Journal of Theoretical and Applied Information Technology
15th January 2023. Vol.101. No 1
© 2023 Little Lion Scientific

ISSN: **1992-8645** www.jatit.org E-ISSN: **1817-3195**

A GRID CONNECTED HYBRID RENEWABLE ENERGY SYSTEM FOR OPTIMAL ENERGY MANAGMENT BASED ON ANT-LION OPTIMIZATION ALGORITHM

IBRAHIM A. ALTAWIL[1,2], KHALED A. MAHAFZAH [1], AMMAR ALMOMANI[3]
[1]Faculty of Engineering, Al-Ahliyya Amman University, Department of Electrical Engineering, Jordan
[2]Hijjawi Faculty for Engineering Technology, Yarmouk University, Department of Power Eng., Jordan
[3]Ministry of Education, United Arab Emirates
E-mail: i.altawil@ammanu.edu.jo, k.mahafzah@ammanu.edu.jo

ABSTRACT

Over the past several years, the need of hybrid renewable energy systems (HRES) integrated with the electrical grid system has significantly increased. This integration provides a better reliability, continuous supply, and improved system performance. The optimal size (rating) of a grid connected HRES is proposed in this paper. The Ant-Lion Optimization (ALO) algorithm is used for optimization. For the ALO algorithm, the decision variables are the number of PV panels (N_{PV}) and wind turbines (N_{WT}). The optimization considers a particular priority based on limitations to supply the load demand connected with the hybrid system from PV arrays, wind turbines, and ultimately the grid. Additionally, the impact of independently combining solar PV and wind with a single objective function is examined. The Total Net Present Cost (TNPC) and the Index of Reliability (IR), which serve as the objective function, are minimized using the ALO. Two different scenarios are proposed. After running the optimization algorithm, the two proposed scenarios are compared with each other in term of TNPC and IR. Thus, this determines the number of PVs and wind turbines to build HRES.

Keywords: *Hybrid Renewable Energy Sources (HRES), Load Demand, Electrical Grid, Ant-Lion Optimizer, Energy Cost*

1. INTRODUCTION

The high cost of conventional power sources forces different countries to adopt Renewable Energy Sources (RES) as a serious substitutional solution [1]. Additionally, RES are environment-friendly, non-depletable, and green. On the other side, the use of fossil fuels harms the environment by causing soil erosion and air pollution [2].

Particularly for the oil-importing countries, the integrated use of renewable energy sources like solar and wind power systems has grown in appeal and desirability [3-4]. Therefore, using Hybrid Renewable Energy Systems (HRES), see Figure 1, is a better solution as a grid auxiliary power supply to meet the load demand. While, the HRESs have unpredictable nature of these resources that can affect the electrical power generation process [2]. Solar and wind energy resources have discontinuity in energy generation according to the wither conditions. In this regard, HRESs have a higher reliability to produce electricity constantly than system that are individually placed [5].

However, ss shown in Figure 1, the grid connected HRES comprises of wind farm and PV farm connected to the grid through power electronics converters and step-up transformer.

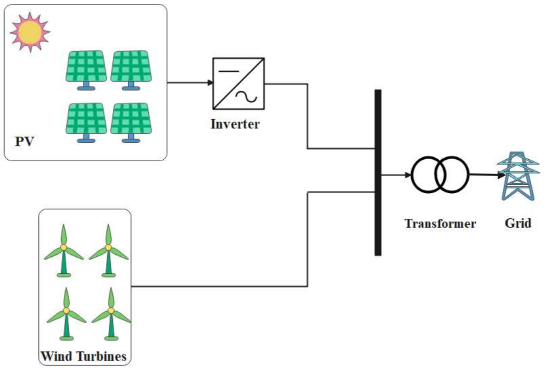

Figure 1: A grid connected HRES

Optimizing the size (rating) of the grid connected HRES's component parts and choosing the mode of operation are the main obstacles to installing these HRES. Due to the high cost of renewable energy systems, it is essential to make the most of the system rating in order to reduce costs while maintaining power supply reliability [6].

A number of research have recently been carried out to determine the optimum a grid connected hybrid energy system size (HES). In [7] the authors studied a methodology for sizing distributed energy resources (DER) and investigated the Cost of Energy (COE) in microgrids for those energy resources and concluded that the reliability and self-sufficiency is the justification for the slight increase in COE for microgrids in comparison with Distributed Generators (DG) and hybrid DG.

