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Research Article

A COST-EFFECTIVE SYSTEM OF RENEWABLE MICRO GRID USING GLOWWORM SWARM OPTIMIZATION ALGORITHM

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ABSTRACT

Due to today's rapid socioeconomic expansion and environmental concerns, many modern civilizations are interested in researching alternate energy options, notably renewable ones. In this sense, a Micro-grid (MG) of multiple renewable energy sources can help achieve the intended goals while delivering electricity more efficiently, affordably, and safely. This paper presents an expert multi-objective Glowworm Swarm Optimization Algorithm (GSO) for optimal operation of a typical MG with Renewable Energy Sources (RESs). The objective is to minimize both the overall operating cost and the net emission. The proposed algorithm is tested on a typical MG, and its superior performance is compared to those from other evolutionary algorithms.

Keywords—Micro-grid, RESs, Glowworm Swarm Optimization Algorithm, and DG

I. INTRODUCTION

Wind, biomass, solar, and hydropower are just a few examples of alternative energy sources that have recently gained popularity due to their lower cost and less environmental impact. On the other hand, it has been proposed to combine these renewable energy sources with MG. Photovoltaic (PV), micro-turbines, fuel cells, and storage devices all have a role in the future of energy production.

However, when more DGs are integrated into the grid, new electrical system difficulties may emerge. An integrated distribution system and distributed generation can help alleviate this by using medium-sized generators (MGs). Regarding MGs in this context, approaches used for managing and monitoring their operation change with time, making it necessary to schedule energy sources more precisely in MGs to achieve various goals [1].

A slew of studies has been done on the best way to schedule processes in various types of environments. Economic scheduling was initially proposed to solve the optimization problem by looking for an outstanding collection of generators to meet power requirements and operational restrictions while being economically efficient. A multivariable optimization problem should be used in this case because of the environmental concerns and toxins released by typical fossil fuel units.

Strategies based on several objectives, including emission, have been developed in publications to determine a certain number of units for supplying the load while considering minimal cost levels and grid emissions. To produce distributed resources like renewable and fossil fuels, companies use distributed generation (DG). There are two basic types: those with and those without access to energy. Fuel-supplied forms may include microturbines and fuel cells. Scaled-down turbine engines include microturbines, which have integrated generators and energy electronics.

Using DG will save money on transmission and distribution resources and maintenance expenses while also reducing pollutants. Concentric transmission line losses will be reduced as well. Additionally, it can reduce the total grid capacity while increasing the quality of the peak and valley periods and the reliability of electricity delivery.

It has a powerful and efficient power supply for the network. As the DG spreads, it reveals more and more flaws. Because of the high costs and problems with control, only one person should have access. To begin with, because DG is a problematic source to manage, large systems are usually restrained and segregated to keep their impact on the power grid to a minimum. Distributed generation, on the other hand, has specific properties that make it function as a load [2], resulting in an extremely constrained structure for distributed generation.

The MG definition is recommended to integrate distributed generation into the net and maximize distributed generation's economic, energy, and environmental benefits. Small, self-sufficient, and decentralized, MG comprises batteries, turbines, and energy storage devices. It reduces feeder losses and improves the local electricity supply's dependability and efficiency, improving the stability of the power supply.

II. GLOBAL OPTIMIZATION TECHNIQUES

Typically, meta-heuristic products fall into two broad categories: solution-based and population-based. The search technique begins with one of the earlier class's possible solutions (Simulated Annealing, for example). This single candidate answer is then strengthened during the iterations. Nevertheless, population-based metaheuristics optimize the process by generating a succession of solutions (population). In this situation, the search process begins with a random population (many answers), which is gradually enhanced throughout the procedure [3].

Meta-heuristic algorithms in population have several advantages over single-solution algorithms: Multiple candidate solutions share search data, resulting in unexpected leaps into the promising search field. Multiple applicant solutions assist one another in avoiding locally optimal solutions. Meta-heuristics based on populations often perform better than single-solution algorithms in terms of analysis. Swarm Intelligence is an enthralling branch of population-based meta-heurism [4].

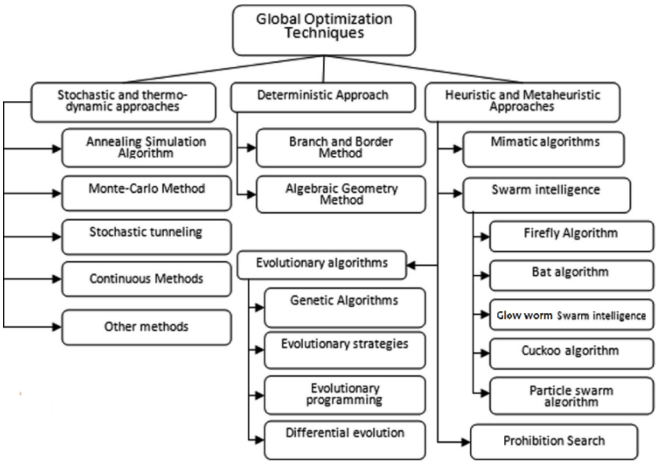

Fig. 15. Flow chart of Global Optimization Techniques.

