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Memory

ACADEMIC MASTER

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Presented by :

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Theme :

Dynamic Economic Emission Dispatch with Integrating Electric Vehicles and Renewable Energy Source using new Approach of Optimization

Submitted to the jury composed of:

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Thank

First of all, we thank God Almighty for giving us the strength and will to complete this work. We would first like to thank our supervisor, Dr. Larouci benyekhlef, who entrusted us with this topic for his help, advice, encouragement, availability to us, and benefiting from his scientific experience to carry out this work.

We extend our sincere thanks and appreciation to all members of the judging committee Mr Benaouedj Mahdi and Mr Boudjella Houari -who accepted their cooperation in judging our work. We also extend our thanks to all the professors of the Department of Electrical Engineering Who allowed us to gain knowledge and also thanks to them we developed and reached this level.

Finally, we thank everyone who contributed directly or indirectly to the smooth conduct of this work.

.

Dedication

We are dedicated to this work:

To our dear parents

To our brothers and sisters

To our families, Adila and Boubakri

To our friends and comrades

ملخص:

هذه الاطروحة لنيل شهادة الماستر في الهندسة الكهربائية ,تخصص شبكات كهربائية يتمثل في التوزيع الاقتصادي الديناميكي للانبعاثات مع دمج المركبات الكهربائية ومصادر الطاقة المتجددة باستخدام نهج جديد للتحسين.
تمحورت دراستنا حول نهج جديد للتحسين باستخدام" MATLAB" لايجاد الظروف التشغيلية المثلى لانظمة الطاقة مع مرور الوقت بعد دمج المركبات الكهربائية(EVs)ومصادر الطاقة المتجددة (RES) مع انشاء جداول للمستخدم في "MATLAB" يتالف برنامجنا من التعامل طريقة تشغيل وحدات توليد الطاقة على مدار فترة زمنية معينة بهدف تقليل تكاليف التشغيل والانبعاثات الضارة مع الحفاظ على استقرار وموثوقية الشبكة الكهربائية.

كلمات مفتاحية:المركبات الكهربائية(EVs) ,مصادر الطاقة المتجددة(RES) ,MATLAB,التوزيع الديناميكي للانبعاثات.

Résumé:

Ce memorie vise à obtenir un master en génie électrique, spécialisation en réseaux électriques, qui implique la répartition économique dynamique des émissions avec l'intégration des véhicules électriques et des sources d'énergie renouvelables utilisant une nouvelle approche d'optimisation.

Notre étude s'est concentrée sur une nouvelle approche d'optimisation utilisant « MATLAB » pour trouver les conditions de fonctionnement optimales pour les systèmes électriques au fil du temps après l'intégration des véhicules électriques (VE) et des sources d'énergie renouvelables (RES) avec la création de tables d'utilisateurs dans « MATLAB Notre programme ». consiste à traiter du mode d'exploitation des unités de production d'électricité sur une certaine période de temps dans le but de réduire les coûts d'exploitation et les émissions nocives tout en maintenant la stabilité et la fiabilité du réseau électrique.

Abstract:

This dissertation aims to obtain a master degree in electrical engineering, specialization in electrical networks, which involves the dynamic economic dispatch of emissions with the integration of electric vehicles and renewable energy sources using a new optimization approach.

Our study focused on a novel optimization approach using “MATLAB” to find the optimal operating conditions for power systems over time after the integration of electric vehicles (EVs) and renewable energy sources (RES) with the creation of user tables in “MATLAB Our Program”. consists of dealing with the mode of operation of electricity production units over a certain period of time with the aim of reducing operating costs and harmful emissions while maintaining the stability and reliability of the electricity network.

Keywords: electric vehicles (EV), renewable energy sources. (RES), MATLAB, dynamic distribution of emissions.

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Abbrevation

CEED	Combined economic environmental dispatch	$\alpha_i\beta_i\gamma_i$	Emission curve coefficients
P_{solar}	Solar generation (MW)	ω_i	Weighting factor
P_{wind}	Wind generation(MW)	$B_{ij}; B_{00}$	Network loss coefficients
$P_{ch.t}$,$P_{Dch.t}$	EV S charging and discharging power at time t	**MaxIter Max**	Number of iterations
DEED	Dynamic economic emission dispatch.	**BF**	Benchmark Function
FC	Fuel cost	**UM**	Unimodal
EM	Fuel cost and pollution emission objective function	**TLBO**	Teaching-Learning-Based Optimization
$P_{L\,T}$	Transmission loss at time t	**MM**	Multimodal
P_{rate}	Rated and active output wind power	**IWO**	Invasive Weed Optimization
V_{out}^{K}	Rated ,cut-in and cut-out wind speed	**FM**	Fixed-dimension Multimodal
V_{rate}	Rated ,cut-in and cut-out wind speed	**GOA**	Grasshopper Optimization Algorithm
S_t	Battery remaining power at time t	**PSO**	Particle Swarm Optimization
ΔS	Average power consumption of unit distance	**WFLO**	Wind Farm Layout Optimization
$P_{i,t}^{max}$	Minimum and maximum amount of active power	**WOA**	Whale Optimization Algorithm

General Introduction

In the current era of technological progress and environmental awareness, the integration of electric vehicles (EVs) and renewable energy sources (RES) into the electricity grid presents both opportunities and challenges. One of the crucial aspects of this integration is the Dynamic combined Economic Emissions Dispatch (DCEED), which aims to balance costs, emissions and energy efficiency in electricity grid operations in real time. This manuscript explores a new approach to DCEED optimization that leverages cutting-edge techniques to improve the synergy between electric vehicles and renewable energy. By optimizing the shipping process, we can build a more sustainable and efficient energy system, helping to reduce carbon emissions and encouraging the adoption of cleaner energy solutions.

A compromise is therefore established between these two objectives and the problem is resolved for a compromised solution. This combinatorial and bi-objective problem is called Dynamic Combined Economic dispatch of Emissions (DCEED). This is a nonlinear optimization problem and can be solved by optimization theory.

In this work, the hippopotamus optimization algorithm (HO) is used to solve DCEED problem. The hippopotamus optimization algorithm is based on the behaviors of hippopotamuses in nature, especially how they interact with and adapt to their environment Different conditions to achieve certain goals, such as searching for food, protecting themselves from enemies, and staying alive. Different test cases having different combinations of thermal, solar and wind units with integration of electric vehicles (EVs) are solved using the proposed algorithm.

The results show the superiority of this study compared to existing research results in terms of production cost and emissions.

This manuscript titled as “Dynamic Economic Emission Dispatch with Integrating Electric Vehicles and Renewable Energy Source using new Approach of Optimization” is divided into three chapters; the brief discussion is as follows:

Chapter-I, a brief introduction on Dynamic Combined Economic Emission Dispatch Problem with integration of Renewable energy sources (Solar and wind energy) and electric vehicles is given. Awareness of the problem, Hypothesis, problem formulation, Assumption is also given. Organization of the thesis is also discussed.

Chapter-II, The hippopotamus optimization technique (HO) is based on the behaviors of hippopotamuses in nature has been discussed.

Chapter-III, Hippopotamus Optimization (HO) technique and its algorithm has been discussed. A Multi-objective or Dynamic Combined Economic Emission Dispatch Problem Solution has been solved for the test system of 3 generator system by HO technique with Price Penalty Factor Approach.

General conclusion, deals with the conclusion and the future scope of the work.

Theoretical part

Chapter .I

Chapter I:

Dynamic Combined Economic Emission Dispatch with integrating of Renewable Energy Sources and Electric Vehicles

I. 1.Introduction:

The objective of solving the economic dispatch problem in electric power system is to determine the generation levels for all on-line units which minimize the total fuel cost and minimize the emission level of the system, while satisfying a set of constraints. The objective of economic dispatch is to simultaneously minimize the generation cost and to meet the load demand of a power system over some appropriate period of time while satisfying various operating constraints.

The objective function of an economic dispatch problem can be formulated as. One of the key objective functions is emission reduction due to environmental concerns. Accordingly, the dynamic combined economic emission dispatch (DCEED) is defined as a multi-objective problem which tends to minimize the operational cost and emissions emitted by thermal units. For solving the DCEED, different computational methods and techniques have been introduced that are discussed as follows [1] .

I. 2. Model Dynamic Economic Dispatch:

A comprehensive study of basic DED problem is done here. A non-smooth, non-convex, non-differentiable single- and multi-objective multi-constraint model of ED problem is formulized in this section.

I. 2.1.Objective function :

The objective function of DED problem, which is to minimize the total production cost over the operating horizon, can be written as:[2], [17]

$$\min C_T = \sum_{t=1}^{T}\sum_{i=1}^{n} C_{i,t}(P_{i,t}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where: CT (in$/h) is the total generation cost, Ci,t is the generation cost of ith unit at time t, n is the number of dispatch-able power generation units; here, n=5, 10 and 30, and $P\ i,t$ (in MW) is the power output of ith unit at time t. T is the total number of hours from operational point of view.

The basic ELD objective function is represented by a smooth curve (quadratic polynomial) function as shown in Eq. (2).

$$C_T = \sum_{i=1}^{n} C_i(P_{i,t}) = \sum_{i=1}^{n} a_{i,t} + b_{i,t}P_{,ti} + C_{i,t}(P_{i,t})^2 \quad \ldots\ldots\ldots(2)$$

Where ai (in $/h), bi (in $/MWh) and ci (in $/MW2 h) are the cost coefficients of the ith unit. Pmin,i (in MW) is the minimum generation capacity limit of unit i. In the generation cost function. The objective function (Eq.1) of the DED problem should be minimized subject to the following constraints.[3] [18]

I. 3. Dynamic emission load Dispatch:

The operation of thermal power plants releases various pollutants such as sulfur dioxide, nitrogen oxides and carbon dioxide. Reduction of these pollutants is

Mandatory for every production unit. In order to achieve this goal, new criteria are included in the formulation of the economic shipping problem as follows:

$$E_{T_i}(P) = di_{i,t} + e_{i,t}P_{i,t} + f_{i,t}P^2{}_{i,t} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .(3)$$

di, ei, fi Emission coefficients of generating unit i [kg/MW2h], [kg/MWh] And [kg/h] respectively[4] .

I. 4. Modeling of DCEED Problem:

A multi-objective optimization becomes a single-objective optimization called Combined Economic Emissions Allocation (CEED) problem by introducing a price penalty hi to the various pollutants [5] :

$$F_T = \sum_{i=1}^{n}(a_{i,t} + b_{i,t}P_{i,t}\, C_{i,t}(P_{i,t})^2) + h_{i,t} * (di_{i,t} + e_{i,t}P_{i,t} + f_{i,t}P^2{}_{i,t}) \quad \ldots\ldots\ldots(4)$$

I. 5.Modeling of DCEED Problem with EVs and RESs:

Many uncertain factors, such as the charging and discharging behavior of EVs, the wind power output, and the system load demand, are involved in the DEED problem. In this section, a DEED model is proposed to minimize the fuel cost and the pollution emission.

