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Multi-Objective Management of Island and Grid Connected Renewable Micro-Grid Using Improved Whale Optimization Algorithm

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Abstract: Today's high social economic development and environmental problems have led many western societies to emphasize the importance of a safe and reliable service. In addition, Micro-grids are often used to deliver power efficiently and utilize renewable energy sources efficiently. In this analysis, various optimization algorithms are implemented for direct operation of a standard Micro-grid (MG) mill connected to renewable energy sources to cover the power mismatch or to store surplus of energy when required. The problem proposed with Improved Whale optimization algorithm (IWOA) to mitigate both running expense and net pollution was conceived as a multi-objective problem. The suggested algorithm is evaluated on a standard MG with stand-alone and grid connected mode of operation and contrasts its superior results.

Keywords: Micro grid, IWOA, wind, biomass, solar and Hydro turbines.

I. Introduction

In recent years, alternative energy sources such as wind, biomass, solar, hydro, and others have gained popularity since they produce cheaper energy while also having a smaller negative impact on the environment. It is proposed that these renewable sources should be integrated with the micro grid. In the not-too-distant future, distributed generation, which may include photovoltaics (PV), microturbines, fuel cells, and other storage devices, may play an essential part in the production of energy [1].

However, this could result in new challenges for the electrical system if a higher proportion of DGs are integrated into the setting of the grid. Micro-grids, which are defined as an aggregation of distributed generation, loads, and the distribution system coupled between them, offer a potential solution to this problem. Micro-grids can help address this issue in part. In this regard, the approaches that are used to handle and monitor the operation of MGs are undergoing continuous change in order to make these networks configured and active structures. As a result, there is a strong need for more precise scheduling of energy sources in MGs taking into consideration a variety of different objectives.

There have been a great number of research publications written and published on the topic of optimal process scheduling in a variety of different environmental situations. In the beginning, classical economic scheduling was proposed as a solution to the optimization problem. This technique involved finding the best possible combination of generators to satisfy power demands and operational restrictions in a manner that was also economically efficient. In light of the problems posed to the natural world by traditional fossil fuel units and the toxic waste they produce, this scenario calls for the use of a multivariable optimization problem.

Multi-objective optimization-based strategies have been developed in publications to incorporate the emission as a distinct goal in order to pick a specific number of units for serving the load in certain circumstances, taking into consideration both minimal cost levels and grid emissions. This is done in order to choose a particular number of units for serving the load in certain circumstances. The production of a wide variety of distributed resources, such as fossil fuel and renewable energy, can be accomplished through a process known as distributed generation. It is possible to classify it into two primary groups: those that require fuel supply and those that do not require fuel supply. Micro turbines and fuel cells have the potential to be combined into a single unit for the form that requires fuel. Micro turbines are scaled-down versions of turbine engines that typically include integrated generators and energy electronics.

Distributed generation has a number of advantages, including a reduction in emissions, an increase in energy efficiency, and installations that are more adaptable. Additionally, transmission and distribution resources, as well as maintenance costs, can be avoided, and concentric transmission line loss can be decreased. Additionally, it has the potential to decrease total power grid capability while simultaneously improving peak and valley quality and power supply dependability.

It provides power to the power network in a reliable and effective manner. The DG's intrinsic faults become more and more apparent as it penetrates more and more. The costs of single access as well as the control difficulties are significant. First, because distributed generation is not an easily managed source, large systems have a tendency to be constrained and separated to deal with it. This is done to ensure that its effects on the power grid are kept to a minimum. On the other hand, distributed generation (DG) has specific features that cause it to link and operate as a load, which would result in the distributed generation having a relatively limited shape. This is because DG has certain qualities.

The MG concept is offered as a means of incorporating distributed generation into the network and maximizing the potential benefits of distributed generation in terms of the economy, energy, and environment. Chargers, turbines, and energy storage devices are all contained into MG, which is a smaller, more autonomous, and decentralized device. It does so by lowering the amount of feeder loss while simultaneously raising both the dependability and the energy efficiency of the local electricity supply. The electricity from the host grid can be shared by MG both while it is operating in the isolated mode and when it is operating in the grid-connected mode. In grid-connected modes, MG and the host grid provide assistance for one another, which helps to increase the stability of the power supply.