In [8] the researchers used Particle Swarm Optimization (PSO) algorithm to model a hybrid system for a stand-alone RES, to minimize the investment and fuel cost, and ensure energy delivered to customers sufficiently. Also, in [9] the authors used GA and PSO to investigate the optimal sizing of stand-alone PV-wind-biomass hybrid energy system and concluded that the price of energy for the load following strategy is 0.2396 $\$/kwh$ using GA and 0.2617 $\$/kwh$ using PSO.

In [10] the researchers explored a methodology using Artificial Bee Colony (ABC) algorithm to investigate the optimal sizing for hybrid PV-biomass energy system in case of stand-alone and grid-connected systems and concluded that the grid-connected system is more effective than stand-alone system.

In [11], the researchers studied the feasibility of microgrid composed of PV, wind, biomass, and a battery storage system in a rural area to meet their electrical load demand and used Artificial Bee Colony (ABC) algorithm to obtain an optimally size the system.

A Jordanian grid lacks a study that discusses the optimal design of a grid connected HRES considering Total Net Present Cost TNPC and Index of Reliability IR factors.

This paper proposes the use of Ant-Lion Optimizer (ALO) to size, a friend of the environment a grid connected hybrid renewable energy systems (wind and solar). The ALO is used to size the system by finding the optimal number of Photo-Voltaic Panels (N_{PV}) and wind turbines (N_{WT}) to meet the load demand with lowest possible cost and with high grid Index of Reliability (IR). Therefore, the main objective function of the algorithm is set to estimate both the Total Net Present Cost (TNPC) and IR. The use of the ALO is realized by using a real data from a power station located in southern of Amman-Jordan. To show the effectiveness of ALO, two different scenarios are proposed and compared in terms of TNPC and IR.

The rest of the paper proceeds as follow. Section 2 discusses an overview of the grid connected PV arrays and wind turbines. Section 3 introduces the ALO objective functions and variables that are used in this paper. Section 4 discusses the simulation results. Finally, Section 5 concludes the work.

2. A GRID CONNECTED RENEWABLE ENERGY SYSTEMS

Due to the fact that it is one of the most crucial and necessary components for countries to move forward and meet their people's demand, the need for energy sources and energy security is growing over time. However, the traditional energy supply will eventually run out because of the tremendous rise in the world's energy demand. So, the world must find alternative options to look for energy sources. Furthermore, traditional energy resources have caused a damage to the ecological system. Therefore, it is the best time to look for RES as an alternative, because they are free, and ecological [12].

In essence, wind and solar energy are irregular sources of energy since they can only produce energy when the Sun is shining, and the wind is blowing. As a result, compared to systems that are installed separately, grid-connected PV-wind HRES is seen as having a higher reliability to produce power constantly [13]. To meet the energy needs with a higher degree of reliability, it is recommended to have either an on-grid or standalone PV-wind HRES.

2.1 Solar Energy and Grid Connected PV

There are different terminologies used in PV systems, such as irradiance (power density), radiation (insulation), and air mass (AM). The solar irradiance is measured in kw/m^2, and it is defined as the momentary amount of solar power falling on a surface that has an area of 1 m^2. The solar radiation or insulation is measured in kwh/m^2/unit area, and it is defined as the amount of solar energy that is falling on a surface per unit area per unit time [14].

When the light falls dawn on the PV cell, the electron in the valence band receives energy. The electron then has enough energy to jump out from the valence band to the conduction band and will move freely to conduct electrical current if the energy delivered by the photon is more than the band gap energy. In the absence of this, the energy difference between the band gap and the electron energy will be transferred to kinetic energy, raising the temperature of the PV cell [15]. However, this energy is transferred to electrical grid by connecting the DC voltage of PV arrays to the inverter. See Figure 1.

2.2 Wind Energy and Grid Connected WT

Compared to solar energy, wind energy is unexpected and variable in time, space, and sensitive to variation related to topographies and weather patterns [16]. Also, it is very important to choose a suitable location to reduce the overall cost of the Wind Energy Conversion System (WECS) [17]. Wind turbines (WT) are used to produce electricity from wind by converting the kinetic energy created by air into an electric energy which changes the kinetic energy to rotational energy.

The amount of output power extracted from the wind turbine depends on location, and aerodynamic performance of the blade. The most important factors to be considered are the average annual wind speed, rotor swept area, pitch, air density that is affected by altitude and temperature [16,17]. The global installed wind capacity was 620 GW at the end of 2019 [18]. However, the WT curve for any WT model depends on the manufacturer data, and many models have been used in literature to model the output curve for WT, which includes linear, quadratic, or cubic models. Also, the part that needs to be modelled is between the cut in and rated wind speeds. See Figure 1.