Krishnanand K.N. and Ghose D. introduced the Glowworm Swarm Optimization Algorithm (GSO) in 2005 [5], a nature-inspired heuristic intelligence algorithm that mimics the behavior of a glowworm swarm while moving by employing luciferin to attract other glowworms nearby or looking for food. The more valuable luciferin is, the more desirable the glowworm will be since it is brighter. Numerous domains have benefited from the glowworm swarm optimization algorithm, including multimodal function and combinatorial optimization. The glowworm swarm optimization algorithm has been used in multiple disciplines, such as multimodal function and combination optimization, robotics applications, and wireless sensor networks.

III. COST-EFFECTIVE ECONOMIC DISPATCH OF MICROGRID

The total operating cost of the MG in $ includes the fuel costs of DGs, start-up/shut-down costs and the costs of power exchange between the MG and the utility [5]. The cost objective function aims to find OPFs from energy sources to load centres for a definite period economically. Such objective function can be formulated as below:

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

Where $u_i(t)$ status of unit i at hour t, $P_{Gi}(t)$ active power output of ith generator at time t, $P_{sj}(t)$ active power output of jth storage at time t, $B_{Gi}(t)$ and $B_{Sj}(t)$ 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 *j*th 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 and is described as follows:

$$X=\left[P_g,U_g\right]_{1\times 2nT}$$

$$P_g=\left[P_G,P_S\right]$$

$$n=N_g+N_s+1 \qquad (2)$$

where n is the number of state variables, N_g and N_s are the total numbers of generation and storage units; respectively, P_g is the power vector including active powers of all $DG_{s,}$ and U_g is the state vector denoting the ON or OFF states of all units during each hour of the day. These variables can be described as follows:

$$P_G=\left[P_{G1},P_{G2},...,P_{G,Ng}\right]$$

$$P_G=\left[P_{Gi}(1),P_{Gi}(2),...,P_{Gi}(t),...,P_{Gi}(T)\right];i=1,2,...,N_g+1$$

$$P_s=\left[P_{s1},P_{s2},...P_{s,Ns}\right] \qquad (3)$$

$$P_{sj}=\left[P_{sj}(1),P_{sj}(2),...,P_{sj}(t),...,P_{sj}(T)\right];\ j=1,2...,N_s$$

Where T represents the total number of hours, $P_{Gi}(t)$ and $P_{sj}(t)$ are the real power outputs of *i*th generator and *j*th storage at time t, respectively.

$$U_g=\left[u_1,u_2,...,u_n\right]=\left\{u_i\right\}_{1\times n}\in\left\{0,1\right\};$$

$$u_k=\left[u_k(1),u_k(2),...,u_k(t),...,u_k(T)\right];k=1,2,...,n \qquad (4)$$

where $u_k(t)$ is the status of unit k at hour t.

A. Power balance Constraints

The total power generation from DGs in the MG must cover the entire demand inside the grid. Since a small 3-feeder radial L.V system is proposed in work, there is no urgent need to consider transmission losses which are low numerically. Hence,

$$\sum_{i=1}^{N_g}P_{Gi}(t)+\sum_{J=1}^{N_s}P_{sj}(t)+P_{Gird}(t)=\sum_{k=1}^{N_k}P_{LK}(t) \qquad (5)$$

where P_{Lk} is the amount of *k*th load level and N_k is the total number of load levels.

B. Real power generation capacity

For a stable operation, the active power output of each DG is limited by lower and upper bounds as follows:

$$P_{Gi,\min}(t)\le P_{Gi}(t)\le P_{Gi,\max}(t)$$

$$P_{sj,\min}(t)\le P_{sj}(t)\le P_{sj,\max}(t)$$

$$P_{grid,\min}(t)\le P_{Grid}(t)\le P_{grid,\max}(t) \qquad (6)$$

where $P_{G,\min}(t)$, $P_{s,\min}(t)$ and $P_{grid,\min}(t)$ are the minimum active powers of *i*th DG, jth storage and the utility at the time t. Similarly, $P_{G,\max}(t)$, $P_{s,\max}(t)$ and

$P_{grid,\max}(t)$ are the maximum power generations of corresponding units at hour t.