Because EVs and RESs participate in power system dispatch, the objective functions become dynamic compared with the classical EED problem.

a) Solar energy [19]:

According to Bhoye et al. (2016a) and Trivedi et al. (2016),the cost function of solar generation unit can be written as follows:

$$F(P_{solar}) = aI^{sp} P_{solar} + G^{S} P_{solar} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

In (3), the Annuitization coefficient, represented by *a*, iscalculated as follows:

$$a = \frac{r}{(1-(1+r)^{-N}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

In the above equations, *PSolar*, *r*, *N*, *ISp* and *GS* respectively denote the solar generation (MW), the interest scale (0.09), the investment duration (20 years), the ratio of investment cost to unit power (5$/MWh), and the operational and maintenance costs considered as 0.000016$/MWh. Consequently, the cost function of the solar energy unit can be obtained by (5).

$$F(P_{solar}) = 0.5477483 \times P_{solar} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

b) Wind generation:

In (6), the general cost function of wind energy is written according to [6].

$$F(P_{wind}) = aI^{wp}P_{wind} + G^{W}P_{wind} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

where, *PWind*, *IWp*, and *GW* respectively denote the wind generation (MW), the ratio of investment cost to unit power (1.4 $/MWh), and the operational and maintenance costs considered as 0.000016 $/MWh. Accordingly, the cost function of the wind energy unit can be calculated as follows:

$$F(P_{wind}) = 0.1533810 \times P_{wind} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

the DCEED problem can be re-written as an integrated equation as described in the following:

$$MIN(F_C) = \sum_{i=1}^{NG}(u_i P_i + v_i P_i + w_i) + 0.1533810 * P_{wind} + 0.5477483 * P_{solar} \quad .(10)$$

I. 6. Modeling of Electric Vehicles:

It is difficult to control a single EV, therefore, the model using the double-layer dispatch strategy is employed, i.e., the upper layer is the grid power dispatch center, the middle layer is the EVs agency, and the substratum is the user unit. The agency has a sub-regional management of EVs, and one region is an EVs cluster. First, the upper management sends the dispatch plan to the agency. Then, the agency management according to the actual situation assign the dispatch plan to the EVs cluster. As shown in Figure 1

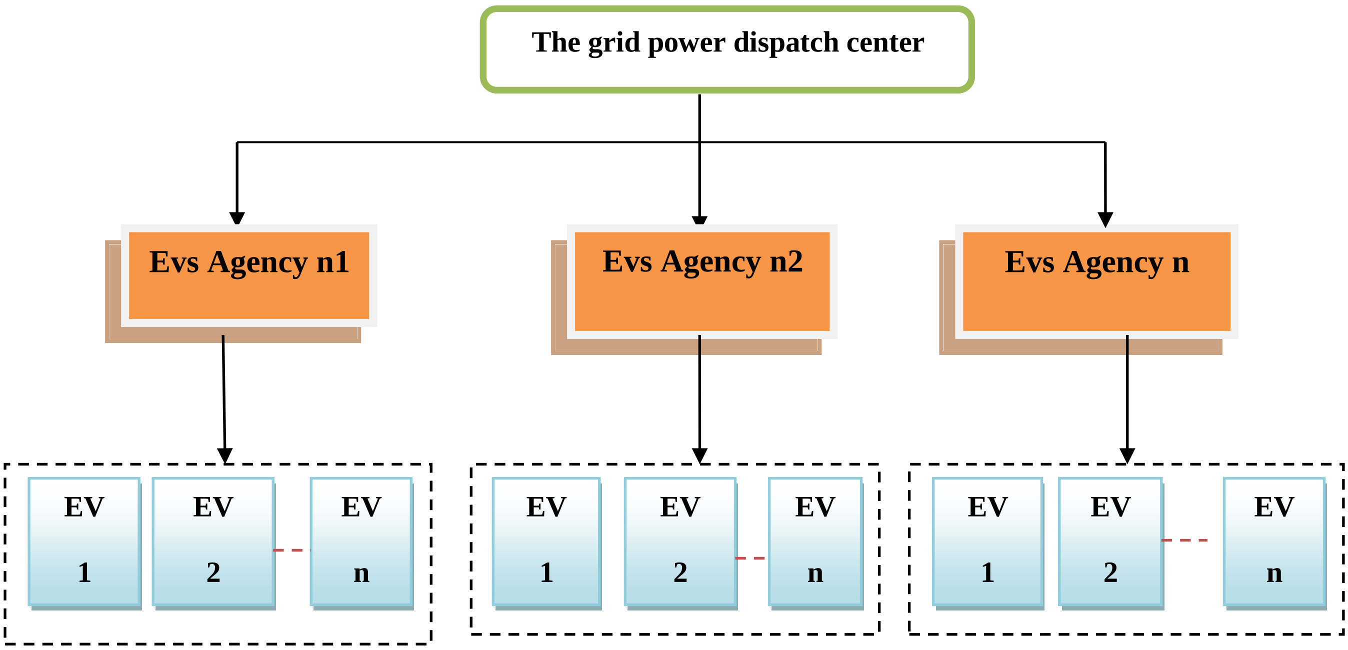

Figure 1. The double-layer dispatch strategy framework.

Since EVs are already registered in the power system, the owners have opted for their vehicles' batteries to participate in V2G transactions. Assume that the number of EVs is *Nv2g* in the system and each of them has the same energy demand. The total EVs rated power in an interval of dispatch can be expressed as:

$$P_{v2g} = \sum_{i=1}^{N_{v2g}} P_{rv2g} \ldots\ldots(11)$$

where *Prv*2*g* (*i*) is rated power of the *i*th EV and *Pv*2*g* is the total EVs ratted power. In each interval of dispatch, the EVs charging and discharging are not simultaneous, the states of which can be represented by the sign function (sgn) as follows:

$$\begin{cases} P_{c\square.t=sgn(x\,)P_{v2g,}} & {\scriptstyle x<0} \\ P_{Dc\square.t=sgn(x)P_{v2g,}} & {\scriptstyle x>0} \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

where *x* < 0 and *x* > 0 denote the charge and discharge states, respectively. At *x* = 0, EVs do not participate in power system dispatch.

- **EVs Charging and Discharging Power Constraint:**

The charging and discharging power of the EVs is less than the rated power.

$$\begin{cases} P_{ch.t} \le P_{Nch} \\ P_{Dch.t} \le P_{NDch} \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(13)$$

Where: P_{Nch} and $P_{NDc}h$ are the charging and discharging rated power of the EVs, respectively.

- **.Real power balance constraint:**

In Eq. (3), *Pi* (in MW) is the power generated by the *i*th unit, *P*D (in MW) is the total load demand and *P* L (in MW) is the total transmission loss of the system at time *t*.

$$\sum_{i=1}^{n} P_{i,t} = P_{D,t} + P_{L,t} + L_{EV,t} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(14)$$

The charging load L_{EV} of PEVs, which is a new extra load type and will be further addressed in Eq 33.

- **Generator capacity constraint:**

The generator power output (*P*i) of *i*th generator is within minimum power p_i^{min} and maximum power P_i^{max} (in MW):[8]

$$p_i^{min} \le P_{i.t} \le P_i^{max} \qquad i = 1,2 \ldots\ldots.n; \quad t = 1,2 \ldots\ldots..t \ \ldots.(15)$$

Conclusion

These renewable energy resources are unexhausted, available worldwide and free. Advances in wind and solar technology have led to significant declines in the installed and global cost of electricity from these sources. Therefore, the penetration of renewable energy sources and electric vehicles in the generation mix can provide a promising solution to the above-mentioned problems.

In this chapter, we treat by modeling of simultaneously reducing fuel consumption in terms of “Fuel Cost” and “Emission” in thermal power plants with the time is called a dynamic combined economic emission dispatch problem.

The addition of renewable energy resources (RERs) adds more complexities to this problem because they are intermittent. In the next chapter, hippopotamus optimization algorithm (HO) is used to solve the dynamic combined economic emission dispatch problem.

Chapter **I**

Pratical

Part

Hippoptamus Optimization Algorithm: A Novel Nature-Inspired Optimization Algorithm

Chapter: Hippopotamus Optimization Algorithm: A Novel Nature-Inspired Optimization Algorithm

Ⅰ. Introduction:

Many problems and challenges in today's science, industry, and technology can be defined as optimization problems. All optimization problems have three parts: an objective function, constraints, and decision variables. Optimization algorithms can be classified in different ways to solve such problems.

In this chapter, we propose a new meta heuristics algorithm for solving a dynamic combined economic emission dispatch with integration of RESs and EVs called “Hippopotamus Optimization Algorithm” HO approach introduced.

2. Hippopotamus Optimization Algorithm:

The hippopotamus is one of the fascinating creatures residing in Africa. This animal falls under the classification of vertebrates and specifically belongs to the group of mammals in the vertebrate category [9]. Hippos are semi-aquatic organisms that primarily spend their time in aquatic environments, particularly rivers and ponds, as part of their habitat.

Hippos live in groups on a territory, a portion of lake or river which varies depending on the body of water and the season. On a river bank, a smaller space is sufficient for a greater number of animals than on a lake bank. Thus, 33 hippos can share 100 meters of riverside, while only 7 animals coexist on 100 meters of lakeside.

The dominant male reigns over 50 to 100 meters of river while his territory can reach 500 meters of lake. He is responsible for territorial marking. Positioning itself at the edge, with its back to the bank, it scatters its droppings over a radius of 2 meters. This kind of scene seems to fascinate young people, who come to smell the excrement, and sometimes consume it [10].