3. ANT-LIOIN OPTIMAIZATION (ALO)

The ALO algorithm is basically encouraged by the hunting method of antlions. This technique mimics the interactions of Ant-Lions and ants in nature which was developed by Ali Mirjalili in 2015.

Furthermore, this algorithm has been used widely to solve optimization problems in applied engineering. This is because it provides enhanced optimal designs for different optimization challenges with various constraints at which other numerical methods fail [19-23]. Note that, these constraints are categorized as the equality and inequality constraints.

The cause behind using Ant-Lion as an nature inspired optimization algorithm back to several reasons. Firstly, ants move randomly when searching for their food and builds and rebuilds their traps. This reflects the searching for the decision variables which are the number of PV panels and wind turbine. Hence, at each time step in each iteration of the search space, the decision variables will be updated as the position of the best new ant to be hunted by the antlion. Therefore, considering the random walk of ants in these traps, a huge number will be found and located in the matrix as in (3) and Figure 2.

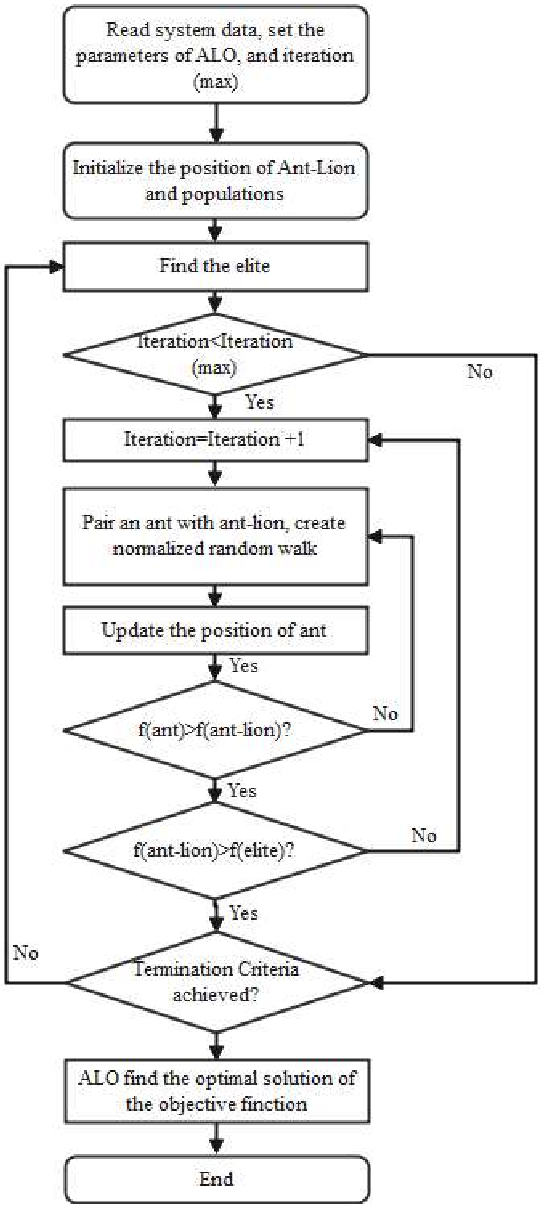

Figure 2: ALO algorithm flow chart [24-26]

However, before updating the new position side by side with the best optimal solutions we need to set the movement type for these ants. Accordingly, the movements of these ants' "Npv and Nwt" will be described using random walks as in (1) [19].

$$X(z) = |0; cumsum(2r(z_1) - 1); \ldots.; cumsum(2r(z_m) - 1)| \quad (1)$$

Where "*cumsum*" is the cumulative sum for a maximum number of iteration *m*, and *r(z)* is a random function as shown in (2). Also, the location of ants or in other words the decision variables are stored and applied during the optimization process using the matrix in (3) [19, 24]:

$$r(z) = \begin{cases} |\ 1\ if\ rand > 0.5\ | \\ |\ 0\ if\ rand \leq 0.5\ | \end{cases} \tag{2}$$

$$M_{Ant} = \\ = \begin{bmatrix} A(N_{PV}, N_{WT})_{1,1}.\dots\dots.., A(N_{PV}, N_{WT})_{1,d} \\ A(N_{PV}, N_{WT})_{2,1}.\dots\dots.., A(N_{PV}, N_{WT})_{2,d} \\ \vdots \\ A(N_{PV}, N_{WT})_{n,1}\ \dots\dots.., AA(N_{PV}, N_{WT})_{n,d} \end{bmatrix} \tag{3}$$

Where $A(N_{PV}, N_{WT})_{i,j}$ is the j^{th} variables of i^{th} ant for the decision variables, n is the number of these ants in decisions, d is the number of variables, and *f* is the single objective function. Note that, the objective function in this thesis is two separate cases.

