Optimization of a Hybrid Renewable Energy System Based on Meta-Heuristic Optimization Algorithms

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***Abstract*—Islands represent strategic platforms for exploring and exploiting marine resources. This article presents a hybrid renewable electric system (HRES) designed to power the island communities of Djerba in Tunisia. The system integrates photovoltaic panels, wind turbines, tidal turbines, hydraulic systems, biomass, and batteries, taking into account available climatic and land resources. A multi-objective optimization method is proposed for sizing this system to minimize power loss and energy costs. Two optimization algorithms, MOPSO (Multi-Objective Particle Swarm Optimization) and SSO (Social Spider Optimization) have been used to solve this problem. MATLAB simulations show that MOPSO offers better convergence and coverage than SSO. The results confirm the viability of the proposed algorithm and method for optimal sizing. In addition, they enable an in-depth analysis of the electrical production and economic benefits associated with the various system components.**

Keywords—Hybrid renewable energy system; techno-economic optimzation; optimal sizing; MOPSO; SSO

I. INTRODUCTION

Energy demand is growing exponentially due to population growth and industrialization. Distributed renewable energy offers many advantages and is a practical alternative to conventional energy sources. Many renewable energy systems can be integrated into hybrid renewable energy systems (HRES) for on-grid and off-grid applications, as has been widely proposed and discussed.

A thorough and detailed design and modeling of a stand-alone HRES, including conventional and renewable energy resources, has been introduced using meta-heuristic algorithms [1]. Technical and ecological aspects were also taken into account. Other research has focused on transcriber generation in microgrids, peer-to-peer energy exchange in micro/mini-grids with the local electricity community, and statistical analyses of wind and photovoltaic HRES [2], [3], [4].

The optimal sizing of an island hybrid system is studied to establish the optimum capacity and size for an island system comprising a wind turbine (WT), solar panels (PV), and a battery [5]. The off-grid operation of an island hybrid system has been examined to establish the optimal sizing and operation of the WT, photovoltaic (PV), and battery components [6].

In study [7], a PV/wind turbine (WT) hybrid system installed in Jordan was designed to minimize the cost of energy (COE) and maximize the fraction of demand met by the system. A hybrid PV/biomass/fuel cell (FC) system installed in Iran was presented and optimized in study [8], considering the loss of power probability (LPSP) as an objective function. Different optimization approaches have been studied to determine the optimal sizing of a PV/WT/FC hybrid system, as discussed in study [9].

The methodology presented in this article uses 12-variable modeling applicable to a wide range of microgrid configurations [10]. A multi-objective particle swarm optimization (MOPSO) algorithm is used to minimize system cost and dependence on external energy sources [11], [12], [13]. After optimization, this external energy cost is used to determine the best system configuration for a given location and consumption profile.

The social spider optimization (SSO) algorithm is used to solve the economic dispatch problem [14], [15]. It is also used for the first time to estimate the thermophysical properties of phase-change materials [16].

In research [17], a recent methodology is developed based on the SSO. The objective is to determine the optimal sizing of a microgrid containing photovoltaic, wind, diesel, and batteries in the Aljouf region. The study focused on three configurations: PV/battery/diesel,wind/battery/diesel, and PV/wind/battery/diesel. In addition, several algorithms are used to optimize the energy cost, respecting the loss of power probability (LPSP) as a technical factor. In study [18], the design of the PV/FC/battery system and a sensitivity analysis study are presented.

The choice of an optimization method for a hybrid system depends on both specific objectives, such as minimizing operating costs and maximizing revenue, and sustainable objectives, such as reducing carbon emissions and adopting renewable energies. There is a growing trend towards holistic approaches that balance economic and environmental considerations to achieve sustainable goals [19], [20].

The optimal performance of the grid with a distributed generator (DG) and an energy storage system (ESS) on several objective functions, such as loss minimization, unbalanced generation at the substation, and overall energy costs as well as peak load demand, is introduced in study [21]. In study [22], and [23], a SSO algorithm is used to solve the economic distribution algorithm, while in study [24], the hybrid SSO algorithm is used to estimate the physical characteristics of the phase thermos for the first time.