Inspiration:

The HO draws inspiration from three prominent behavioral patterns observed in the life of hippopotamuses[12]. Hippopotamus groups are comprised of several female hippopotamuses, hippopotamus calves, multiple adult male hippopotamuses, and a dominant male hippopotamus (the leader of the herd) [13]. Due to their inherent curiosity, young and calf’s hippopotamuses often display a tendency to wander away from the group. As a consequence, they may become isolated and become targets for predators. The secondary behavioral pattern of hippopotamuses is defensive in nature, triggered when they are under attack by predators or when other creatures intrude into their territory. Hippopotamuses exhibit defensive response by rotating themselves toward the predator and employing their formidable jaws and vocalizations to deter and repel the attacker (Fig. 1). Predators such aslions and spotted hyenas possess an awareness of this phenomenon and actively seek to avoid direct exposure to the formidable jaws of a hippopotamus as a precautionary measure against potential injuries. The final behavioral pattern encompasses the hippopotamus' instinctual response of fleeing from predators and actively seeking to distance itself from areas of potential danger. In such circumstances, the hippopotamus strives to navigate toward the closest body of water, such as a river or pond, as lions and spotted hyenas frequently exhibit a version to entering [12]

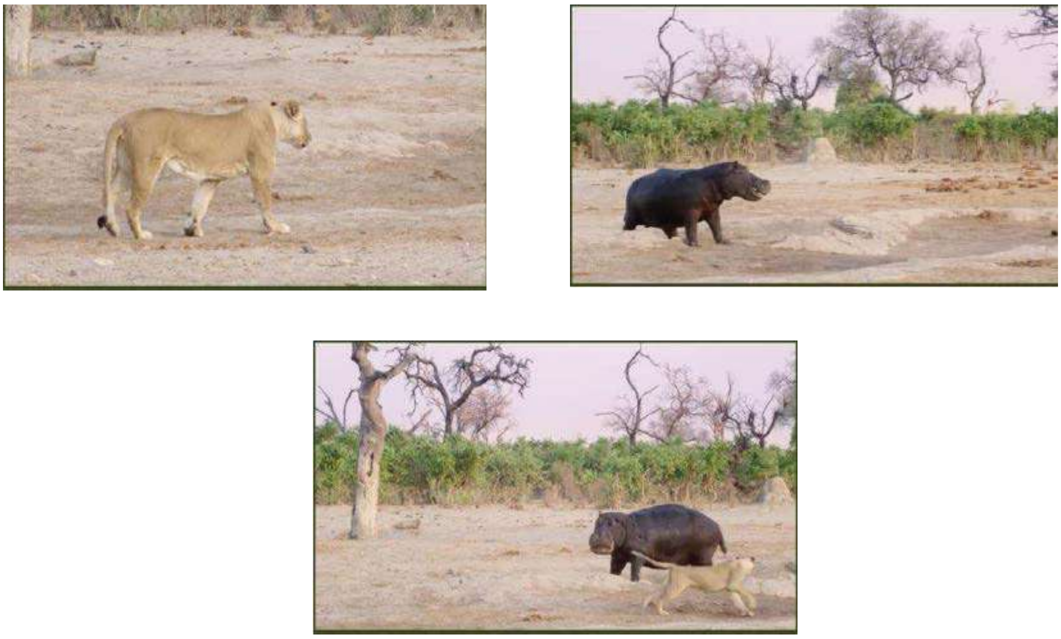

Figure 1. (a) - (d) shows the defensive behavior of the hippopotamus against the predator

3. Mathematical modelling of HO:

The HO is a population-based optimization algorithm, in which search agents are hippopotamuses. In the HO algorithm, hippopotamuses are candidate solutions for the optimization problem, meaning that the position update of each hippopotamus in the search space represents values for the decision variables. Thus, each hippopotamus is represented as a vector, and the population of hippopotamuses is mathematically characterized by a matrix. Similar to conventional optimization algorithms, the initialization stage of the HO involves the generation of randomized initial solutions

[13]. During this step, the vector of decision variables is generated using the following formula:

$$\square_I : x_{i,j} = \ell b_i + r.(ub_i - \ell b_i), i = 1,2, \ldots, N, j = 1,2 \ldots, m \quad (1)$$

Where χi represents the position of the $i$that candidate solution, r is a random number in the range of 0 to 1, and ℓb and ubdenote the lower and upper bounds of the jth decision variable, respectively. Given that $\mathcal{N}$ denotes the population size of hippopotamuses within the herd, and m represents the number of decision variables in the problem, the population matrix is formed by Eq. (2)

$$\square = \begin{bmatrix} \square_1 \\ \vdots \\ \square_i \\ \vdots \\ \square_{\mathcal{N}} \end{bmatrix}_{\mathcal{N} \times m} = \begin{bmatrix} x_{1,1} & \cdots & x_{1,j} & \cdots & x_{1,m} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ x_{i,1} & \cdots & x_{i,j} & \cdots & x_{i,m} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ x_{\mathcal{N},1} & \cdots & x_{\mathcal{N},j} & \cdots & x_{\mathcal{N},m} \end{bmatrix}_{\mathcal{N} \times m} \quad (2)$$

Phase1: The hippopotamuses position update in the river or pond (Exploration). Hippopotamus herds are composed of several adult female hippopotamuses, calf's hippopotamuses, multiple adult male hippopotamuses, and dominant male hippopotamuses (the leader of the herd). The dominant hippopotamus is determined based on the objective function value iteration (The lowest for the minimization problem and the highest for the maximization problem). Typically, hippopotamuses tend to gather in close proximity to one another.

Dominant male hippopotamuses protect the herd and territory from potential threats. Multiple female hippopotamuses are positioned around the male hippopotamuses. Upon reaching maturity, male hippopotamuses are ousted from the herd by the dominant male. Subsequently, these expelled male individuals are required to either attract females or engage in dominance contests with other established male members of the herd in order to establishtheir own dominance. Eq. (3) expresses the mathematical representation of the position of male hippopotamus members of the herd in the lake or pond [13].

$$\square_i^{\mathcal{M}hippo} : x_{i,j}^{\mathcal{M}hippo} = x_{i,j} + y_1.(\mathcal{D}hippo - I_1 x_{i,j}) \quad (3)$$

$$for i = 1,2 \ldots, \left[\frac{\mathcal{N}}{2}\right] and j = 1,2, \ldots m ,$$

In Eq. (3) $\chi i^{\mathcal{M}hippo}$ represents male hippopotamus position, $\mathcal{D}hippo$ denotes the dominant hippopotamus position (The hippopotamus that has the best cost in the current iteration).$\vec{r}_{1\ldots,4}$ is a random vector between 0 and 1, $r5$ is a random number between 0 and 1 (Eq. (4)), I_1 and I_2 is an integer between 1 and 2 (Eq. (3) and Eq. (6)). $\mathcal{G}_i$ refers to the mean Values of some randomly selected hippopotamus with an equal probability of including the current considered hippopotamus (χi) and $y1$ is a random number between 0 and 1 (Eq. (3)). In Eq. (4) ϱ_1 and ϱ_2 are integer random numbers that can be one zero[13].

$$. \ h = \begin{cases} I_2 \times \vec{r_1} + (\sim Q_1) \\ 2 \times \vec{r_2} - 1 \\ \vec{r_3} \\ I_1 \times \vec{r_4} + (\sim Q_2) \\ r_5 \end{cases} \quad (4)$$

$$T = exp\left(-\frac{t}{\mathcal{T}}\right) \quad (5)$$

$$\square_i^{\mathcal{FB}hippo} : x_{i,j}^{\mathcal{FB}hippo} = \begin{cases} x_{i,j} + h_1.(\mathcal{D}hippo - .I_2\mathcal{MG}_i)T > 0,6 \\ \Xi \qquad else \end{cases} \quad (6)$$

$$\Xi = \begin{cases} x_{i,j} + h_1.(\mathcal{MG}_i - \mathcal{D}hippo)r_6 > 0,5 \\ \ell b_j + r_7.(ub_j - \ell b_j \qquad else \end{cases} \quad (7)$$

$$for\ i = 1,2 \ldots.,\left[\frac{\mathcal{N}}{2}\right] andj = 1,2,\ldots m\ ,$$

Eq. (6-7) describe female or immature hippopotamus position ($\chi_i^{\mathcal{FB}\ hippo}$) within the herd. Most immature hippopotamuses are near their mothers, but due to curiosity, sometimes immature hippopotamuses are separated from the herd or away from their mothers. If T is greater than 0.6, it means the immature hippopotamus has distanced itself from its mother (Eq. (5)). If $r6$, which is a number between 0 and 1 (Eq. (7)), is greater than 0.5, it means the immature hippopotamus has distanced itself from its mother but is still within or near the herd, Otherwise, it has separated from the herd.

This behavior of immature and female hippopotamuses are modelled according to Eq. (6) and Eq. (7). $h1$ and $h2$ are numbers or vectors randomly selected from the five scenarios in the h equation. In Eq. (7) r_7 is a random number between zero and one. Eq. (8-9) describe male and female or immature hippopotamus position update within the herd. $\mathcal{F}$ is objective function value.

$$\square_i = \begin{cases} \square_i^{\mathcal{M}hippo} \mathcal{F}_i^{\mathcal{M}hippo} < \mathcal{F}_i \\ \square_i \qquad else \end{cases} \quad (8)$$

$$\square_i = \begin{cases} \square_i^{\mathcal{FB}hippo} & \mathcal{F}_i^{\mathcal{FB}hippo} < \mathcal{F}_i \\ \square_i & else \end{cases} \quad (9)$$

Using h vectors, $I1$ and $I2$ scenarios enhance the global search and improves exploration in the proposed algorithm. It leads to a better global search and enhances the exploration process in the proposed algorithm.

Phase2: Hippopotamus defence against predators (Exploration). One of the key reasons for the herd living of hippopotamuses can be attributed to their safety and security. The presence of these large and heavy-weighted herding's of animals can deter predators from approaching them closely. Nevertheless, due to their inherent curiosity, immature hippopotamuses may occasionally deviate from the herd and become potential targets for Nile crocodiles, lions, and spotted hyenas, given their relatively lesser strength in comparison to adult hippopotamuses. Sick hippopotamuses, similar to immature ones, are also susceptible to being preyed upon by predators [13].