The 1st scenario where to maximize the index of reliability and the 2nd scenario where to minimize the total net present cost. However, it is worth mentioning that in some cases the antlions may hide in different locations in the variable search space which will cause some hazard and slowing in the system to find the best optimal solutions. So, to store their positions, the fitness of each antlion matrix (M_{oAL}) can be calculated as shown in (4) and (5) [19, 25]. where f is the single objective functions for the two case scenarios, i.e., "$f(IR)$ and $f(TNPC)$.

$$M_{oAL} = \begin{bmatrix} f(IR)\left(\left|A(N_{PV}, N_{WT})_{L_{1,1}}\dots.A(N_{PV}, N_{WT})_{L_{1,d}}\right|\right) \\ f(IR)\left(\left|A(N_{PV}, N_{WT})_{L_{2,1}}\cdots, A(N_{PV}, N_{WT})_{L_{2,d}}\right|\right) \\ \dots\dots\ddots\dots\dots\ddots\dots\dots\dots\dots\dots. \\ f(IR)\left(\left|AA(N_{PV}, N_{WT})_{L_{n,1}}\cdot, A(N_{PV}, N_{WT})_{L_{n,d}}\right|\right) \end{bmatrix} \tag{4}$$

And

$$M_{oAL} = \begin{bmatrix} f(TNPC)\left(\left|A(N_{PV}, N_{WT})_{L_{1,1}}\cdot, A(N_{PV}, N_{WT})_{L_{1,d}}\right|\right) \\ f(TNPC)\left(\left|A(N_{PV}, N_{WT})_{L_{2,1}}\cdots, A(N_{PV}, N_{WT})_{L_{2,d}}\right|\right) \\ \dots\dots\ddots\dots\dots\dots\dots\dots. \\ f(TNPC)\left(\left|AA(N_{PV}, N_{WT})_{L_{n,1}}\cdot\cdot, A(N_{PV}, N_{WT})_{L_{n,d}}\right|\right) \end{bmatrix} \tag{5}$$

In ALO algorithm, ants tend to alter and update their positions in each optimization step using the random walk which requires the random space to be inside the search space. So, the decision variables need to be set and normalized as shown in (6) [25].

$$(N_{PV}, N_{WT})_i^z = ((N_{PV}, N_{WT})_i^z - a_i) \times (d_i - c_i^z) / \\ (d_i^z - a_i) + c_i \tag{6}$$

Where a_i, b_i are the minimum and maximum number of random walks of i_{th} variable, and c_i^z, d_i^z are the minimum and maximum values of i_{th} variable at z_{th} iteration. To sum up, the whole procedure of the optimization problem for the two scenarios are solved using the ALO algorithm, as shown in Figure 2 [24,26]. As a result, the ALO algorithm finds the best optimal value of the decision variables N_{PV}, N_{WT}, for each case of the single objective functions with respect to the technical equality and inequality constraints as shown in Figure 2.

4. SIMULATION RESULTS AND DISCUSSION

4.1 The Measured System Data for Simulation

The number of wind turbines (N_{WT}) and solar panels (N_{PV}) are employed as the two decision variables in the ALO technique to solve the single objective optimization problem. This is carried out in two different scenarios, each including reliability and cost. Moreover, the National Electric Power Company (NEPCO), Jordan Meteorological Department (JMD), and the Royal Scientific Society (RSS) provided measured realistic input data for the solar irradiance (in MW/m2), ambient temperature (in C°), load demand (in MW), and wind speeds (in m/s). See Table 1.

In order to identify the best solution for the system, two scenarios will be examined in this research. The ALO algorithm's primary goal in the first scenario will be to identify the optimal values for the decision variables and system outputs. The ALO algorithm's primary goal in the second scenario, on the other hand, is to determine the best values for the decision variables and system configurations.

The measurements for the planned hybrid system are taken in the Jordanian south in 2020. The hourly tilted solar incident, hourly solar ambient temperature, hourly electricity load demand, and hourly wind speed are the data needed to execute the ALO algorithm and identify the best solution for the specified problem. Table 1 represents the min, mean, and max values of the input hourly measured data. It can be noticed that the solar incidence irradiance and ambient temperatures show the highest values during summer. For instance, an irradiance of 1.2 kW/m^2 and an ambient temperature of 39 °C. Additionally, the minimum and peak load demand is around 3 and 5.9 MW for the chosen feeder in south of Amman.