Since there are some limitations on the charge and discharge rate of storage devices during each time interval, the following equation and constraints can be expressed for a typical battery[6]:

$$W_{ess,\min} = W_{ess,t-1} + \eta_{charge} P_{charge} \Delta t - \frac{1}{\eta_{discharge}} P_{discharge} \Delta t \tag{7}$$

$$\begin{cases} W_{ess,\min} \le W_{ess,t} \le W_{ess,\max} \\ P_{charge,t} \le P_{charge,\max} ; P_{discharge,t} \le P_{discharge,\max} \end{cases} \tag{8}$$

Where $W_{ess,t}$ and $W_{ess,t}$ 1 are the amount of energy storage inside the battery at hour t and t-1 respectively, $P_{charge}(P_{discharge})$ is the permitted rate of charge(discharge) during a definite period (Δt), $\eta_{charge}(\eta_{discharge})$ is the efficiency of the battery during charge(discharge) process. $W_{ess,min}$ and $W_{ess,max}$ are the lower and upper limits on the amount of energy storage inside the battery and $P_{charge,max}(P_{discharge,max})$ is the maximum rate of battery charge(discharge) during each time interval Δt.

IV. GLOW WORM SWAM OPTIMIZATION

GSO uses a swarm of agents that are first dispersed over the search space at random. The agents in this work are based on glowworms and will be referred to as glowworms. As a result, they are equipped with a substance called luciferin, which emits light when exposed to a specific wavelength of light. The intensity of the light emitted by the glowworms luciferin is related to that of the surrounding environment. It's important to note that the neighborhood is specified as a local-decision domain with an adjustable neighborhood range, defined as the distance from one end of the field to the other, defined as the distance from one end to the other. A glow worm I consider another glow worm j as its neighbor if j is within the neighborhood range of I and the luciferin level of j is higher than that of i's. The decision domain facilitates the creation of fragmented sub-swarms by allowing for selected neighbor contacts. Another way to describe it is that every glowworm in the area is drawn to the more intense lights of the other glowworms. GSO agents make decisions solely based on information that is readily available to them in their immediate surroundings.

A. *Algorithm description:*

n glowworms are randomly distributed in the search space to begin the search process. The luciferin concentration in all of the glowworms is the same in the beginning. A luciferin-update phase is followed by a movement phase based on a transition rule in each iteration.

B. *Luciferin-update phase:*

The luciferin update is dependent on the glowworm position's function value. Luciferin-update phase: each glow-worm adds an amount of luciferin to its previous luciferin level proportionate to the fitness of its current position objective function domain. Luciferin-update phase: The luciferin value is also decremented to imitate luciferin degradation over time. When it comes to the luciferin updating rule,

$i\ (t+1) = (1-\rho)i\ (t) + \gamma J\ xi\ (t+1)$, (9)

where i (t) represents the luciferin level associated with glow worm i at time t , ρ is the luciferin decay constant ($0<\rho<1$), γ is the luciferin enhancement constant, and J(xi (t)) represents the value of the objective function at agent i's location at time t .

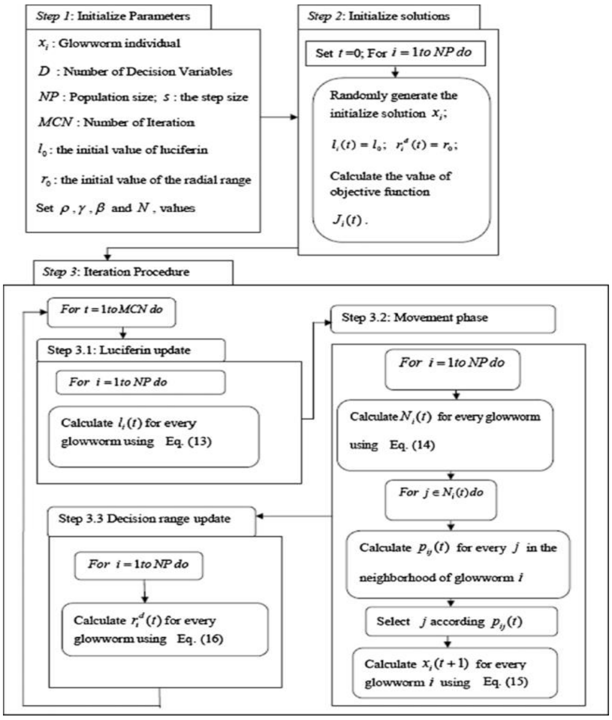

Fig. 16. Flow chart of Glowworm Swam Optimization

TABLE VIII. 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*
1	0	12.5	0	0	7.5	0	1	0	0	1	6.9	6.525
2	0	3.27	0	0	14.23	0	1	0	0	1	5.7	6.369
3	0	3.34	0	0	14.16	0	1	0	0	1	4.2	6.363
4	0	7.42	0	0	11.08	0	1	0	0	1	3.6	6.392
5	0	3.09	0	0	20.41	0	1	0	0	1	3.6	8.664
6	6	3.04	0	0	22.46	1	1	0	0	1	6	12.17
7	6	3	0	0	28.5	1	1	0	0	1	6.9	14.454
8	6	6.5	0	0	30	1	1	0	0	1	11.4	16.053