The primary defensive tactic employed by hippopotamuses is swiftly turning towards the predator and emitting loud vocalizations to deter the predator from approaching them closely (Fig. 2). During this phase, hippopotamuses may exhibit a behavior of approaching the predator to induce its retreat, thus effectively warding off the potential threat. Eq. (10) represents the predator's position in search space where $\vec{r}_8$ represents a random vector ranging from zero to one.

$$\mathcal{P}\text{redator}: \mathcal{P}\text{redator}_\text{j} = \ell b_\text{j} + \vec{\text{r}_8}.\left(ub_\text{j} - \ell b_\text{j}\right), \text{j} = 1,2 \dots, \text{m}. \quad (10)$$

$$\vec{D} = \left|\mathcal{P}redator_j - x_{i,j}\right| \quad (11)$$

Eq. (11) indicates the distance of the ith hippopotamus to the predator. During this time, the hippopotamus adopts a defensive behavior based on the factor $\mathcal{F}_{\mathcal{P}redator j}$ to protect itself against the predator. If $\mathcal{F}_{\mathcal{P}redator j}$ is less than $\mathcal{F}_i$, indicating the predator is in very close proximity to the hippopotamus, in such a case, the hippopotamus swiftly turns towards the predator and moves towards it to make it retreat. If $\mathcal{F}_{\mathcal{P}redator j}$ is greater, it indicates that the predator or intruding entity is at a greater distance from the hippopotamus's territory Eq. (12). In this case, the hippopotamus turns towards the predator but with a more limited range of movement. The intention is to make the predator or intruder aware of its presence within its territory.

$$\square_i^{\mathcal{H}ippo\mathcal{R}} : \square_{i,j}^{\mathcal{H}ippo\mathcal{R}} = \begin{cases} \overrightarrow{RL} \oplus \mathcal{P}redator_{J,} + \left(\frac{f}{(c-d\times cos(2\pi g))}\right).\left(\frac{1}{\vec{D}}\right) \mathcal{F}_{\mathcal{P}redator_j} < \mathcal{F}_i \\ \overrightarrow{RL} \oplus \mathcal{P}redator_{J,} + \left(\frac{f}{(c-d\times cos(2\pi g))}\right).\left(\frac{1}{2\times\vec{D}+\vec{r_9}}\right) \geq \mathcal{F}_{i,} \end{cases} \quad (12)$$

$\square^{HippoR}$ is a hippopotamus position which was faced to predator. $\overrightarrow{RL}$is a random vector based on the Levy distribution, which represents Levy movements, depicting sudden changes in predator positions during hunting? The mathematical model for the random movement of Lévy movement[46] is calculated as Eq. (13). w and v are the random numbers in [0,1], respectively; ϑ is a constant (ϑ = 1.5), Γ stands for Gamma function and σ can be obtained by Eq. (14).

$$\mathcal{L}ev\mathcal{y}(\vartheta) = 0{,}05 \times \frac{w\times\sigma_w}{|v|^{\frac{1}{\vartheta}}} \quad (13)$$

$$\sigma_w = \left[\frac{\Gamma(1+\vartheta)\sin(\frac{\pi\vartheta}{2})}{\Gamma\left(\frac{(1+\vartheta)}{2}\right)\vartheta 2^{\frac{(\vartheta-1)}{2}}}\right]^{\frac{1}{\vartheta}} \quad (14)$$

In Eq. (12) f is a uniform random number between 2 and 4, c is a uniform random number between 1 and 1.5 and d is auniform random number between 2 and 3. g represents a uniform random number between -1 and 1. $\vec{r}_9$ is a random vector with dimensions 1 × m.According to the Eq. (15), if $\mathcal{F}^{\mathcal{H}ippo\mathcal{R}}$ is greater than $\mathcal{F}$, it means that the hippopotamus has been hunted and another hippopotamus will replace it in the herd, otherwise the hunter will escape and this hippopotamus will return to the herd. Significant enhancements were observed in the global search process during the second phase[13].

The first and second phases complement each other and effectively mitigate the risk of getting trapped in local minima.

$$\square_i = \begin{cases} \square_i^{\mathcal{H}ippo\mathcal{R}} \mathcal{F}_i^{\mathcal{H}ippo\mathcal{R}} < \mathcal{F}_i \\ \square_i \mathcal{F}_i^{\mathcal{H}ippo\mathcal{R}} \geq \mathcal{F}_i \end{cases} \quad (15)$$

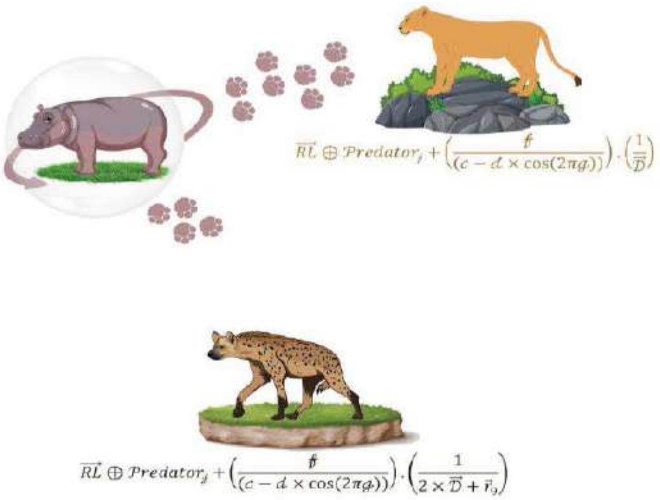

Figure 2. Graphic representation of the phase 2.

Phase3: Hippopotamus Escaping from the Predator (Exploitation). Immature hippopotamuses or even adult hippopotamuses that are separated from the herd and face a herd of lions or spotted hyenas are prone to attack by predators. In this situation, the hippopotamus tries to move away from the area (Fig .3). Usually, the hippopotamus tries to run to the nearest lake or pond to avoid the harm of predators because spotted lions and hyenas avoid entering the lake or pond. This strategy leads to the hippopotamus finding a safe position close to its current location and modeling this behavior in Phase Three of the HO results in an enhanced ability for exploitation in local search.

This strategy leads to the hippopotamus finding a safe position close toits current location and modelling this behavior in Phase Three of the HO results in an enhanced ability for exploitation in local search. To simulate this behavior, a random position is generated near the current location of the hippopotamuses. This behavior of the hippopotamuses is modelled according to Eq. (16) to Eq. (19). When the newly created position improves the cost function value, it indicates that the hippopotamus has found a safer position near its current location and has changed its position accordingly. t denotes the current iteration, while $\mathcal{T}$ represents the MaxIter.

$$\ell b_j^{\ell ocal} = \frac{\ell b_j}{t}, u b_j^{\ell ocal} = \frac{u b_j}{t}, t = 1,2 \dots, \mathcal{T} \quad (16)$$

$$\square_i^{\mathcal{H}ippo\mathcal{E}} : \square_{i,j}^{\mathcal{H}ippo\mathcal{E}} = x_{i,j} + r_{10}. (\ell b_j^{\ell ocal} + s_1. (u b_j^{\ell ocal} - \ell b_j^{\ell ocal}))$$
(17)

$$i = 1,2, \dots, \mathcal{N}, j = 1,2 \dots, m$$

In Eq. (17), $\chi i^{\mathcal{H}ippo\mathcal{E}}$ is the position of hippopotamus which was searched to find the closest safe place. $\mathcal{s}1$ is a random vector or number that is randomly selected from among three scenarios $\mathcal{s}$ Eq. (18). The considered scenarios ($\mathcal{s}$) lead to a mo suitable local search or, in other words, result in the proposed algorithm having a higher exploitation quality

$$\mathcal{s} = \begin{cases} 2 \times \vec{r_{11}} - 1 \\ r_{12} \\ r_{13} \end{cases} \tag{18}$$

In Eq. (18) $\vec{r}_{11}$ represents a random vector between 0 and 1, while r_{10} (Eq. (17)) and r_{13} denote random numbers generated within the range of 0 and 1. Additionally, r_{12} is a normally distributed random number.

$$\square_i = \begin{cases} \square_i^{\mathcal{H}ippo\mathcal{E}} \mathcal{F}_i^{\mathcal{H}ippo\mathcal{E}} < \mathcal{F}_i \\ \square_i \mathcal{F}_i^{\mathcal{H}ippo\mathcal{E}} \geq \mathcal{F}_i \end{cases} \tag{19}$$

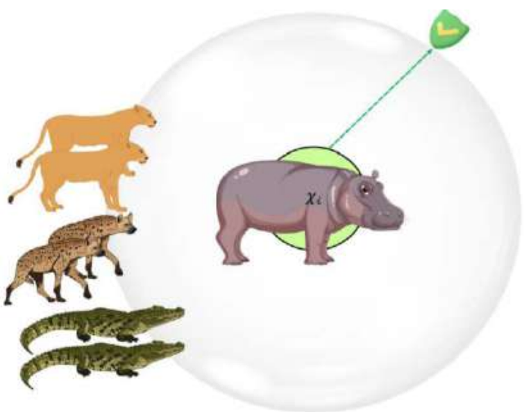

Figure 3. Drawing a Hippopotamus Escaping from the Predator

In the HO algorithm to update the population, we did not divide the population into three separate categories of immature, female, and male hippopotamus because although dividing them into separate categories would be better modelling of their nature, it would reduce the performance of the optimization algorithm [13].

3.1.Repetition process, and flowchart of HO:

After completing each iteration of the HO algorithm, all population members are updated based on Phases 1 to 3 this process of updating the population according to Eqs. (3) to (19) continues until the final iteration. During the execution of the algorithm, the best potential solution is consistently tracked and stored. Upon the completion of the entire algorithm, the best candidate, referred to as the dominant hippopotamus solution, is unveiled as the ultimate solution to the problem. The Ho's procedural details are shown in Fig. 4's flowchart and Algorithm 1's pseudo-code:

Algorithm 1. Pseudo-code of HO.

Start HO

1. Define an optimization problem
2. Set the maximum number of iterations ($\mathcal{T}$) and number of hippopotamus ($\mathcal{N}$)
3. Generate the initial position of all hippopotamus based on Eq. (1) and objective function evaluation for this initial population
4. For t:1: $\mathcal{T}$
5. Update dominant hippopotamus position based on objective function value criterion 6. **Phase 1**: The hippopotamus's position update in the river or pond (**Exploration Phase**)
7. For i=1: $\mathcal{N}/2$
8. Calculate the new position for $i$the hippopotamus using Eq. (3,6)
9. Update position of $i$the hippopotamus using Eq. (8,9)
10. End for
11. **Phase 2**: Hippopotamus defines against predators (**Exploration Phase**)
12. For i= 1 + $\mathcal{N}/2$: $\mathcal{N}$
13. Generate random position for predator using Eq. (10)
14. Calculate the new position for $i$the hippopotamus using Eq. (12)
15. Update the position of $i$the hippopotamus using Eq. (15)
16. End for
17. **Phase 3**: Hippopotamus Escaping from the Predator (**Exploitation Phase**)
18. Calculate new bounds of variables decision using Eq. (16)
19. For i=1: $\mathcal{N}$
20. Calculate the new position for $i$the hippopotamus using Eq. (17)
21. Update the position of $i$the hippopotamus using Eq. (19)
22. End for
23. Save the best candidate solution found so far.
24. End for
25. Output the best solution of the objective function found by HO

End HO.