Table 1: The Min, Mean, And Max Values Of The Realistic Input Hourly Measured Data

	Min	Mean	Max
Load demand (MW)	0.1	3.0016	5.8989
Wind Speed in (m/s)	0.5	4.8146	18.45
Solar Incident Irradiance in (W/m^2)	10	273.9843	1,195.8
Solar Ambient Temperature in (°C)	-1.9	16.9475	39.4

4.2 The Simulation results of The Proposed Two Scenarios

A single objective function of TNPC and IR, has been examined for two case scenarios, with two decision variables—N_{WT} and N_{PV} in each case. Additionally, it should be noted that the optimization method discovered optimal solutions for N_{WT} and N_{PV}, which are smaller in the first scenario, where the TNPC is the major target. On the other hand, when the IR is used as the primary objective function, as shown in Table 2, the optimization algorithm discovered optimal solutions that are better than the first case.

Table 2 shows that the TNPC for the first scenario, which uses 19506 PV panels and 12 wind turbines to generate electricity to meet load demand, is 58.2673 million dollars, while the IR for the second scenario, which uses 24909 PV panels and 14 wind turbines, is 98.994%, indicating a higher cost than the first scenario.

The analysis of the first scenario leads to the conclusion that the PV array's maximum hourly production was 4.2879 MW, which happened in August since summertime temperatures and irradiance are higher.

Table 2: The Best Optimal Values Of The Optimized Proposed System

Systems' Configurations	1st Scenario	2nd Scenario
Objective Function	TNPC: 58.2673 million $	IR: 98.994 %
1st Decision Variable (N_{PV})	19,506	24,909
2nd Decision Variable (N_{WT})	12	14

The hybrid system's capacity to generate power varies from time to time, thus a grid-connected system will boost system reliability and guarantee that the load is met. Additionally, a reliability analysis will be performed, and this will be the ALO algorithm's primary goal.

In reality, the south of Jordan is thought to be among the best suitable areas in Jordan for year-round production of electrical energy from wind turbines. It is also a fantastic place to invest because the cost of land is lower than in other parts of the country, making it a low-risk alternative. The output power produced by wind turbines reaches high values throughout the year and is not just restricted to one particular month.

Additionally, the largest amounts of power sold and bought from the grid during the year are 2.1825 MW and 20.6567 MW, respectively. However, if the PV-wind hybrid system is unable to meet the load requirement, the purchased power must be used. The excess energy from the hybrid system will be sold to the grid and used to meet the load in other feeds.

Additionally, when TNPC is the primary goal, the average shortage power of the load demand for the optimized system is 0.5189155 MW. In fact, when the load demand isn't fully met by the grid's purchased electricity or by renewable energies, there is a power deficit. The grid is regarded as an endless bus, but there is a capacity on how much power can be bought from it. This capacity is set by NEPCO and is equal to the maximum amount of power that can be bought.

At this stage, the TNPC is considered as the priority while analyzing the hybrid PV-wind system using the ALO algorithm, and the decision factors are assessed in accordance with this. However, the primary goal may not be TNPC but rather another variable, such as IR. Whereas the maximum value of the output power is 5.2559 MW. This value is higher than the output value in the first scenario because the ALO algorithm discovered the best solution for the decision variable with IR as the primary objective.

It can be concluded that when comparing the output power generated from the wind turbines in the 1st scenario, and the 2nd scenario, the output power generated from the wind turbines in the 2nd scenario is greater since the IR is considered to be the main objective.

As a matter of fact, the mean cost of the acquired power in the second scenario is 1.5763 MW as opposed to 1.3385 MW in the first. This is due to the algorithm's focus in the second case being on meeting demand rather than cost as in the first. As a result, as previously mentioned, there is more power purchased from the gird.

The sold electricity to the grid in the second scenario with a mean value of 0.2 MW as opposed to 1.1242 MW in the first scenario. The power shortage for the second scenario with a mean value of 0.0037627 MW as opposed to 0.5189155 MW in the first scenario. Since IR is regarded as the primary goal of the ALO algorithm, it can be seen that the value in the second situation is lower than the value in the first scenario.