This article focuses on optimizing the structure of a hybrid system comprising photovoltaics, wind turbines, tidal turbines, hydraulics, biomass, and batteries. This optimization is carried out using two meta-heuristic algorithms, MOPSO (Multi-Objective Particle Swarm Optimization) and SSO (Social Spider Optimization). These algorithms were also used to reduce energy costs and the probability of power loss.

This careful selection process ensures the integration of state-of-the-art methodologies adapted to the complexities of the research problem, leading to a robust and innovative solution.

The remainder of this paper is organized as follows: In Section II, we describe a hybrid electrical system. In Section III, the economic analysis of the optimization parameters is clarified. In Section IV, the optimization problem is formulated. Section V presents the optimization algorithms. Section VI provides a case study. Results are given in Section VII. Section VIII presents a conclusion.

II. DESCRIPTION OF THE HYBRID ELECTRICAL SYSTEM

The schematic diagram of the proposed Hybrid Renewable Energy System (HRES) is shown in Fig. 1. The system integrates several energy sources, including photovoltaic (PV) solar panels, wind turbines (WT), tidal turbines, hydroelectricity, biomass and batteries (BESS). The HRES is configured for alternating current (AC), with all renewable energy sources connected to the same AC bus. Direct current (DC) sources such as PV, WT, and BESS are connected to the AC bus via DC/AC inverters. In addition, wind turbines require a controlled inverter to adjust power output to voltage and frequency specifications. The project's economic and technical data are presented in Table I for the system studied.

A. Photovoltaic Modeling

The power output of the photovoltaic panel, P_{pv}, is defined by [28]:

$$P_{pv} = \eta_{pv} N_{pv} P_{max} \frac{G(t)}{G_{stc}} [1 - K_T(T_C(t) - T_{stc})] \tag{1}$$

Where T_C and T_{STC} represent respectively the ambient and the surface temperature of the photovoltaic cells, in this work, T_C is assumed to be equal to 25 °C under standard test conditions (STC). G designates the solar radiation measured as W/m2. G_{STC} and K_T represent the constants of photovoltaic cells whose values are fixed at 1 kW/m2 and -3.7×10^{-3} °C^{-1}, respectively.η_{pv} Implies the efficiency of the solar panels and includes the efficiency of the power converter, tracking systems, and connection wires,N_{pv}represents the photovoltaic panel numbers. P_{max} is the nominal output power for STC.

B. Wind Turbine Modeling

In the case of the wind turbine, the power output depends on the wind speed, which in turn is a function of the turbine height. The relationship between the wind speed and the turbine hub height is represented by the equation as shown below [28]:

$$\frac{v_2}{v_1} = \left(\frac{h_2}{h_1}\right)^{\alpha} \tag{2}$$

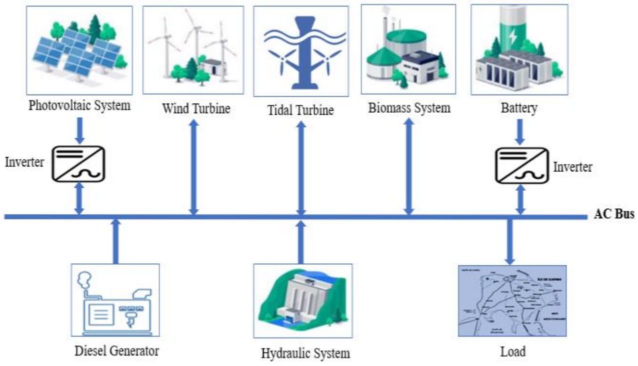


Fig. 1. Hybrid energy system configuration.