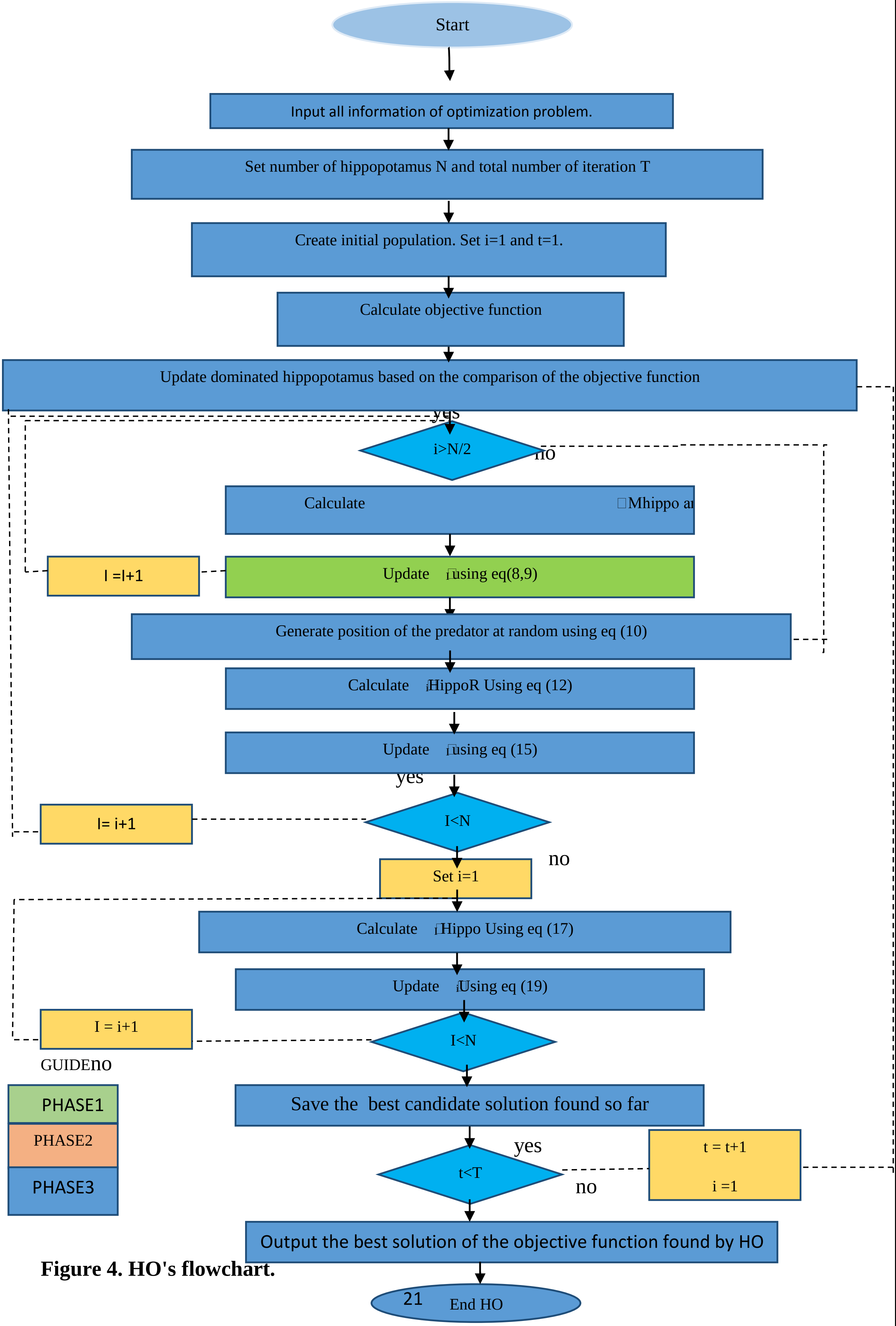

Figure 4. HO's flowchart.

5. Conclusions:

In this chapter, we introduced a novel non parametric optimization algorithm called the Hippopotamus Optimizer (HO). The real inspiration behind the HO is to simulate the behaviours of hippopotamuses, incorporating their spatial positioning in the water, defines strategies against threats, and evasion techniques from predators. The algorithm is outlined conceptually through a trinary-phase model of their position update in river and pound, defines, and evading predators, each mathematically defined. In light of the results from addressing four distinct engineering design challenges, the HO has effectively achieved the most efficient resolution while concurrently upholding adherence to the designated constraints. We suggest in the next chapter for solving a dynamic combined economic emission dispatch with integration of RESs and EVs this approach called "Hippopotamus Optimization Algorithm" HO.

Theoretically part

Chapter .III

Result And Discussion

III. Chapter: result and discussion

Introduction

In this chapter, the investigated system is introduced and the considered information is given. In fact, the investigated system is a standard system of 03 units during the day and night. Information and coefficients for the cost, the emission and constraint function are given in Table 1. The amount of load required, solar power and wind generated in a 24 -h period is shown in Table 2 [06]. The proposed algorithm "Hippopotamus Optimization" HO is applied to the introduced 03-unit system for solving a dynamic combined economic emission dispatch with integration of RESs and EVs. As mentioned earlier, the goal is to reduce the cost and emission to the system. The simulation results for the 24 -h period are shown in Table 3 [14]. Now, in order to compare the obtained results and show the better efficiency of the proposed method in solving the dynamic power problem, the obtained results for cost and emission are compared with other methods**.** In fact, to compare the results obtained, the improvement percentage of the results of the proposed algorithm with respect to the mentioned methods is expressed.

Characteristic	**Generators**	**1**	**2**	**3**
Power generation limits	**Minimum**	37	40	50
	Maximum	150	160	190
Fuel cost coefficients	**u ($/MW2h)**	0.024	0.029	0.021
	v ($/MWh)	21	20.16	20.4
	w ($/h)	1530	992	600
Emission coefficient	**x (kg/MW2h)**	0.0105	0.008	0.012
	y (kg /MWh)	− 1.355	− 0.6	− 0.555
	z (kg /h)	60	45	30

Table 1 Characteristic of the generators

Time (h)	**Solar (MW)**	**Wind (MW)**	**Time**	**Solar (MW)**	**Wind (MW)**	**Time**	**Solar (MW)**	**Wind (MW)**
1	0	1.7	9	24.05	20.58	17	9.57	3.44
2	0	8.5	10	39.37	17.85	18	2.31	1.87
3	0	9.27	11	7.41	12.80	19	0	0.75
4	0	16.66	12	3.65	18.65	20	0	0.17
5	0	7.22	13	31.94	14.35	21	0	0.15
6	0.03	4.91	14	26.81	10.35	22	0	0.31
7	6.27	14.66	15	10.08	8.26	23	0	1.07
8	16.18	26.56	16	5.30	13.71	24	0	0.58

Table 2: Solar and wind generation data profile for 24 h

Time (h)	Power demand MW	Time	Power demand MW	Time	Power demand MW
1	140	9	210	17	170
2	150	10	230	18	185
3	155	11	240	19	200
4	160	12	250	20	240
5	165	13	240	21	225
6	170	14	220	22	190
7	175	15	200	23	160
8	180	16	180	24	145

Table 3: Power demand profile [15,16]

Four cases are defined, and their results are presented and discussed. These scenarios and their cases are depicted in Fig. 4 and are listed in the following:

Case1:	DED: no renewable energy sources and EVs
Case2:	DCEED: no renewable energy resources and EVs
Case 3:	DCEED with renewable energy resources and without EVs
Case 4:	DCEED with renewable energy resources and EVs

Table 4: Studied cases

Case 1: DED: no renewable energy sources

In this test system, the micrograids with 03 generators and without transmission and generation limits have been considered. This study without contains energy sources en electric vehicles (generation units). The results of Case 1, which are the hourly cost of the generation units, are presented in Table 5. As seen, the proposed approach outperforms other methods by scheduling generations with the least expenditure.

Case 01						
Hour	HO	RGM($/h)[6]	ACO($/H)	CSA($/h)	ISA($/h)	SACDE
1	**6151.583**	6298	6152	6157	6157	6152.155
2	**6380.3649**	6483	6380	6393	6395	6381.719
3	**6495.3619**	6579	6496	6509	6531	6495.561
4	**6610.7629**	6677	6611	6625	6635	6611.172
5	**6726.5774**	6778	6727	6741	6742	6727.319
6	**6842.7765**	6881	6844	6856	6858	6847.733
7	**6959.3895**	6986	6969	6973	6971	6960.835
8	**7076.4062**	7094	7078	7088	7087	7077.144
9	**7786.9908**	7795	7788	7793	7793	7787.495
10	**8268.7934**	8300	8284	8272	8272	8269.342
11	**8512.1374**	8569	8513	8514	8514	8512.979
12	**8757.0606**	8848	8760	8758	8758	8758.343
13	**8512.1374**	8569	8513	8514	8433	8519.312
14	**6151.583**	8040	8031	8032	8026	8029.449
15	**7548.5183**	7548	7549	7556	7571	7548.87
16	**7076.4062**	7094	7078	7088	7086	7076.606
17	**6842.7765**	6881	6844	6856	6856	6842.947
18	**7193.8273**	7204	7194	7204	7203	7196.408
19	**7548.5183**	7548	7549	7556	7555	7550.118
20	**8512.1374**	8569	8513	8514	8511	8512.582
21	**8147.7397**	8168	8149	8152	8151	8150.121
22	**7311.6518**	7316	7313	7319	7322	7311.897
23	**6610.7632**	6677	6611	6625	6625	6611.063
24	**6265.7722**	6389	6266	6275	6268	6266.105
total	**174290.04**	177291	176212	176370	176320	176197.27

Table 5. Compromise dispatch schemes obtained by different algorithms.

In Table 5, the hourly and total generation costs of different approaches for Case 4 of Scenario 1, where microgrid includes only fuel-based generation units (no renewable energy sources). Based on these results, the proposed approach is ranked as the best algorithm for obtaining the least generation cost (174290.04 ($/day)) among all methods In addition, Fig. 8 presents different units' generations acquired by the proposed approach. [15]

The convergence process of cost for the HO algorithm at 20:00h with load demand 240MW is plotted in Figures 3.1. It can be seen that in terms of cost, the proposed HO shows a significant advantage in the convergence performance. The reason for this may be that the optimal search strategy speeds up the convergence of the HO. So, the best cost in the order of 8511.9844$/h with the optimal power generation Pg1=71.1157 MW, Pg2= 73.3255 MW, Pg3=95.5467MW

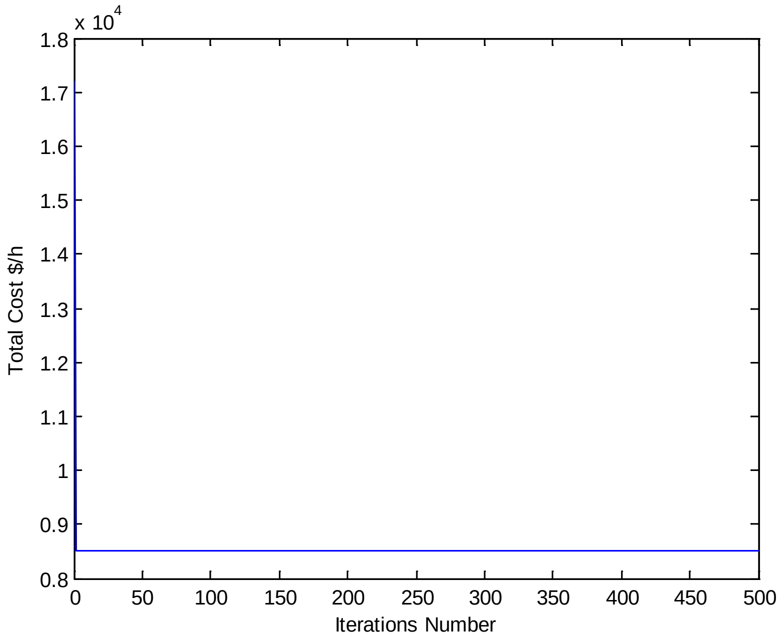

Fig. 3.1 The convergence of cost for ED.