Additionally, as indicated in Table 3, the values of the total output energies of the system's components are assessed using the ALO method. Because the N_{PV} are larger in the second situation, it can be seen that the inverted energy (E_{PV}) has a higher value than in the first scenario. For the same reason, the second scenario's wind energy production (E_{WTg}) is higher than the first scenario. On the other hand, because the primary goal is the IR, the energy loss from the second scenario is lower than the one from the first.

Table 3 The Total Output Energies Of The Systems' Components

System Energies in (GWh)	1st Scenario	2nd Scenario
Solar Energy (E_{PV})	8.456531	10.3652909
Wind Energy (E_{WTg})	8.235748	9.557498
Energy deficit (E_{def})	0.006341	0.0045457
Sold Energy (E_{gs})	2.268745	2.84731
Purchased Energy (E_{gp})	9.5032951	6.675904

Furthermore, it can be seen that the second scenario has a higher amount of sold energy (E_{gs}) than the first because the N_{WT} and N_{PV} are larger, and the amount of generated power will be bigger as well. Since the N_{WT} and N_{PV} are larger in the second scenario, the amount of purchased energy (E_{gp}) is less because the system's top priority is to meet the load demand from the RE system.

As shown in Table 4, the dependable, economic, and ecological configurations are assessed at the best optimal value for each objective function. It should be noted that the TNPC for the first scenario is 58.2673 million dollars, which is less than the TNPC for the second scenario, which is 74.608 million dollars. This is because in the second scenario, the N_{PV} and N_{WT} are higher because the IR is the most crucial factor when sizing the system. The ACS for the second scenario, which is 5.0801 million dollars, is also lower than 6.5047 million dollars for the second scenario for the same reason, which results in a lower LCE in the first scenario, which is 0.1932 dollars per kWh.

Table 4: Economic, Reliability And Ecological Configurations Of The Systems', At The Best Optimal Value Of Each Objective Function At Each Case Scenario.

Indicators	1st Scenario	2nd Scenario
TNPC (Million \$)	58.2673	74.608
IR (%)	97.384	98.994
Annual Cost of System ACS (Million \$)	5.0801	6.5047
Levelized Cost of Energy LCE (\$/kWh)	0.1932	0.247385
Loss of Power Supply Probability LPSP (%)	2.616	1.006
GHG emissions (Gg CO_2/year)	11.06192	8.8378
Emission reduction Er (Gg CO_2/year)	6.51625	6.961389

In fact, IR is LPSP's complement, therefore their combined value is 100%. The results show that, at the best ideal value, the value of the LPSP in the first scenario is 2.616%, complementing the value of the IR, which is 97.384%. Additionally, the value of LPSP for the second situation is 1.006%, complementing the value of IR for the identical circumstance, which is 98.994%.

Since there are more N_{PV} and N_{WT} in the second scenario, there are 2.22412 Gg CO_2/year fewer GHG released into the atmosphere than in the first scenario. Also, since more renewable energy systems (RES) have been incorporated into the system, which is a good ecological indicator and satisfies the need for using and expanding RES into the grid, the amount of Er in the second scenario is 6.961389 Gg CO_2/year greater than the amount in the first scenario, which is 6.51625 Gg CO_2/year.

The ALO algorithm is used for the improved system which has also been researched for one day in summer. The data illustrates the hourly records results for all powers, and it must be noted that the wind power produced on that particular day is larger than the PV power produced. Additionally, according to the PV curve characteristics, it begins in the morning, achieves its highest value in the afternoon, and then begins to decline at night, whereas the wind curve is unpredictable.

Furthermore, it is apparent that throughout the night when the PV arrays are not producing electricity, the amount of power purchased increases. On the other hand, the system produces more electricity than is required during the day and can sell it to the grid.

4.3 Summary of Section 4

The system is simulated based on a real data from a power station in southern of Amman. Two scenarios are proposed: The ALO algorithm's primary goal in the first scenario will be to identify the optimal values for the decision variables and system outputs. The ALO algorithm's primary goal in the second scenario, on the other hand, is to determine the best values for the decision variables and system configurations.

ALO is used a single objective function of TNPC and IR, has been examined for two case scenarios, with two decision variables—N_{WT} and N_{PV} in each case. According to the scenario’s assumption, the number of optimal PVs and WTs are differing, therefore, the TNPC is changed.

Moreover, the simulation results expect that the second scenario has IR higher that the first scenario. Whereas the first scenario has 97.384% and the second one IR reaches 98.994%. Additionally, in both scenarios, the ALO algorithm's decision variables are the number of PV panels (NPV) and wind turbines (NWT) with a specific priority based on constraints to satisfy the load demand connected with the hybrid system from PV arrays, wind turbines, and ultimately the utility grid.