TABLE I. ECONOMICAL AND TECHNICAL DATA [25],[26],[27]

Components	Parameters	Value	Unit
Diesel generator	Lifetime	24000	Hours
	Initial cost	1000	$/kW
	Rated power	4	kW
Wind Turbine	Wind regulator cost	1000	$
	Cut out	21	m/s
	Cut in	3	m/s
	Rated speed	12	m/s
	Rated power	10	kW
	Price	2000	$/kW
	Lifetime	25	Year
Photovoltaic	PV regulator efficiency	95	%
	Lifetime	25	Year
	Initial cost	3400	$/kW
	Rated power	300	kW
	PV regulator cost	1500	$
Tidal Turbine	Tidal regulator cost	1000	$
	Cut out	3.05	m/s
	Cut in	1	m/s
	Rated power	40	kW
	Price	1535	$/kW
Hydraulic	Lifetime	25	Year
	Initial cost	750	$/kW
	Rated power	10	kW
Biomass	Replacement cost	200	$
	Capital cost	1500	$
	Rated power	1	kW
	Operating and maintenance	0.1	$
Battery	Efficiency	80	%
	Lifetime	12	Year
	Initial cost	280	$/kW
	Rated power	1	kWh

Where: h_1 and $h_2$represent the reference height and hub height required, and v_1, v_2 correspond to the wind speed. α is the coefficient of friction and is determined by several characteristics of the site, especially the roughness, the temperature, the speed, the height, and the time of year. The power produced by the wind turbine is presented by Eq. (3) [28].

$$P_{wt}(t) = \begin{cases} 0 & v(t) < v_{in} \\ \eta_{wt} N_{wt} P_{wt_r} \frac{(v^2(t) - v_{in}^2)}{(v_m(t) - v_{in}^2)} & v_{in} < v(t) < v_r \\ \eta_{wt} N_{wt} P_{wt\_r} & v_r < v(t) < v_{off} \\ 0 & v(t) > v_{off} \end{cases} \tag{3}$$

Where N_{wt} represents the wind turbinenumbers, η_{wt} represents the wind turbine efficiency, P_{wt_r} implies the rated power of a single WT operated at the rated wind speed (v_r) in (m/s), andv_{in}, v_{off}denotes the velocity in (m/s) at which the WT starts running and stopped, respectively.

C. Tidal Modeling

The operating principles of tidal turbines are generally based on those of wind turbines since they operate similarly. The available power may be determined by Eq. (4), as described in detail in [29]. Where: S_t is the surface area of the turbine (m2), ρ_t equals the density of the water (1000 kg/m3), v_t equals the speed of the water (m/s), and C_{pt} equals the power coefficient.

$$P_t = \frac{1}{2} N_{tid} \rho_t S_t C_{pt} v_t^3 \tag{4}$$

D. Hydraulic Modeling

The pump is designed to raise the water level in the lower cascade basin to the upper reservoir [30]. The power required to operate the pump is represented by Eq. (5):

$$P_{hy} = N_{hyd} \eta_P \rho_w g h Q(t) \tag{5}$$

where, η_P is the efficiency of the pump installation, the density of the water is represented by ρ_w (kg/m3), the flow rate of the water is represented by Q in (m3/s), an effective head corresponds to h (m)and accelerated gravity is represented by g (m/s2).

E. Biomass Modeling

The biomass generator is considered a production base to satisfy energy needs, complementing other energy production sources. The biomass generator's production of electrical energy can be evaluated by [28]:

$$P_b(t) = N_b \eta_g \omega H_{hv} Q_{sr}(t) \tag{6}$$

where, η_g corresponds to the gasifier efficiency and is equal to 75%, ω corresponds to a conversion factor from kJ to kWh (27.78×10^{-5}), $Q_{sr}(t)$ indicates the biomass flow rate (kg/h), and H_{hv} corresponds to the higher calorific yield of the biomass introduced by the system.

F. Battery Modeling

The final component connected to the DC bus is the battery, characterized by its capacity, C_{bat}, as shown below [28]:

$$C_{bat} = \frac{E_{load} \times A_d}{DOD \times \eta_{inv} \times \eta_b} \tag{7}$$

where, A_d represents the days of autonomy, and E_{load} denotes the load. The depth of discharge (DOD) is assumed to be 8%. The inverter efficiency (η_{inv}) is taken to be 95%, and the battery efficiency (η_b) is taken to be 85%.