II. OPTIMIZATION TECHNIQUES

Meta-heuristic products can typically be divided into two major categories: one-solution-based and population-based. The search procedure begins at one candidate solution in the earlier class (Simulated Annealing for example). In the course of the iterations, this single candidate solution is then strengthened [2]. However, population-based metaheuristic optimize the method with a series of solutions (population). In this case, the search process begins with an initial population of the random population (multiple solutions), which is strengthened during the processes.

Meta-heuristic in population have some advantages as compared to single solution-based algorithms: multiple candidate solutions share search information which leads to sudden jumps into the promising search field. Multiple applicant solutions enable each other to avoid optimum solutions locally. Meta-heuristics based on populations typically have a better analysis than single solution algorithms. Swarm Intelligence is one of the fascinating industries of population-based meta-heurism.

2.1 Improved Whale optimization algorithm

The IWOA algorithm based on the hunting technique is a new algorithm in this work, which belongs in these groups of so-called nature influenced algorithms [3]. While it is a question for scientists to debate about the real goal of and the details of this complex biochemical process of generating this flashing light, many researchers feel that it allows fireflies to locate matrons, defend them against predators and attract their possible prey.

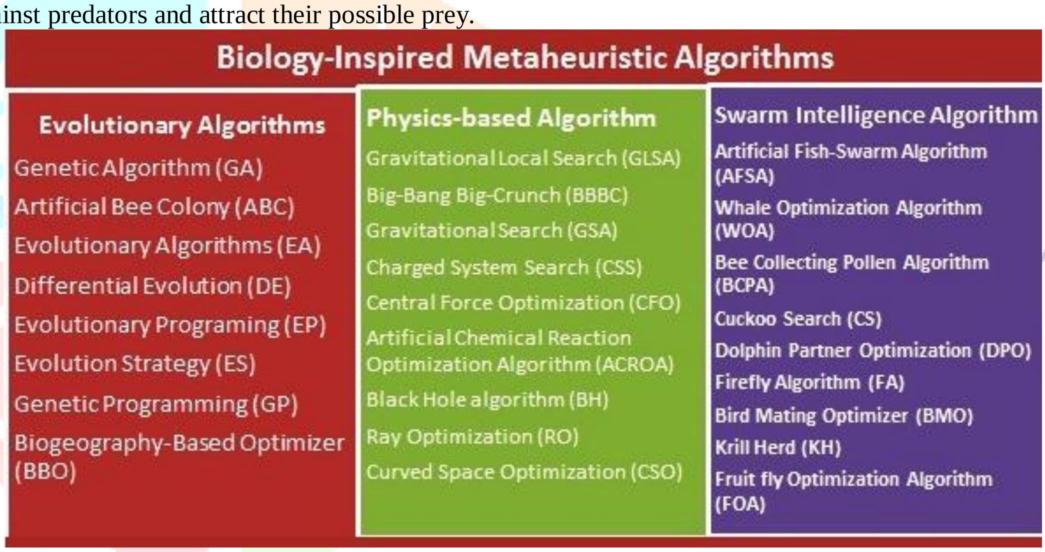

Fig.1: Bio Inspiration Metaheuristic Algorithm

This hunting method or bubble net strategy, which enables the IWOA swarm to travel to brighter and desirable spaces to achieve the most effective optimum solutions, is associated with the objective function of a certain optimization problem.

In this paper, we will demonstrate how the newly developed IWOA algorithm can be used to address the reputed problem of micro grid economic load optimization. This challenging problem of optimization constitutes one of the most critical problems for the operation and design of power systems in which a direct solution cannot be found, and metaheuristic methods such as the IWOA algorithm must therefore be used to find near optimum solutions. This issue deals with allotting loads for a minimum overall fuel cost to power generators in a plant while respecting the power demand restrictions. This problem is modeled in several different ways in the two objective functions and constraints.