As a result, an optimal solution of the cost, and the reliability have been found enhancing various indicators. Also, the ecological feasibility configurations have been studied and analyzed. Decision variables sizing (N_{PV}, N_{WT}) has been configured with a specific priority based on constraints to satisfy the load demand connected with the hybrid system from PV arrays, wind turbines, and finally the utility grid.

After running the optimization algorithm for the 1st scenario taking into consideration the TNPC as the objective function, it turns out that the TNPC and IR are 58.2673 million $ and 97.384%, respectively. The corresponding N_{PV} and N_{WT} are found to be 19,506 and 12, respectively. Further, in the 2nd scenario when the IR is taken into consideration as the main objective function, it turns out that the value of the TNPC and IR are 76.608 million $ and 98.994%, respectively. Also, the corresponding N_{PV} and N_{WT} are found to be 24,909 and 14, respectively.

Moreover, the amount of Green Gashouse Emissions (GHG) and Energy reduction (Er) have been calculated in both scenarios. It turns out in the 1st scenario that the amount of GHG and Er are 11.06192 Gg $CO_2/year$ and 6.51625 Gg $CO_2/year$, respectively. Further, in the 2nd scenario, it turns out that the amount of GHG and Er are 8.8378 Gg $CO_2/year$ and 6.961389 Gg $CO_2/year$, respectively. As a result, the proposed system is recommended to be used by the design engineers in Jordan and around the globe in addition to being an ecologically friendly system.

In conclusion, the second scenario is able to reduce the CO_2/year emission due to use of conventional fuel generators by 20.11%. Table 5 gives a brief summary for main aspects of Section 4.

Table 5: Summary of Section 4.

Indicators	1st Scenario	2nd Scenario
TNPC-cost	Cheap	Expensive
Grid in terms of IR	Not bad	Better
GHG emissions ($Gg\ CO_2/year$)	High	Reduced by 20.11%

5. CONCLUSIONS

This paper proposes the use of Ant-Lion Optimizer to size a grid connected HRESs. The objective function is established to find the best number of PVs and Wind Turbines (WTs) that composes the HRESs. The objective function employs the Total Net Pries Cost (TNPC) and Index of Reliability (IR) as hyperparameters. The results of optimization determine the size, TNPC, and IR of HRESs. The optimizer uses real data from one sub-station located in the south of Jordan. The results of two different scenarios are compared: the first one primary goal is to identify the optimal values for the decision variables and system outputs. The second scenario's primary goal is to determine the best values for the decision variables and system configurations.

The comparison shows that the second scenario has the best comparison aspects. For example, the IR of the second scenario is better than the first one. Whereas it costs more pries than the first one. Moreover, the second scenario has more ability to reduce the second carbon-dioxide emission compared to the first scenario. The presented results and methodology in this paper will be very helpful for decision-makers to relay further on the HRESs.

REFERENCES:

[1] J. Wang, L. Feng, X. Tang, Y. Bentley, And M. J. F. Höök, "The Implications Of Fossil Fuel Supply Constraints On Climate Change Projections: A Supply-Side Analysis," Vol. 86, Pp. 58-72, 2017.

[2] L. Qoaider And D. J. A. E. Steinbrecht, "Photovoltaic Systems: A Cost Competitive Option To Supply Energy To Off-Grid Agricultural Communities In Arid Regions," Vol. 87, No. 2, Pp. 427-435, 2010.

[3] M. Elhadidy And S. J. R. E. Shaahid, "Parametric Study Of Hybrid (Wind+ Solar+ Diesel) Power Generating Systems," Vol. 21, No. 2, Pp. 129-139, 2000.

[4] T. Ma, H. Yang, And L. J. A. E. Lu, "A Feasibility Study Of A Stand-Alone Hybrid Solar–Wind–Battery System For A Remote Island," Vol. 121, Pp. 149-158, 2014.

[5] Kjaer, S. B., Pedersen, J. K., & Blaabjerg, F. (2005). A Review Of Single-Phase Grid-Connected Inverters For Photovoltaic Modules. Ieee Transactions On Industry Applications, 41(5), 1292-1306.

[6] Sinha, S., & Chandel, S. S. (2014). Review Of Software Tools For Hybrid Renewable Energy Systems. Renewable And Sustainable Energy Reviews, 32, 192-205.

[7] S. Tafreshi, H. Zamani, S. Ezzati, M. Baghdadi, And H. Vahedi, "Optimal Unit Sizing Of Distributed Energy Resources In Microgrid Using Genetic Algorithm," In 2010 18th Iranian Conference On Electrical Engineering, 2010, Pp. 836-841: Ieee.