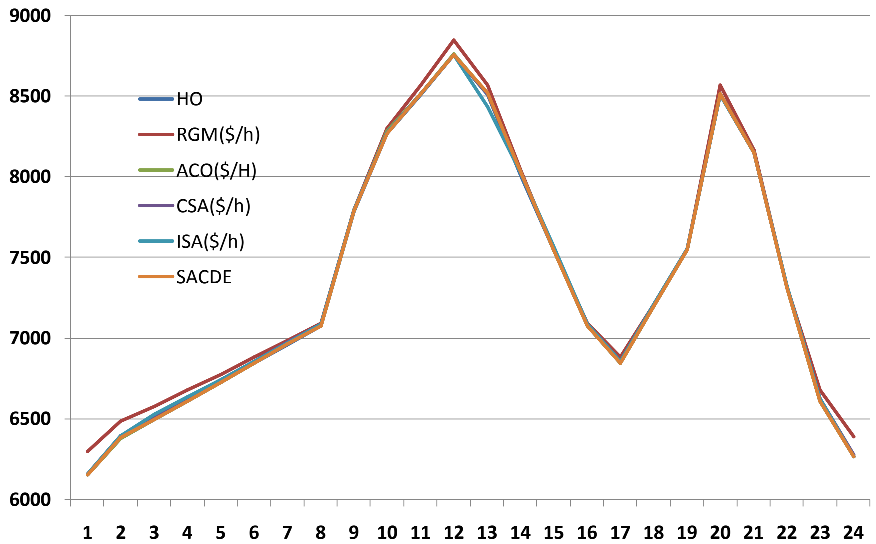

Fig. 3.2 Total costs of different algorithms

Case 2: DCEED no renewable energy resources

In Table 6, the hourly and total operational costs with the economic and emission are simultaneously, where the microgrid includes no renewable energy sources, are listed. According to the results, the proposed algorithm gives cost [15]

(244980 ($/day)). Besides, Fig. 3.2 shows different units' generated powers which are obtained by the proposed approach. [15]

Case 02: hi=[56.1290,32.2497,14.6306]			
Hour	**New.app($/H)**	**Hour**	**New.app($/H)**
1	8757.5534	13	12036.677
2	8881.6194	14	11182.936
3	8989.4026	15	10407.604
4	9114.581	16	9711.5403
5	9252.0096	17	9394.2704
6	9394.2704	18	9877.7588
7	9548.7149	19	10407.604
8	9711.5403	20	12036.677
9	10785.47	21	11389.018
10	11599.998	22	10050.539
11	12036.677	23	9114.6063
12	12492.938	24	8804.2618
13	12036.677	total	244980

Table 6. DCEED results.

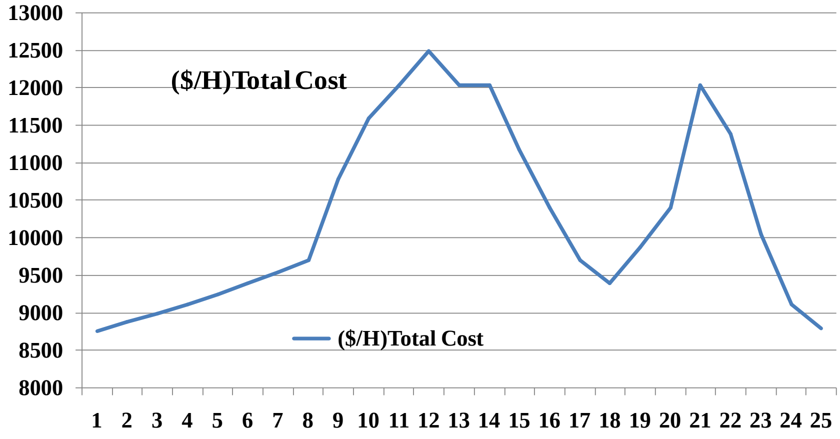

Fig. 3.3 Total costs DCEED

The convergence process of toal cost and emission for the HO algorithm at 20:00h with load demand 240MW is plotted in Figures 3.4. It can be seen that in terms of cost, the proposed HO shows a significant advantage in the convergence performance. The reason for this may be that the optimal search strategy speeds up the convergence of the HO. So, the best cost in the order of 8049.4846$/h with the optimal power generation Pg1=64.6855MW, Pg2= 68.0007MW, Pg3=88.2367MW.

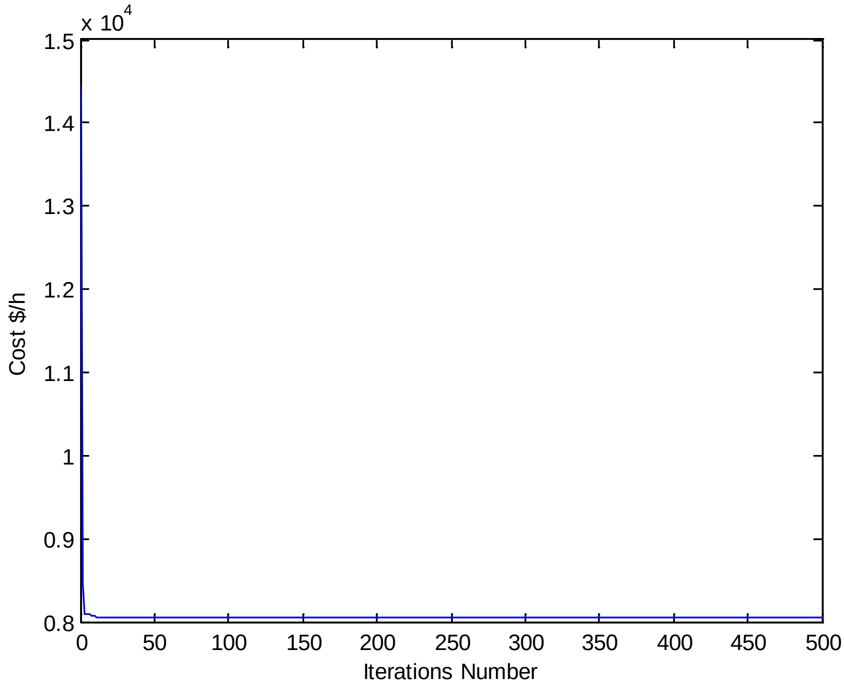

Fig. 3.4 The convergence of total cost.

Moreover, in Case 4, the cost has the highest value because the demand is merely supplied by the thermal units. Consequently, it is clear that the more renewable energies are integrated into the microgrid, the more reduction in the cost and emission can be achieved. The total emission emitted from thermal units is also depicted in Fig. 18 where it is obvious that the microgrid experiences a higher emission if there is no renewable energy integration. While, the cost significantly decreases by employing solar energy and wind turbine. [15]

Case 3: DCEED with renewable energy resources and without EVs

In this case, the test system includes RESs (Wind and Solar power). The results of Case 1, which are the hourly cost of the generation units, are presented in Table 5. As seen, the proposed approach outperforms other methods by scheduling generations with the least expenditure. In Fig. 5, the generated powers of different generation units in Case 1 for the proposed approach are presented. [15]

Case 03: hi=[56.1290,32.2497,14.6306]									
Hour	**Psolar**	**Pwid**	**New app**	**RGM($/h)[6])**	**ACO($/h)**	**CSA($/h)**	**ISA($/h)**	**SACDE($/h)** [16]
1	0	1.7	6112.9962	6297	6134	6117	6117	6113.35
2	0	8.5	6186.9943	6474	6312	6192	6192	6188.205
3	0	9.27	6283.7814	6565	6439	6291	6292	6285.583
4	0	16.66	6230.2547	6650	6512	6235	6234	6230.801
5	0	7.22	6560.4624	6759	6682	6573	6575	6560.708
6	0.03	4.91	6728.6082	6867	6807	6742	6735	6728.862
7	6.27	14.66	6479.5055	7209	6837	6487	6488	6479.81
8	16.18	26.56	6102.0073	7762	6780	6093	6093	6102.521
9	24.05	20.58	6751.362	8649	7457	6758	6750	6751.723
10	39.37	17.85	6931.7437	9713	7852	6930	6936	6931.916
11	7.41	12.8	8027.917	8722	8358	8026	8026	8028.953
12	3.65	18.65	8217.7851	8794	8594	8216	8213	8218.94
13	31.94	14.35	7418.9089	9654	8146	7425	7408	7419.068
14	26.81	10.35	7159.2001	9013	7760	7154	7154	7160.281
15	10.08	8.26	7122.0094	7905	7424	7126	7129	7122.418
16	5.3	13.71	6638.5455	7268	6943	6648	6649	6639.498
17	9.57	3.44	6546.8984	7276	6756	6555	6553	6547.099
18	2.31	1.87	7097.0638	7288	7146	7107	7107	7098.672
19	0	0.75	7530.6807	7544	7538	7530	7525	7530.902
20	0	0.17	8507.8604	8567	8517	8510	8510	8508.714
21	0	0.15	8144.0029	8167	8153	8150	8148	8145.102
22	0	0.31	7304.2571	7314	7316	7313	7313	7306.453
23	0	1.07	6586.0776	6674	6605	6599	6599	6587.643
24	0	0.58	6252.4769	6389	6275	6267	6266	6252.836
Total	**182.97**	**214.37**	**166921.4**	**183520**	**173343**	**167044**	**167012**	**166,940.1**

Table 7. Compromise DCEED with RESs without EVs.