G. Diesel Generator Modeling

A stand-alone diesel generator is connected to the AC bus as a second source. This is essential for the stable operation of the HRES, particularly when renewable resources cannot meet the load demand. The generator fuel consumption q(t) can be calculated as follows [28]:

$$q(t) = aP(t) + bP_{rated} \tag{8}$$

Where a and b represent the fuel consumption coefficients, estimated at 0.246 and 0.08415 l/kWh respectively. P_{rated} is the rated power, and P(t) is the power output at a specified time.

III. ECONOMIC ANALYSIS OF OPTIMIZATION PARAMETERS

A. Cost of Energy

The cost of energy (COE) represents the average cost of the usable electricity produced by a hybrid system and can be determined by the following equation [31]:

$$COE = \frac{NPC}{\sum_{i=1}^{8760} P_{load}} \times CRF \tag{9}$$

where, P_{load} represents the power demand per hour, and CRF (Capital Recovery Factor) is defined as follows:

$$CRF = \frac{i \times (1+i)^n}{(1+i)^n - 1} \tag{10}$$

B. Loss of Power Supply Probability

Reliability is the basis for the operation of the entire system. In this article, the loss of power probability (LPSP) is presented as an indication of system reliability. LPSP measures the ability of power generation to meet load requirements.LPSP can be calculated from the total power outage duration divided by the total report duration [31].

$$LPSP = \frac{\sum_{i=1}^{8760} \left[P_{load}(t) - \left(P_{pv}(t) + P_{wt}(t) + P_{tid}(t) + P_{hyd}(t) + P_b(t)\right)\right]}{\sum_{i=1}^{8760} P_{load}(t)} \tag{11}$$

where $P_{load}(t)$ represents the power of load.

C. Renewable Factor

Renewable Factor (RF) determines the quantity of electricity produced by renewable resources about the non-renewable resources (diesel generator) used by the HRES and can be calculated in the following equation [31]:

$$RF(\%) = 1 - \left(\frac{\sum_{i=1}^{8760} P_{diesel}(t)}{\sum_{i=1}^{8760} P_{gen}(t)} \right) \times 100 \tag{12}$$

where P_{gen} is the total power of renewable energies. And, when RF is equal to 100%, this means an ideal system that relies solely on power generated from renewable energy resources. When it is at zero percent, it means that the power generated by the diesel generator is the same as the power produced by renewable energy resources.

IV. FORMULATION OF THE OPTIMIZATION PROBLEM

The HRES system, integrating renewable energy sources such as photovoltaic, wind,tidal, hydro, biomass, and batteries, is designed to supply electricity to a remote island in south-eastern Tunisia. It aims to guarantee system reliability, reduce energy costs, and minimize the probability of power loss. In this article, the cost of energy (COE) and the probability of power loss (LPSP) are used as optimization objectives.

A. *Objective Function*

To assess overall hybrid system performance, the probability of power loss (LPSP) and energy cost (COE) are suggested as the two objective functions, with the main goal being to minimize both functions to achieve high reliability and the minimum possible cost of the hybrid systems studied.

$$\min\{\mathrm{COE}, \mathrm{LPSP}\} \tag{13}$$

The various sizing optimization objectives depend on some restrictions deriving from each of the sources used in the system under study.

B. *Constraints*

Constraints are shown for achieving the required system design. For this HRES system, restrictions are defined in the following terms:

$$\begin{gathered} N_{pvmin} \le N_{pv} \le N_{pvmax} \\ N_{wtmin} \le N_{wt} \le N_{wtmax} \\ N_{tidmin} \le N_{tid} \le N_{tidmax} \\ N_{hydmin} \le N_{hyd} \le N_{hydmax} \\ N_{bmin} \le N_{b} \le N_{bmax} \\ LPSP \le LPSP_{max} \\ RF_{min} \le RF \\ A_d^{min} \le A_d \end{gathered} \tag{14}$$

V. OPTIMIZATION ALGORITHMS

To meet the design challenges of our HRES system, we are investigating two different optimization approaches: MOPSO and SSO. These methods offer a flexible economic analysis platform and are based on natural principles, bringing new optimization perspectives. In this section, we present these methods in detail, describing their specific application to the sizing of hybrid energy systems to identify optimal and economically sustainable solutions.