In addition, we will show how the IWOA algorithm operates and how this approach can be easily adapted to solve this problem. We will also understand that this approach is adequately reliable and simple for the operation and management of power systems in real time. We will use, for example, a sample practical trial system with six power generators for the efficiency and validation of this algorithm.

III. PROBLEM FORMULATION

The multi-operation management problem of a typical MG is described in a way that minimizes the operational costs of MGs and the emissions of net contaminants into the grid at the same time and satisfies many equalities and inequality limitations. It also includes allocating optimal power generation sets to divisive units. The following can be expressed in the mathematical model of this problem

3.1Cost Minimization

The overall cost of service of MG in $ includes DG fuel costs, start-up and shutdown costs, as well as power exchange costs between MG and utilities.

$$Min\ f_1(X)=\sum_{t=1}^{T}\left\{\sum_{i=1}^{N_g}\left[u_i(t)P_{Gi}(t)B_{Gi}(t)+S_{Gi}\,|u_i(t)-u_i(t-1)|\right]+\sum_{j=1}^{N_s}\left[u_j(t)P_{sj}(t)B_{sj}(t)+S_{sj}\,|u_j(t)-u_j(t-1)|\right]+P_{Grid}(t)B_{Grid}(t)\right\} \quad (1)$$

where BGi(t) and BSj(t) are the bids of the DGs and storage devices at hour t, S_{Gi} and Ssj represent the start-up or shut-down costs for i^{th} DG and jth storage respectively, $P_{Grid}(t)$ is the active power which is bought (sold) from (to) the utility at time t and $B_{Grid}(t)$ is the bid of utility at time t. X is the state variables vector which includes active power of units and their related states.

3.2 Power loss

Total electricity provided by DGs within the MG must cover total grid demand. Since the project is planned for a small 3-feeder radial L.V system, no numerically low transmission losses need to be considered urgently.

$$\sum_{i=1}^{N_g}P_{Gi}(t)+\sum_{J=1}^{N_s}P_{sj}(t)+P_{Gird}(t)=\sum_{k=1}^{N_k}P_{LK}(t) \quad (2)$$

Where P_{Lk} is the amount of k^{th} load level and N_k is the total number of load levels

IV. Improved Whale optimization algorithm

In this proposed approach, each whale is represented and linked to a true power supply (i.e., the potential solution) which is encoded as a real number for each power generator unit, while a bubble net of the whales is correlated with the cost of the fuel (i.e. the problem's objective function). The values for the control parameters of this simulation are: α = 0.2, α = 1.0, ß0 = 1.0, n = 12, and maximum whale generation (iterations) is 500. As inputs to the Whales Algorithm are given the fuel costs, the coefficients, the power limits of each generator and the total demand for power.

Three idealized laws are used by IWOA

(1) Every whale is trying to capture the fish close to the surface.

(2) Then it was observed that this search was finished close to the surface to provide a bubble net covering the small fish to fish.

(3) The value of the objective function of a given problem defines the bubble net around a whale. The bubble net is proportional to the value of the objective function for maximization problems.

Moreover, the algorithm is very efficient and may be superior to other traditional algorithms for the solution of a number of optimization problems, for example genetic algorithms, according to recent bibliography. The fact is justified in the recent research in which statistical efficiency was evaluated using standard stochastic against other established optimization algorithms. Its key benefit lies in the fact that the swarming particles (i.e., whale), primarily use real random numbers and thus appear more successful in the multi-target optimization such as the economic problem of shipment of loads, in our case.

Three especially idealized rules are found in the whales algorithm, based on certain major net bubble characteristics of real whales. The following are:

(1) Every whale is trying to capture the small fish close to the surface.

(2) Then, it was found that this search was performed close to the surface to ensure the bubble net around the small fish is caught.

(3) The value of the objective function of a given problem shall evaluate the bubble net surrounding a whale. The bubble net is proportional to the value of the objective function for maximization problems.

It is necessary, finally, to note that for every generation (iteration), the swarm of whales is classified as brighter (i.e. an optimal solution is possible), while the others are modified on the basis of objective function and according to their bubble net strategies the swarm of the whale is ranked. In the final round, the walnuts with the surrounding net strategy of the bubble swarm are chosen as the encircling strategy which is the best solution for the problem.