Fig. 3.5 Total costs of different algorithms

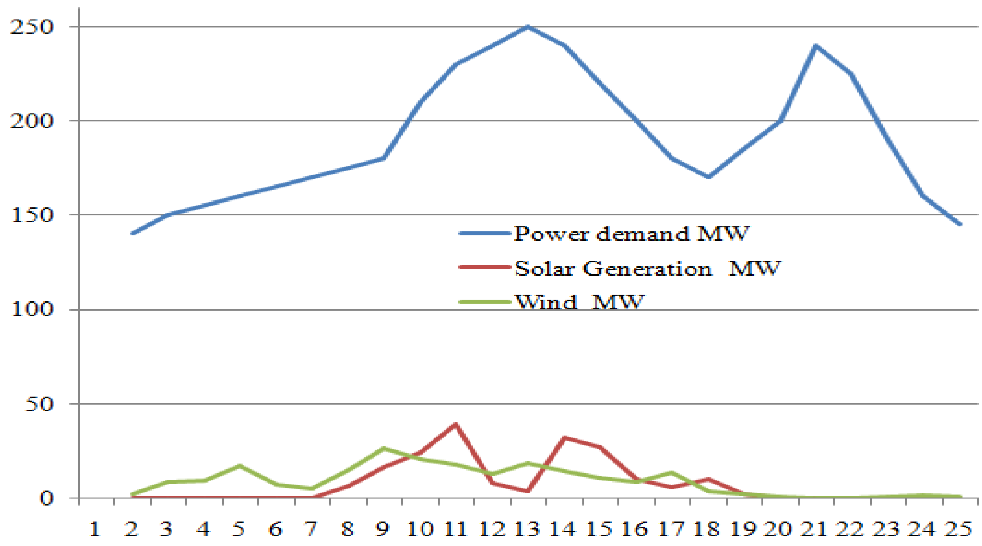

Fig. 3.6 Solar-wind powers and power demand in 24h

The convergence process of toal cost and emission for the HO algorithm at 20:00h with load demand 240MW, Wind power=0.17MW aand solar power=0MW is plotted in Figures 3.5. It can be seen that in terms of cost, the proposed HO shows a significant advantage in the convergence performance. The reason for this may be that the optimal search strategy speeds up the convergence of the HO. So, thebest cost in the order of8511.9863$/h with the optimal power generation Pg1=71.206MW, Pg2= 73.1107MW, Pg3=95.6711MW

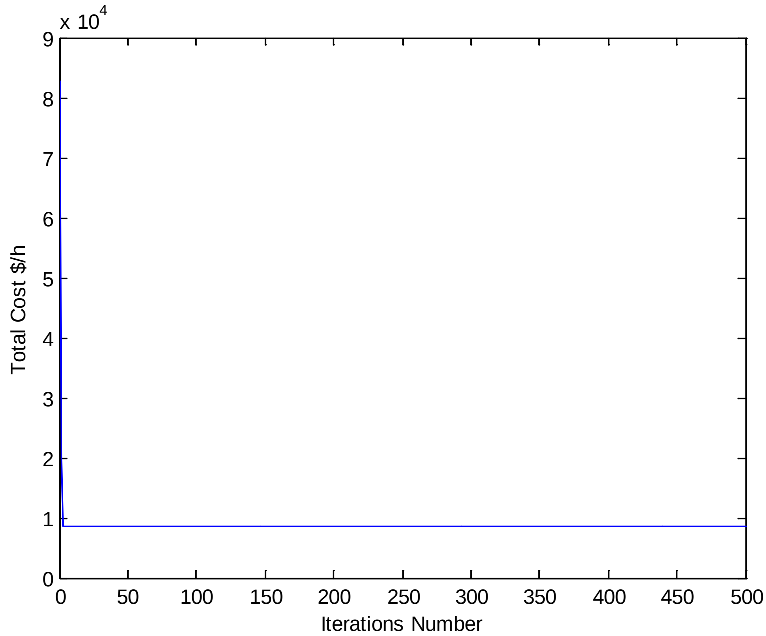

Fig. 3.7 The convergence of total cost.

In Table 7, the hourly and total generation costs of different approaches for Case 3, where micro-grid includes only fuel-based generation units with renewable energy sources. Based on these results, the proposed approach is ranked as the best algorithm for obtaining the least generation cost (166921.4 ($/day)) among all methods. In addition, Fig. 3.3 presents different units' cost acquired by the proposed approach.

According to these figures, utilization of renewable energy sources can remarkably decrease both hourly and total operational costs of the system. If PV and WT engage in power generation alongside thermal units, larger cost savings are observed. Through this comparison, it can be seen that more renewable energy integration results in greater cost and emission minimization.

Case 4: DCEED with renewable energy resources and EVs:

In this subsection, 5000 EVs were selected in the DCEED RESs and Evs model. The type of the EV used in the model was the Toyota RAV4 [16].

				hi=[56.1290,32.2497,14.6306]					
Hour	**Psolar**	**Pwind**	**P EVs [16]**	**New app($/h)**	**Hour**	**Psolar**	**Pwind**	**P EVs**	**New app($/h)**
1	0	1.7	-16,290	8748.915	13	31.94	14.35	9,224	10199.667
2	0	8.5	-19,960	8769.6248	14	26.81	10.35	4,875	9821.8193
3	0	9.27	-10,558	8815.061	15	10.08	8.26	-10,088	9772.3563
4	0	16.66	-10,959	8787.9114	16	5.3	13.71	-17,144	9145.9579
5	0	7.22	-10,125	9058.8957	17	9.57	3.44	0,000	9044.4147
6	0.03	4.91	-0,785	9252.1761	18	2.31	1.87	-9,004	9739.2691
7	6.27	14.66	0,000	8972.8992	19	0	0.75	-8,601	10380.17
8	16.18	26.56	3,780	8757.8933	20	0	0.17	9,705	12029.113
9	24.05	20.58	5,104	9276.5942	21	0	0.15	8,090	11382.804
10	39.37	17.85	7,283	9504.0652	22	0	0.31	1,378	10040.9
11	7.41	12.8	13,803	11180.406	23	0	1.07	-12,637	9087.1249
12	3.65	18.65	16,274	11507.244	24	0	0.58	-19,065	8797.3485
					Total	182.97	214.37	-65,700	232070

Table 8. Compromise DCEED with RESs and EVs.

Detailed information for the compromise solution obtained by the HO is shown in Table 7. It can be seen that the charging of EVs is mainly concentrated from 23:00 to 6:00, which are the low load intervals of the day. During the load peak periods, from 08:00 to 14:00 and from 20/00 to 2200, EVs discharge. This indicates that the dynamic management for EVS charging and discharging is realized in the DCEED RESs and EVs model. The power balance constraints can be checked for each interval in Figure 4.

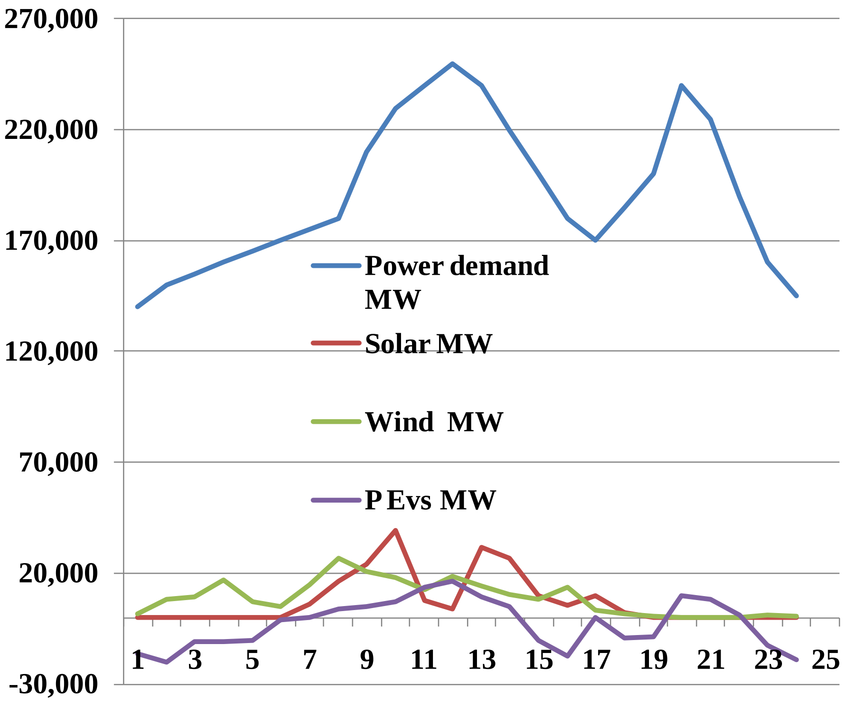

Fig. 3.8 Solar-wind-EVs powers and power demand in 24h

The convergence process of toal cost and emission for the HO algorithm at 20:00h with load demand 240MW, Wind power=0.17MW, solar power=0 MW and PEvs=9.017MW is plotted in Figures 3.6. It can be seen that in terms of cost, the proposed HO shows a significant advantage in the convergence performance. The reason for this may be that the optimal search strategy speeds up the convergence of the HO. So, the best cost in the order of 8511.9884$/h with the optimal power generation Pg1=71.3727MW, Pg2= 73.3913MW, Pg3=95.2238MW

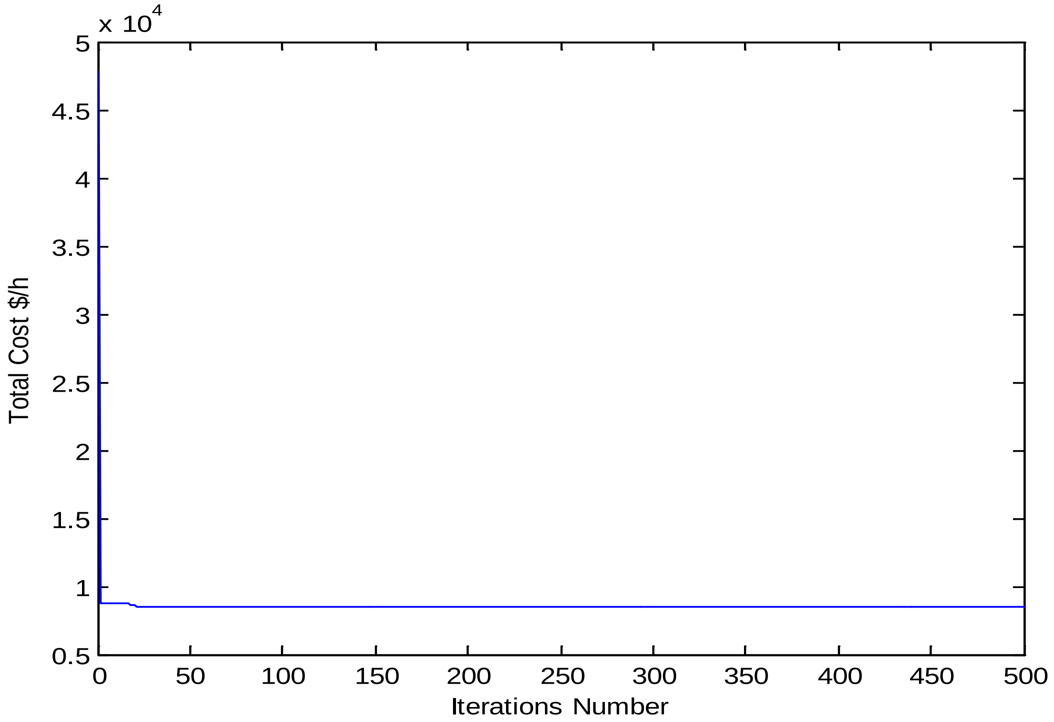

Fig. 3.9 The convergence of total cost.

