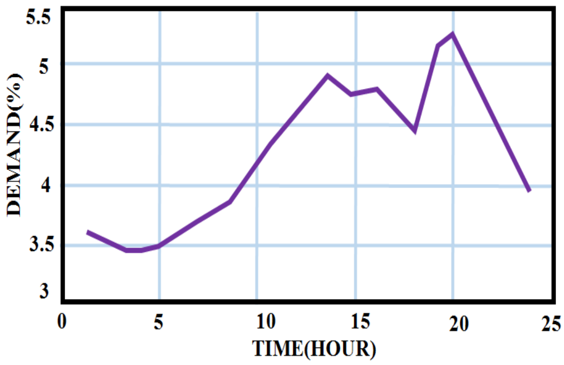

Figure 11: Analysis of demand per hour

Figure 10 represented the observation of Wind speed based on month, from the result it is evident that the wind speed raised at initial month and gradually dropped by the following months and finally the wind speed again raised 8.3(M/S) at 12 th month.Analyzation of demand based on Hour is illustrated in Figure 11, which observed that at initial time the demand is low and the times goes on the demand also get raised. Finally, the demand gradually slowdown at 4.1%.Understanding demand patterns is crucial for optimizing system operation. Matching energy generation to peak demand periods enhances efficiency and reduces strain on the grid. By monitoring and adapting to these fluctuations and trends, operators maximize reliability and operational efficiency of PV systems, ensuring consistent and sustainable energy supply.

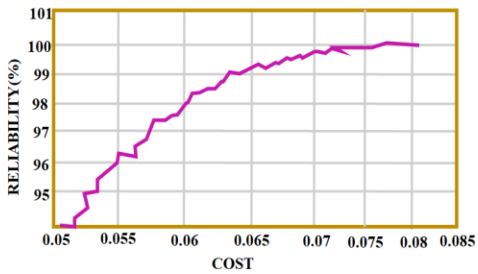

Figure 12: Analyze the optimal system sizing average component cost

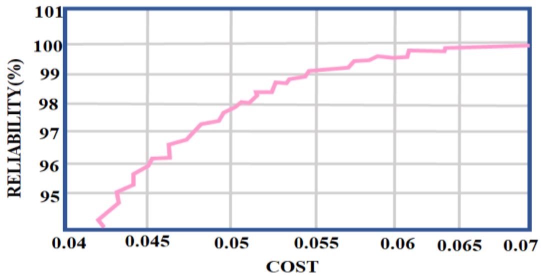

Figure 13 :Analyze the optimal system sizing at minimum cost

Observation of optimal sizing average component cost is illustrated in Figure 12, from the result it is stated that initially the reliability is at 91% after it is highly raised up to 110% and maintained.Figure 13 indicates the analyzation of optimal system sizing at minimum cost, which is observed that the reliability is at 91% in initial time after it is highly raised up to 105% and maintained.

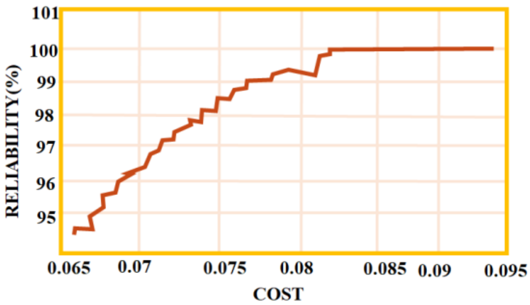

Figure 14: Analyze the optimal system sizing at maximum cost

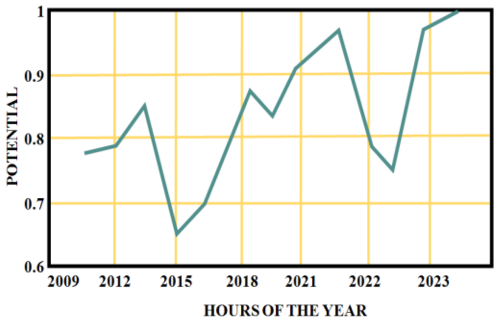

Figure 15: Analyze the Possibility of Wind

Similarly, the optimal system sizing at maximum cost is illustrated in Figure 14, which evident that the reliability is initially at 94% after it increased highly up to the level at 100% respectively.Figure15 represents the analyzation of Possibility of Wind, which represents that, in traditional years the possibility of wind is low. After 2023, the possibility is enhanced higher upto the potential level of 1.

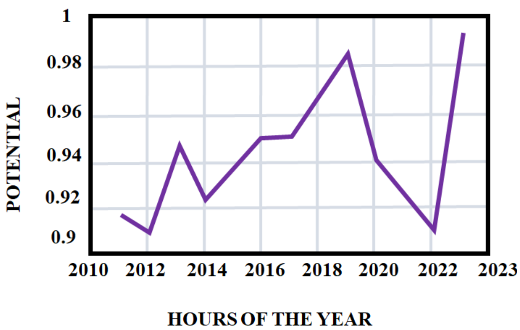

Figure 16: Analyze the Possibility of PV system

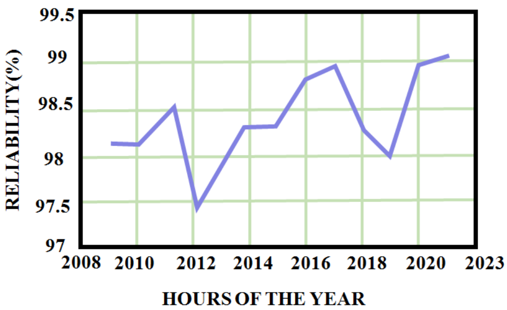

Figure 17: Analyze the Possibility of PV and Wind Energy system

The possibility of PV system is represented in Figure 16, which analyses that, in 2010, the possibility of PV is low and after the years passed, the possibility is highly increased. Finally, in 2023, the possibility is greatly increased upto the level of 0.99.Figure 17 represents the analyzation of Possibility of Wind and PV, from the result, it is concluded that the year by year the possibilities are changes and finally, at 2023 year the possibility of wind and PV gets increased as shown in above figure.