This section of the paper uses the proposed IWOA algorithm to solve the issue for a standard MG. as shown in the Figure 2

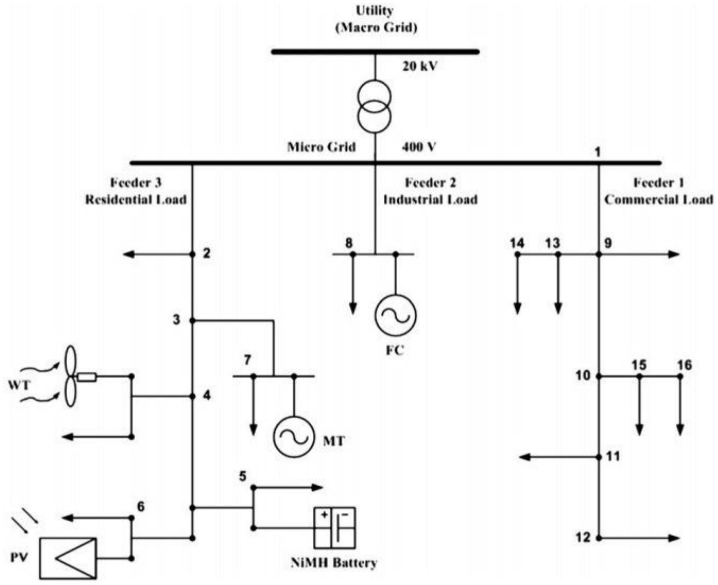

Fig.2: A typical L.V micro-grid

4.1 Grid Connected Mode

Table.1 Optimal output power and corresponding status of each DG and Utility power grid – Grid Connected Mode

Time (h)	Demand, DG sources and outputs (kW)					Status					Cost ($)		
	MT	FC	PV	WT	Grid	MT	FC	PV	WT	Grid	Grid	DG	sc
1	6.00	29.95	0.00	0.00	14.05	1	1	1	1	1	3.232	11.548	0.000
2	6.01	29.98	0.00	0.00	11.52	1	1	0	0	1	2.188	11.558	0.000
3	14.60	3.00	0.00	0.00	29.89	1	1	1	1	1	4.185	7.557	0.000
4	29.92	29.92	0.00	0.00	-11.34	1	1	0	0	1	-1.225	22.470	0.000
5	23.66	3.00	0.00	0.00	26.84	1	1	1	1	1	3.221	11.694	0.000
6	30.00	30.00	1.82	1.83	-2.15	1	1	1	1	1	-0.387	29.199	0.000
7	29.83	7.85	0.00	0.00	29.83	1	1	0	0	1	6.860	15.938	0.000
8	30.00	30.00	1.37	14.86	-3.73	1	1	1	1	1	-1.276	42.014	0.000
9	30.00	30.00	1.55	14.93	-2.98	1	1	1	1	1	-4.018	42.549	0.000
10	30.00	30.00	24.82	0.81	-8.14	1	1	1	1	1	-29.294	87.545	0.000
11	30.00	30.00	20.58	13.17	-18.74	1	1	1	1	1	-67.480	89.832	0.000
12	30.00	30.00	3.23	14.98	-5.71	1	1	1	1	1	-20.547	46.943	0.000
13	30.00	30.00	0.01	14.02	-4.03	1	1	1	1	1	-5.438	37.599	0.000
14	30.00	30.00	24.76	0.24	-15.00	1	1	1	1	1	-53.994	86.768	0.000
15	30.00	30.00	1.00	14.68	-2.18	1	1	1	1	1	-3.929	40.868	0.000
16	30.00	30.00	24.44	0.14	-7.07	1	1	1	1	1	-12.412	85.818	0.000
17	24.71	29.40	0.00	0.00	29.40	1	1	0	0	1	17.637	19.934	0.000
18	29.07	29.07	0.00	0.00	27.86	1	1	1	1	1	11.424	21.830	0.000
19	29.15	28.93	0.00	0.00	28.93	1	1	1	1	1	10.124	21.825	0.000
20	30.00	30.00	0.55	0.55	-0.01	1	1	1	1	1	-0.002	86.320	0.000
21	30.00	30.00	15.00	15.00	-1.42	1	1	1	1	1	-1.493	44.874	0.000
22	10.13	29.93	0.00	0.00	29.93	1	1	0	0	1	16.164	13.431	0.000
23	29.97	29.97	0.00	0.00	2.05	1	1	0	0	1	0.616	22.510	0.000
24	25.35	3.00	0.00	0.00	25.15	1	1	1	1	1	6.539	12.467	0.000