A. *Overview of the MOPSO Algorithm*

A PSO algorithm was born out of the study of the predatory behavior of flocks. For PSO, a search for the birds within the population pool's empty zone is the solution to the optimization problem, i.e. "particles". All particles have a fitness value, as determined by the optimization function. Furthermore, each particle's direction and distance are defined by its velocity. All particles are traced to the optimal particles in the population, to find the optimum solution in the interval. The process of updating is as follows [30]:

$$\begin{gathered} V_{i+1} = \omega V_i + C_1 \mathrm{rand}()(\mathrm{pbest}_i - X_i) + C_2 \mathrm{rand}()(\mathrm{gbest}_i - X_i) \\ X_{i+1} = X_i + V_{i+1} \end{gathered} \tag{15}$$

Where V_i represents the velocity and X_i the position of the particle; gbest represents the optimal location for all particles found in the entire population; rand() represents the random number between (0,1); X_i represents the particle's current position; c_1 and c_2 represent training factors. ω represents the particle swarm's dynamic weight value, whose value is:

$$\omega = \omega_{max} - \omega_{min} \times \frac{\mathrm{inter}}{\mathrm{inter}_{max}} \tag{16}$$

where ω_{max} is the initial weight of inertia; ω_{min} is the weight of inertia during iteration to maximum algebra; inter_{max} is the maximum number of iterations; inter is the actual iteration number.

1) Description of the MOPSO algorithm: A criterion to classify a meta-heuristic algorithm for optimization problem solving consists of the number to be achieved: a single objective, a multi-objective problem, or a multiple-objective problem. The MOPSO (Multi-ObjectiveParticle Swarm Optimization) approach was developed to solve multi-objective optimization problems. MOPSO makes use of particles that represent possible solutions, which move in the search space following swarm-inspired rules. By updating the positions and velocities of these particles as the best solutions are identified, the system identifies non-dominated solutions forming the Pareto front. This makes it possible to determine optimal trade-offs among different objectives, offering a range of optimized options for making decisions in a highly complex environment [32].

Algorithm 1: Pseudocode of MOPSO

```
Step 1
Input data includes meteorological, load demands, technical, economic, and constraint data.
Step 2
Set an upper bound and a lower bound for the source of HRES.
Step 3
$C_1$ = 1.5, $C_2$ = 1.5, inertia_weight = 0.9

Step 4
For each particle in particle_swarm:
    particle.velocity = random_value()
    particle.position = random_value()
    particle.fitness = assess_fitness(particle.position)
Step 5
For each particle in particle_swarm:
    Update $p_{best}$ and $g_{best}$ if necessary.
Step 6
For each particle in particle_swarm:
    particle.velocity = inertia_weight × particle.velocity
                        + C1 random_value()
                        × (particle.pbest_position
                        − particle.position) + C2 × random_value()
                        × (global.gbest_position
                        − particle.position) particle.position
                        = particle.position + particle.velocity
Step 7
Until max_iterations or non_dominated_sort_solution_found:
    Repeat steps 5 and 6.
Return the best setting or optimal LPSP and COE values.
End
```

B. Definition of Algorithm SSO

The Social Spider Optimizer (SSO) represents an optimization algorithm inspired specifically by the social behavior of spiders. Using data from spider positions, social interactions, and the best historical solutions, it explores the found space. By encouraging spider cooperation and combining exploration and exploitation, the SSO can generate high-quality solutions for optimizing a particular objective function. Fig. 2 presents the general procedure of the SSO algorithm [29].