Table 3: Comparison of ECOST

References	ECOST
Seyed Arman Shirmardi et al [43]	1184.4
Anoosh Dini et al [44]	3646.4
Hassan et al [45]	696.53
Habib Ur Rahman Habib et al [46]	51.20
ALO-SSO	23.36

Table 3 specifies the comparison of ECOST among various optimization techniques, demonstrating the superior performance of the Hybrid ALO-SSO topology. This method achieves lower ECOST due to its enhanced reliability and cost efficiency. By combining aspects of ALO and SSO, the Hybrid ALO-SSO topology optimizes system parameters more effectively, resulting in minimized operational costs and improved overall system performance. This approach likely balances trade-offs between different factors such as maintenance costs, energy production reliability, and system longevity.

Table 4: Comparison of EENS

References	EENS
Sachin Kumar et al[47]	70MWhr/year
Bimrew Mhari Enyew et al [48]	3501.58 MWh/a
Ernestina Mawushie Amewornu et al [49]	5234.91 MWh/a
Fareed Ahmad et al [50]	5730.17 MWh/a
ALO-SSO	30.21 MWh/yr

Table 4illustrate EENS comparisons, highlighting how the Hybrid ALO-SSO topology achieves lower EENS compared to other methods. A lower EENS indicates reduced instances or durations of energy supply disruptions, translating to improved reliability and customer satisfaction. This outcome is typically achieved through the topology's ability to optimize resource allocation, mitigate potential failures, and enhance system resilience against disturbances. Overall, these findings underscore the efficacy of the Hybrid ALO-SSO topology in optimizing system performance metrics critical for reliable and cost-effective energy supply.

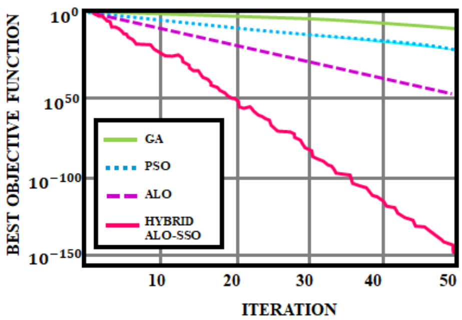

Figure 20: Comparison of Convergence speed

The proposed hybrid approach is compared with the conventional optimization approach for showing the importance of the developed work. From the above graph it is analyzed that proposed ALO-SSO algorithm attains better convergence speed compared to the other approaches.
The research findings highlight significant achievements in reducing costs, enhancing reliability, and showcasing comparative advantages over existing techniques in renewable energy integration. The methodology, validated through MATLAB/Simulink simulations, the proposed algorithm effectively minimized system costs by optimizing component sizes and implementing efficient energy management

strategies as mentioned in the above results. It also improved system reliability by employing advanced control algorithms and optimizing resource allocation, leading to reduced downtime and enhanced grid stability. Looking ahead, future research could expand by exploring more complex scenarios and integrating additional renewable energy sources, aiming to further optimize system performance and advance sustainable energy solutions for broader deployment. Although, the Scalability is potential limitation, as the performance of ALO-SSO could deteriorate with increasing problem complexity or dimensionality. Addressing these limitations through systematic parameter tuning strategies, optimization of computational resources, and scalability assessments will be crucial for realizing the full practical potential of the ALO-SSO hybrid technique across diverse application scenarios.

IV.CONCLUSION

This work deliberates the implications of integrating solar and wind energy sources into the grid using innovative, intelligent solutions with the goal of enhancing power system reliability. In order to decrease loss and boost dependability, this study proposes a new ideal location and sizing scheme for renewable energy sources in the distribution network, which revolves around PVs and WTs. Unlike traditional approaches, which often rely on arbitrary placement, our methodology strategically places PV and WT systems based on comprehensive analyses of local environmental conditions and load profiles. This strategic placement minimizes transmission losses by reducing the distance between energy generation and consumption points, thus optimizing energy distribution efficiency. The proposed hybrid technique converges fast and is completely unrestricted in the local ideal.Finally, MATLAB/Simulink is used to execute the entire implemented technique,by simulating diverse scenarios such as varying solar irradiance, wind speeds, and load profiles, demonstrates the effectiveness and feasibility of our approach in optimizing energy capture, enhancing system efficiency, and ensuring robust performance under different conditions. From the comparison graph, shown in the above analyzed that by using the proposed Hybrid Antlion-Social Spider optimization technique, ECOST (23.36) and EENS to (30.21MWh/yr) are greatly reduced and has rapid convergence speed compared to the other conventional optimization topologies respectively.This outcome underscores the efficacy of our optimization techniques in mitigating energy supply uncertainties and enhancing grid stability.One future research direction could involve extending the Hybrid Antlion-Social Spider optimization technique to dynamically optimize energy storage systems in renewable energy grids, ensuring efficient management of grid stability and enhancing overall renewable energy utilization.On the other hand, in future studies, considering grid constraints and real-time data is crucial for system optimization, which improve reliability and performance. These efforts aim to create smarter, more adaptive distribution generation systems capable of meeting future energy demands sustainably.

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