Table.1 shows optimal schedule of PV, FC, MT and WT in micro grid for a day in grid connected mode. The total cost of DGs in micro grid and power cost to the grid for the proposed method for a day is 956.67403$ and -119.30358$ respectively as shown in Table 2. Suppose if the total generated power from the FC and MT is not sufficient to meet the load demand, then the remaining required power is imported from the main grid to satisfy the total load demand.

Table 2: Optimal cost – Grid Connected Mode

Cost of Grid	-119.30358$
Cost of DG	913.09311$
Start –Up /Shutdown Cost	0.00000$
Maintenance Cost of DG	162.88451$
Operation Cost of MG	956.67403$

The convergence characteristic of IWOA for grid connected mode is shown in Fig. 3. From Fig. 3, it is clearly seen that the optimal result is achieved within 148th iterations hence the proposed approach is much faster in obtaining the results.

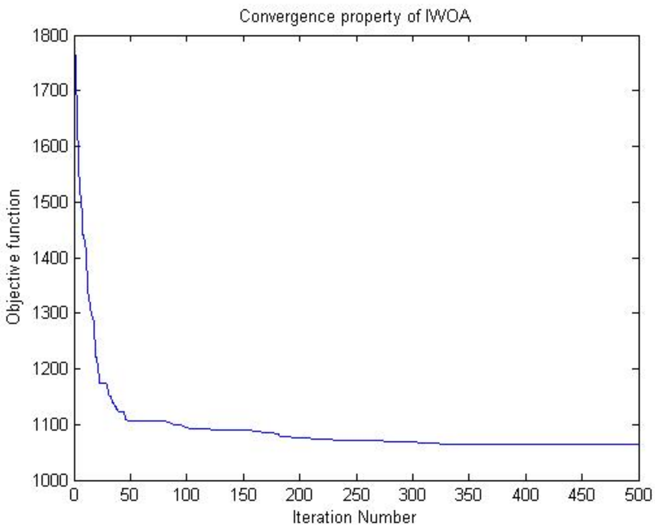

Fig.3: Convergence property of IWOA IN Grıs Connect Mode

4.2 Island Mode

Table 4 shows optimal schedule of PV, FC, MT and WT in micro grid for a day in island mode. The total cost of DGs in micro grid for the proposed method for a day is 1208.90163$ as shown in table.3. Suppose if the total generated power from the FC and MT is not sufficient to meet the load demand, then the remaining required power is imported from the main grid to satisfy the total load demand.

Table 3: Optimal cost – Island Mode

Cost of Grid	0.00000$
Cost of DG	1019.20639$
Start –Up /Shutdown Cost	0.00000$
Maintenance Cost of DG	189.69524$
Operation Cost of MG	1208.90163$

The convergence characteristic of IWOA algorithm for island mode is shown Fig. 4 .From Fig. 4, it is clearly seen that the optimal result is achieved within 150th iterations, hence the proposed approach is much faster in obtaining the results.