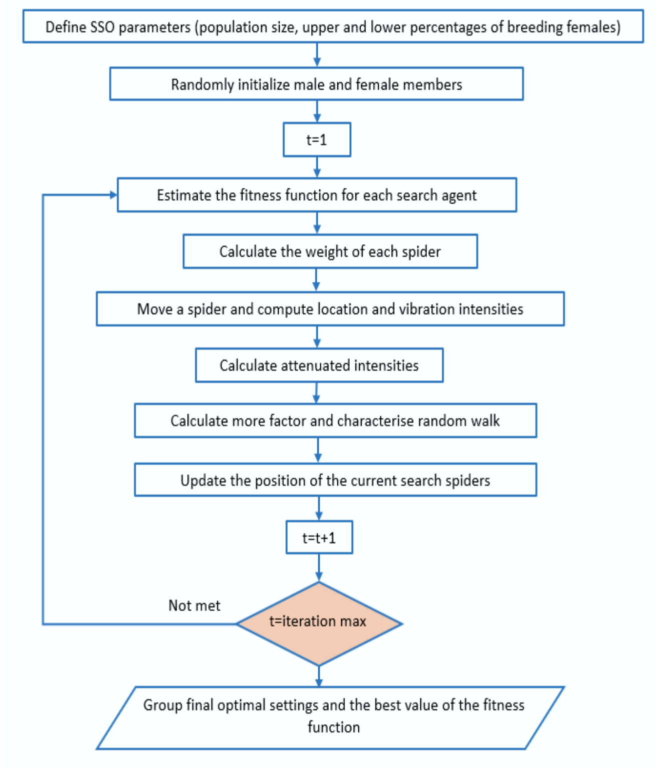


Fig. 2. Flow chart of the SSO process.

1) The proposed SSO-based solution methodology: The proposed methodology using the SSO algorithm for the optimal HRES system sizing is shown in Fig. 3. First, photovoltaic, wind, tidal, hydro, biomass, and battery requirements are defined, in addition to the load. Meteorological data from the installation site, including wind speed, solar radiation, ambient temperature, tidal speed, and water flow, are recorded.

The SSO process is performed for each possible solution, including N_{PV}, N_{WT}, N_{tid}, N_{hyd}, N_b, and N_{bat}. If LPSP converges to unity, this means that the load is not satisfied and that this solution is not reasonable, and these steps are then repeated on the next likely solution in the population. When the LPSP converges to zero, this indicates that the renewable energy sources (RES) realized are capable of satisfying the load. The steps continue until all solutions are satisfied, producing a reliable hybrid power system capable of satisfying the load throughout the systems lifetime.

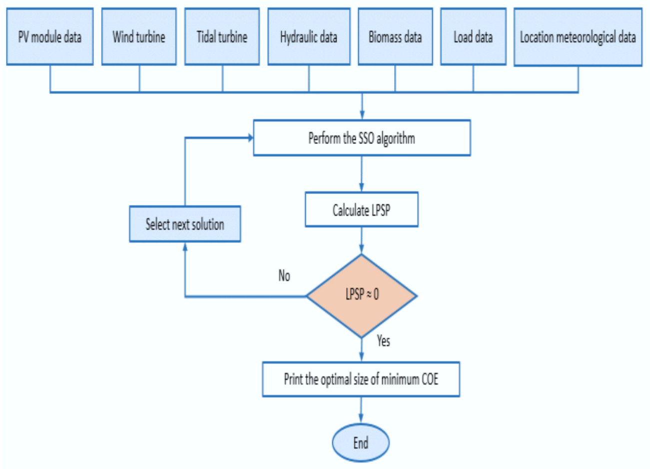


Fig. 3. Flowchart of the solution methodology with the SSO algorithm.

VI. CASE STUDY

Our area of study is located on Djerba, a small island in southeastern Tunisia. Situated on the Gulf of Gabes, the island extends over a surface area of 514 km2. Its geographical coordinates stand at 33° 48′ N, 10° 51′ E. This site is therefore a convenient location for designing a hybrid energy system.

The metrological data for the system studied are presented in Table II with NASA application software, including the wind speed profile available at the chosen location, solar radiation profile, water flow rate, tidal speed, and the load profile for the entire month.