Case 2	DCEED: no renewable energy sources and EVs	244980
Case 3	DCEED with renewable energy sources and without EVs	166921.4
Case 4	DCEED with renewable energy sources and EVs	232070

Table 9. Comparison results DCEED

By analyzing Table 8 and Fig 3.6, this shows that a certain number of EVs involved in the system can reduce the total costs and emissions. The total fuel cost and emission (DCEED) with renewable energy resources and EVs are reduced by 5.2698% compared with DCEED without renewable energy resources and EVs.

Other remark the DCEED with renewable energy sources and without EVs are reduced by 28.0728% compared with DCEED with renewable energy sources and EVs and 31.863% for DCEED without renewable energy resources and EVs.

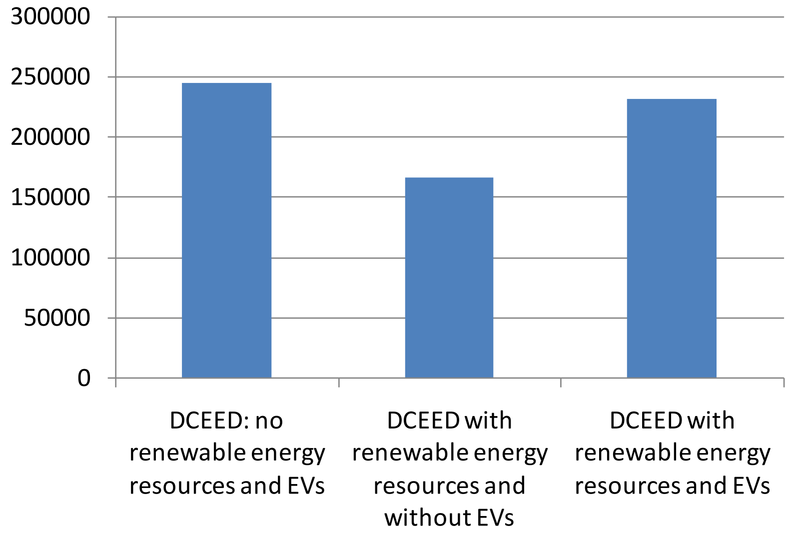

Fig. 3.10 DCEED cases comparison

Conclusion:

In this chapter, a model based on the interaction between electric vehicles and renewable energy sources (wind and solar power) is proposed, and then a multi-objective DCEED model is proposed based on total cost and emissions considerations. Moreover, a multi-objective converted to mono-objective model using a novel approach called Hippopotamus optimization algorithm “HO” is proposed to solve the DCEED problem.

In order to verify the effectiveness of the proposed algorithm and model, a 03-unit test system combining electric vehicles and wind and solar power are used. The results show that the proposed algorithm still shows better performance compared to other advanced algorithms. in terms of total cost and emissions. The proposed DCEED model has been validated by defining three different scenarios, and the results show that the proposed model performs better in terms of cost and emissions reduction.

General conclusion:

In this manuscript, a dynamic economic emission load dispatch model is established with the integrations of plug-in electric vehicle charging EVs scenarios as a constrained dynamic multi-objective to mono-objective optimization problem by integration of renewable energy sources RESs. A new method of optimization called Hippopotamus optimization algorithm "HO" is proposed to solve the DCEED. The performance of HO is investigated on three different cases, including a 3-unit economic emission load dispatch without EVs, with and without RESs. The numerical simulations also show that for four EVs charging and discharging scenarios, the offpeak charging scenario has the advantage in reducing the generation cost and environmental pollutant emissions.

Furthermore, the proposed model was tested under different confidence levels, numbers of electric vehicles and wind and solar power scales, and finally, the most suitable parameter configuration for the system is recommended. In our future work, other renewable energy sources will be considered for integration into the optimal power system with different constraint such as the valve point loading effects, ramp rate constraints, prohibited operating zones, transmission. Moreover, the framework of algorithm presented in this paper could be extended for other types of evolutionary algorithms to solve dynamic multi-objective optimization problems in terms of economic and environmental load dispatch.

REFERENCE:

[1] Larouci, Benyekhlef, Ahmed Nour El Islam Ayad, Hisham Alharbi, Turki EA Alharbi, Houari Boudjella, Abdelkader Si Tayeb, Sherif SM Ghoneim, and Saad A. Mohamed Abdelwahab. "Investigation on new metaheuristic algorithms for solving dynamic combined economic environmental dispatch problems." *Sustainability* 14, no. 9 (2022): 5554.

[2] Benyekhlef, Larouci, Sitayeb Abdelkader, Boudjella Houari, and Ayad Ahmed Nour El Islam. "Cuckoo search algorithm to solve the problem of economic emission dispatch with the incorporation of facts devices under the valve-point loading effect." *Facta Universitatis, Series: Electronics and Energetics* 34, no. 4 (2021): 569-588.

[3] Larouci, Benyekhlef, Houari Boudjella, Ahmed Nour El Islam Ayad, and Abdelkader Si Tayeb. "Solving optimal power flow with considering placement of TCSC and FACTS cost using cuckoo search algorithm." In *Handbook of Nature-Inspired Optimization Algorithms: The State of the Art: Volume I: Solving Single Objective Bound-Constrained Real-Parameter Numerical Optimization Problems*, pp. 135-155. Cham: Springer International Publishing, 2022.

[4] Si Tayeb, Abdelkader, Benyekhlef Larouci, Daoud Rezzak, Yehya Houam, Hamid Bouzeboudja, and Abdelhak Bouchakour. "Application of a new hybridization to solve economic dispatch problem on an algerian power system without or with connection to a renewable energy." *Diagnostyka* 22, no. 3 (2021): 101-112.

[5]. Abido M. Environmental/economic power dispatch using multi-objective evolutionary algorithms. IEEE Trans Power Syst April. 2003;18(4):1529e37.. E. Finnigan and A. A. Fouad, Economic dispatch with pollution constraints, IEEE PES Winter Meeting, New York, USA, 1974, Paper No. C 74 155-8

[6] Yan, L.; Zhu, Z.; Kang, X.; Qu, B.; Qiao, B.; Huan, J.; Chai, X. Multi-Objective Dynamic Economic Emission Dispatch with Electric Vehicle–Wind Power Interaction Based on a Self-Adaptive Multiple-Learning Harmony-Search Algorithm. Energies 2022, 15, 4942. https://doi.org/10.3390/en15144942

[7] Yuwei Zou a,*, Junfeng Zhao b, Diankuan Ding a, Fengdong Miao a, Behrooz Sobhani c,'Solving dynamic economic and emission dispatch in power system integrated electric vehicle and wind turbine using multi-objective virus colony search algorithm', Sustainable Cities and Society, 2021.

[8] Qiao, B., & Liu, J. (2020). Multi-objective dynamic economic emission dispatch based on electric vehicles and wind power integrated system using differential evolution algorithm. Renewable Energy, 154, 316–336

[9] TIMBUKA, Christopher. The Ecology and Behaviour of the Common hippopotamus, Hippopotamus amphibious L. in Katavi National Park, Tanzania: Responses to Varying Water Resources. 2012. Thèse de doctorat. University of East Anglia.

[10] UTETE, Beaven. A review of some aspects of the ecology, population trends, threats and conservation strategies for the common hippopotamus, Hippopotamus amphibius L, in Zimbabwe. African Zoology, 2020, vol. 55, no 3, p. 187-200.

[11] BARKLOW, William E. Amphibious communication with sound in hippos, Hippopotamus amphibius. Animal behaviour, 2004, vol. 68, no 5, p. 1125-1132.

[12] FRITSCH, Camille Jacques-Armand. Aspects of common hippopotamus (Hippopotamus amphibius) behavioural ecology and their consequences in managed systems in South Africa. 2020. Thèse de doctorat.

[13] Amiri, M.H., Mehrabi Hashjin, N., Montazeri, M. et al. Hippopotamus optimization algorithm: a novel nature-inspired optimization algorithm. Sci Rep 14, 5032 (2024). https://doi.org/10.1038/s41598-024-54910-3

[14] Gholami, K., Abbasi, M., Azizivahed, A., & Li, L. (2023). An efficient bi-objective approach for dynamic economic emission dispatch of renewable-integrated microgrids. Journal of Ambient Intelligence and Humanized Computing, 14(8), 10695-10714.

[15]Trivedi IN, Jangir P, Bhoye M, Jangir N (2018) An economic load dispatch and multiple environmental dispatch problem solution with microgrids using interior search algorithm. Neural Comput Appl 30:2173–2189. https:// doi. org/ 10. 1007/ s00521- 016- 2795-5

[16] Elattar EE (2018) Modified harmony search algorithm for combined economic emission dispatch of microgrid incorporating renewable sources. Energy 159:496–507. https:// doi. org/ 10. 1016/j. energy. 2018. 06. 137

[17] Benyekhlef, Larouci, Benasla Lahouari, and Sitayeb Abdelkader. "Static/Dynamic Economic-Environmental Dispatch Problem Using Cuckoo Search Algorithm." *Power Electronics for Green Energy Conversion* (2022): 453-473.

[18] Benyekhlef, Larouci, "Gestion optimale d’un réseau d’énergie électrique avec incorporation des systèmes FACTS", Thesis for: Doctorate of science thesis, Université Mohamed Boudiaf des Sciences et de la Technologie - Mohamed Boudiaf d'Oran (2018).

[19] LAROUCI Benyekhlef, "Dynamic analysis of renewable energy sources in west of Algeria", *Revue des matériaux et énergies renouvelables,* 2016, 46-58. https://www.asjp.cerist.dz/en/article/67677