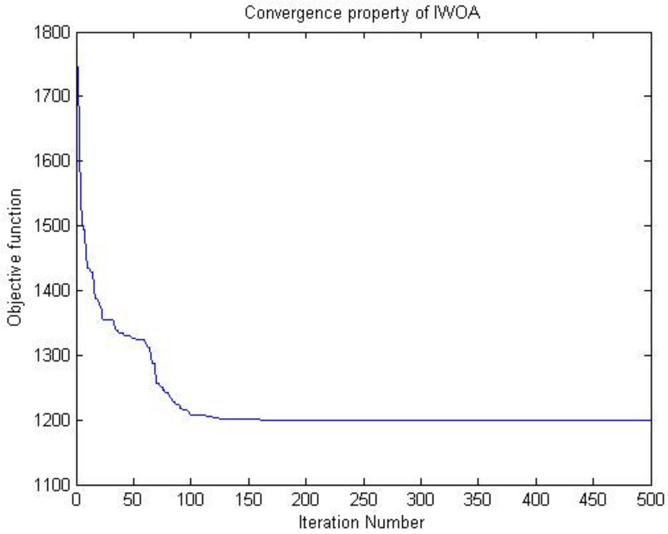

Fig.4: Convergence property of IWOA IN Grıs Connect Mode

Table.4 Optimal output power and corresponding status of each DG and Utility power grid – Island Mode

Time (h)	Demand, DG sources and outputs (kW)					Status					Cost ($)		
	MT	FC	PV	WT	Grid	MT	FC	PV	WT	Grid	Grid	DG	sc
1	20.63	29.37	0.00	0.00	0.00	1	1	1	1	0	0.000	18.063	0.000
2	21.69	25.81	0.00	0.00	0.00	1	1	1	1	0	0.000	17.501	0.000
3	27.12	20.38	0.00	0.00	0.00	1	1	1	1	0	0.000	18.386	0.000
4	23.48	25.02	0.00	0.00	0.00	1	1	1	1	0	0.000	18.087	0.000
5	26.93	26.57	0.00	0.00	0.00	1	1	1	1	0	0.000	20.119	0.000
6	30.00	30.00	0.75	0.75	0.00	1	1	1	1	0	0.000	25.269	0.000
7	30.00	30.00	0.03	7.47	0.00	1	1	1	1	0	0.000	30.625	0.000
8	30.00	30.00	0.00	12.50	0.00	1	1	1	1	0	0.000	35.943	0.000
9	30.00	30.00	0.00	13.50	0.00	1	1	1	1	0	0.000	37.016	0.000
10	30.00	30.00	17.47	0.03	0.00	1	1	1	1	0	0.000	67.709	0.000
11	30.00	30.00	0.00	15.00	0.00	1	1	1	1	0	0.000	38.626	0.000
12	30.00	30.00	0.00	12.50	0.00	1	1	1	1	0	0.000	35.943	0.000
13	30.00	30.00	7.90	2.10	0.00	1	1	1	1	0	0.000	45.195	0.000
14	30.00	30.00	0.00	10.00	0.00	1	1	1	1	0	0.000	33.261	0.000
15	30.00	30.00	0.00	13.50	0.00	1	1	1	1	0	0.000	37.016	0.000
16	30.00	30.00	2.50	15.00	0.00	1	1	1	1	0	0.000	45.085	0.000
17	30.00	30.00	8.50	15.00	0.00	1	1	1	1	0	0.000	60.589	0.000
18	30.00	30.00	25.00	1.00	0.00	1	1	1	1	0	0.000	88.203	0.000
19	30.00	30.00	25.00	2.00	0.00	1	1	1	1	0	0.000	89.276	0.000
20	30.00	30.00	25.00	0.00	0.00	1	1	1	1	0	0.000	87.130	0.000
21	30.00	30.00	1.00	15.00	0.00	1	1	1	1	0	0.000	41.209	0.000
22	30.00	15.00	25.00	0.00	0.00	1	1	1	1	0	0.000	82.722	0.000
23	30.00	30.00	1.00	1.00	0.00	1	1	1	1	0	0.000	26.188	0.000
24	26.48	27.02	0.00	0.00	0.00	1	1	1	1	0	0.000	20.046	0.000

V. Conclusion

A IWOA algorithm is proposed and implemented to solve the problem of multi-operation management in a typical MG with RESs. A number of test cases are added and simulation results are obtained subsequently to determine the efficiency of the proposed algorithm. The numerical findings show that the approach proposed shows not only superior efficiency, but also dynamic stability and excellent swarm convergence. The proposed method gives the device operators a real, well-developed range of optimum solutions to choose a suitable power delivery plan based on economic considerations.

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