TABLE II. MONTHLY ENERGY PRODUCED BY HRES COMPONENTS

Months	**Irradiation (kWh/m2/day)**	**Wind speed (m/s)**	**Tidal speed (m/s)**	**Water flow (l/min)**	**Load (kW)**
Jan	3.02	6.5	1	2.3	20.46
Feb	3.98	6.34	0.5	4.6	17.18
Mar	5.1	6.02	0.3	5	18.88
Apr	6.27	6.01	0.5	4.5	19.26
May	6.88	5.88	0.5	3.7	19.28
Jun	7.43	5.61	0.4	3	19.45
Jul	7.62	5	0.6	3.2	19.45
Aug	6.96	4.83	0.7	2.8	18.43
Sep	5.54	5.22	0.9	2.5	17.93
Oct	4.16	5.18	1	3	17.40
Nov	3.16	6.02	1.2	4.7	19.0
Dec	2.69	6.67	1.4	5	18.50

VII. RESULTS

In this work, we have proposed the MOPSO algorithm for optimal sizing of PV, WT, hydro, hydro, biomass, and battery models. We compared the results obtained by this algorithm with those obtained by the SSO algorithm in order to validate the effectiveness of MOPSO in terms of reliability and cost reduction. We also studied the HRES system in four configurations:

- HRES 1: PV/WT/Tidal Turbine / Hydraulic/ Biomass/ Battery.
- HRES 2: PV/Tidal Turbine /Hydraulic /Biomass /Battery.
- HRES 3: PV/WT /Tidal Turbine /Hydraulic/Battery.
- HRES 4: WT /Tidal Turbine /Hydraulic/Battery.

Table III shows the parameters LCOE (levelized cost of energy), LPSP (loss of power supply probability), RF (renewable fraction), and N_{ad} for the two algorithms, MOPSO and SSO. The results indicate that the HRES 1 configuration offers the lowest energy cost, with an LCOE of 0.1$/kWh, while SSO gives an LCOE of 0.608$/kWh. The associated LPSP limit is 0.99%, and the RF is around 99%. The MOPSO algorithm achieves optimal results for all four configurations compared with the other optimization methods used.

Table IV also shows the component sizes for the four hybrid systems. It can be seen that the best configuration is HRES 1. The hybrid system sizing results obtained by the MOPSO and SSO algorithms offer distinct perspectives. The MOPSO algorithm demonstrated higher cost-effectiveness by increasing component size, while SSO adopted a more conservative approach.

The result obtained by MOPSO for the best configuration includes 181 photovoltaic panels, six wind turbines, one tidal turbine, eight hydraulic systems, three biomass systems, and 60 batteries. These results confirm the superiority of MOPSO for assessing the optimum size of hybrid power systems.

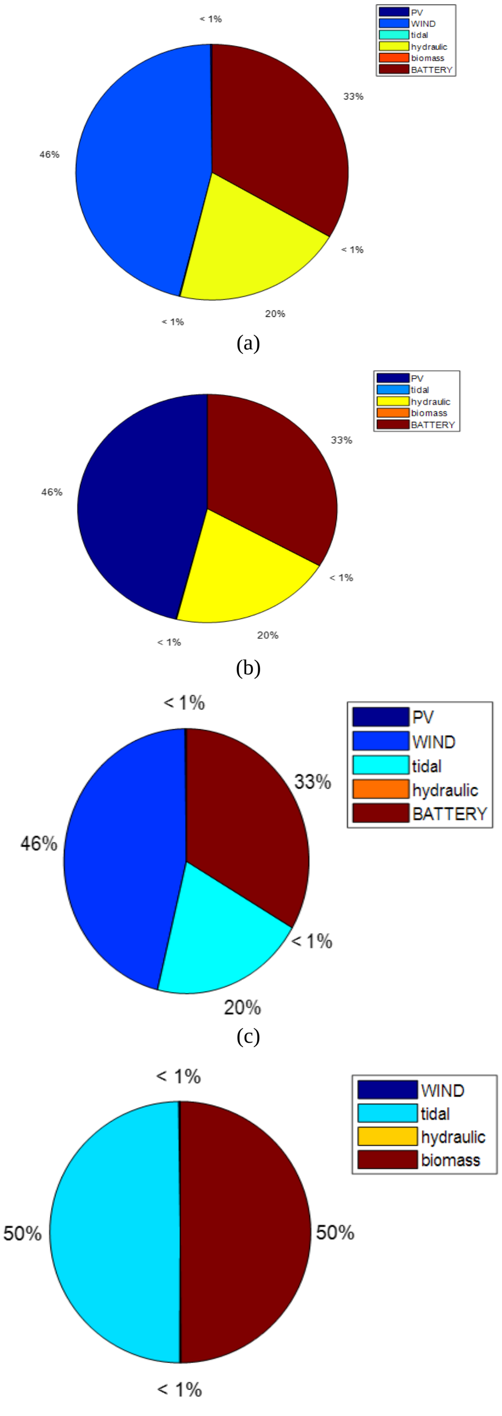
TABLE III. RESULTS BASED ON ECONOMIC AND TECHNICAL FACTORS IN ALL CONFIGURATIONS