[8] A. Y. Saber And G. K. Venayagamoorthy, "Smart Micro-Grid Optimization With Controllable Loads Using Particle Swarm Optimization," In 2013 Ieee Power & Energy Society General Meeting, 2013, Pp. 1-5: Ieee.

[9] Y. SAWLE, S. GUPTA, AND A. K. J. E. P. BOHRE, "OPTIMAL SIZING OF STANDALONE PV/WIND/BIOMASS HYBRID ENERGY SYSTEM USING GA AND PSO OPTIMIZATION TECHNIQUE," VOL. 117, PP. 690-698, 2017.

[10] Karaboga, D., & Basturk, B. (2008). On The Performance Of Artificial Bee Colony (Abc) Algorithm. Applied Soft Computing, 8(1), 687-697.

[11] S. Singh, M. Singh, S. C. J. E. C. Kaushik, And Management, "Feasibility Study Of An Islanded Microgrid In Rural Area Consisting Of Pv, Wind, Biomass And Battery Energy Storage System," Vol. 128, Pp. 178-190, 2016.

[12] E. Takle And R. J. I. J. O. E. R. Shaw, "Complimentary Nature Of Wind And Solar Energy At A Continental Mid-Latitude Station," Vol. 3, No. 2, Pp. 103-112, 1979.

[13] Borowy, B. S., & Salameh, Z. M. (1996). Methodology For Optimally Sizing The Combination Of A Battery Bank And Pv Array In A Wind/Pv Hybrid System. Ieee Transactions On Energy Conversion, 11(2), 367-375.

[14] S. A. Kalogirou, Solar Energy Engineering: Processes And Systems. Academic Press, 2013

[15] Roman, E., Alonso, R., Ibañez, P., Elorduizapatarietxe, S., & Goitia, D. (2006). Intelligent Pv Module For Grid-Connected Pv Systems. Ieee Transactions On Industrial Electronics, 53(4), 1066-1073.

[16] Koçak, K. (2002). A Method For Determination Of Wind Speed Persistence And Its Application. Energy, 27(10), 967-973.

[17] O. Badran And E. Abdulhadi, "Evaluation Of Factors Affecting Wind Power Generation In Jordan," In The Seventh Asia-Pacific Conference On Wind Engineering, 2009, Pp. 8-12

[18] D. Apostolou, P. J. R. Enevoldsen, And S. E. Reviews, "The Past, Present And Potential Of Hydrogen As A Multifunctional Storage Application For Wind Power," Vol. 112, Pp. 917-929, 2019

[19] Mirjalili, S. (2015). The Ant Lion Optimizer. Advances In Engineering Software, 83, 80-98.

[20] Lal, D. K., Dash, B. B., & Akella, A. K. (2011). Optimization Of Pv/Wind/Micro-Hydro/Diesel Hybrid Power System In Homer For The Study Area. International Journal On Electrical Engineering And Informatics, 3(3), 307.

[21] Abualigah, L., Shehab, M., Alshinwan, M., Mirjalili, S., & Elaziz, M. A. (2021). Ant Lion Optimizer: A Comprehensive Survey Of Its Variants And Applications. Archives Of Computational Methods In Engineering, 28(3), 1397-1416.

[22] Assiri, A. S., Hussien, A. G., & Amin, M. (2020). Ant Lion Optimization: Variants, Hybrids, And Applications. Ieee Access, 8, 77746-77764.

[23] Wu, Z., Yu, D., & Kang, X. (2017). Parameter Identification Of Photovoltaic Cell Model Based On Improved Ant Lion Optimizer. Energy Conversion And Management, 151, 107-115.

[24] Kilic, H., Yuzgec, U., & Karakuzu, C. (2020). A Novel Improved Antlion Optimizer Algorithm And Its Comparative Performance. Neural Computing And Applications, 32(8), 3803-3824.

[25] Fathy, A., & Kassem, A. M. (2019). Antlion Optimizer-Anfis Load Frequency Control For Multi-Interconnected Plants Comprising Photovoltaic And Wind Turbine. Isa Transactions, 87, 282-296.

[26] M. Raju, L. C. Saikia And N. Sinha, “Automatic Generation Control Of A Multi-Area System Using Ant Lion Optimizer Algorithm Based Pid Plus Second Order Derivative Controller,” International Journal Of Electrical Power & Energy Systems, Vol. 80, Pp. 52-63, September 2016