Proposed HERS	**Algorithm**	**COE ($/kWh)**	**LPSP (%)**	**RF (%)**	**N_{ad}**
HRES 1	MOPSO	0.10	0.99	99.945	4
	SSO	0.608	0.489	0.015	22
HRES 2	MOPSO	0.55	0.183	0.426	5
	SSO	0.484	0.395	0.011	9
HRES 3	MOPSO	1.163	0.09	0.425	4
	SSO	0.496	0.391	0.014	17
HRES 4	MOPSO	0.562	0.18	0.305	1
	SSO	0.405	0.399	0.022	1

TABLE IV. OPTIMUM SIZING USING THE PROPOSED ALGORITHM FOR ALL CONFIGURATIONS

Proposed HERS	**Algorithm**	**N_{PV}**	**N_{WT}**		**N_{tid}**	**N_{hyd}**	**N_b**	**N_{bat}**
HRES 1	MOPSO	181	6		1	8	3	60
	SSO	7	1		2	3	2	42
HRES 2	MOPSO	50	--		1	3	2	50
	SSO	2	--		4	5	5	30
HRES 3	MOPSO	22	5		0	2	--	20
	SSO	5	4		3	4	--	44
HRES 4	MOPSO	--	11		1	4	3	12
	SSO	--	1		2	3	2	66

The percentage contribution of each energy source to annual load coverage, obtained by the proposed MOPSO for four hybrid system models, is shown in Fig. 4.



(a)

(b)

(c)

(d)

Fig. 4. Contribution of the HRES system based on the MOPSO algorithm: (a) HRES 1; (b) HRES 2 ; (c) HRES 3, (d) HRES 4.

Analysis of the MOPSO simulation results shows considerable variations in the contribution of energy sources. In some models, wind power dominated, accounting for up to 46% of overall production, while in others, photovoltaics also reached 46%. Batteries maintained a stable share of 33% in some models. Significant variations are observed, notably in a model where tidal power and biomass are the main sources, each accounting for 50% of production.

These results underline the importance of diversifying power sources to maintain the stability of energy systems.

VIII. CONCLUSION

This article presents a comparison between two optimization algorithms, MOPSO and SSO, to evaluate their respective performances. The main objective of this research was to determine the optimal size and the best economic configuration for a hybrid stand-alone power system (HRES) on the island of Djerba, Tunisia. The study focused on four different configurations, integrating renewable energy sources (RES) such as photovoltaics (PV), onshore wind (WT), tidal power, hydropower, and biomass, with battery storage systems.

Our results showed that the HRES 1 configuration was the most cost-effective, achieving a cost of energy (COE) of 0.1$/kWh. In addition, the optimal HRES configuration included 181 solar panels, six wind turbines, one tidal energy source, eight hydroelectric plants, three biomass plants, and 60 batteries.

The findings of this study are of crucial importance for decision-makers involved in the development of the renewable energy sector in the south-eastern region of Tunisia. The recommendations formulated can serve as a solid basis for strategic planning and policy development aimed at promoting the use of renewable energies and ensuring a sustainable energy transition in the region.

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