9	30	30	0	0	30	1	1	0	0	1	-22.274	33.93
10	30	30	7.53	3.09	30	1	1	1	1	1	-83.214	56.69
11	30	30	6.23	8.77	30	1	1	1	1	1	-108	59.431
12	30	30	3.47	9.03	30	1	1	1	1	1	-108	52.581
13	30	30	0	0.01	30	1	1	0	1	1	-27.011	33.939
14	30	30	7.63	2.37	30	1	1	1	1	1	-108	56.189
15	30	30	0	1.18	30	1	1	1	1	1	-31.822	35.196
16	30	30	0	0	30	1	1	1	1	1	-21.942	33.953
17	25.74	30	0	0	30	1	1	1	1	1	-1.211	31.984
18	6	30	0	0	30	1	1	0	1	1	8.2	22.962
19	6	21	0	0	30	1	1	0	0	1	10.5	20.316
20	6	30	0	0	30	1	1	0	1	1	8.17	22.962
21	30	30	0	0	30	1	1	0	1	1	-14.742	33.93
22	10	30	0	0	30	1	1	0	0	1	0	24.79
23	6	4.4	0	0	21.6	1	1	0	0	1	9	12.244
24	6	3.38	0	0	14.12	1	1	0	0	1	7.8	9.101

C. Movement phase:

Each glowworm uses a probabilistic method during the movement phase to decide whether or not to go toward an adjacent insect that has a luciferin value greater than its own. On the other hand, Glowworms are drawn to their nearby neighbors with a greater luminescence intensity. There are only two possible directions for e to move in because it is in the sensor overlap region of c and d. The likelihood that a glow-worm I will move toward a neighbor j is provided by the expression:

$$p_{ij}(t) = j(t) - i(t)\ k \in N_i(t)\ k(t) - i(t), \quad (10)$$

Then, the discrete-time model of the glowworm movements can be stated as:

$$x_i(t+1) = x_i(t) + s x_j(t) - x_i(t)\ x_j(t) - x_i(t), \quad (11)$$

V. RESULT AND DISCUSSION

In this part of the work, the proposed Glow warm swarm optimization algorithm is implemented to solve a typical MG's multi-operation management problem, as shown in Fig. 3

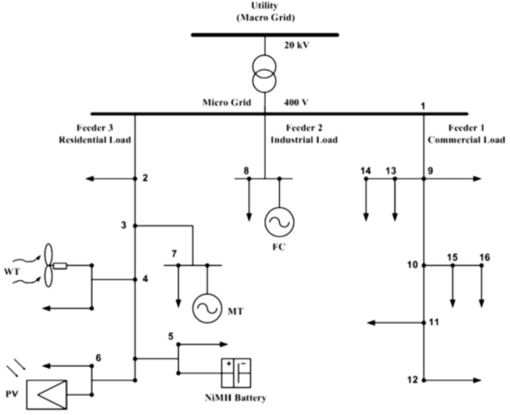

Fig. 3 A typical L.V micro-grid

Table 1 shows the optimal PV, FC, MT and WT schedule in a microgrid for a day in grid-connected mode. For allocation of optimal set points to the units through the entire case studies, all DGs are considered "ON" or in state "1", thus there will be no start-up or shut-down cost for the mentioned units.

TABLE IX. TYPICAL MICRO GRID INPUT DATA

Type	Pmin (kW)	Pmax (kW)	Bid ($/kWh)	OM ($/kWh)	Startup/shut down ($/kWh)
MT	6	30	0.457	0.0446	0.96
FC	3	30	0.294	0.08618	1.65
PV	0	25	2.584	0.2082	0
WT	0	15	1.073	0.525	0
BES	-30	30	0.38	0	0
Utility	-30	30	0	0	0

The bid coefficients in $ per kilo-Watt hour (kWh) and P_{min} and P_{max} for DGs are given in Table 2. To simplify our analysis, all units in this paper are assumed to be operating in electricity mode only and no heat is required for the examined period.

The total cost of DGs in micro grid and power cost to the grip for the proposed method for a day is -434.24651 $ and 258.35740 $, respectively, as shown in Table 3. Suppose if the total generated power from the FC and MT is insufficient to meet the load demand, then the remaining required power is imported from the primary grid to satisfy the total load demand. The cost of DG utilized for each hour is plotted in fig. 4 and cost of grid utilization for 24 hours is shown in fig 5. From this figure, its clearly shows DG utilization on-peak hours that time power supplies to grid shows negative cost

Fig. 4 A Cost of DG in $ over 24 Hours

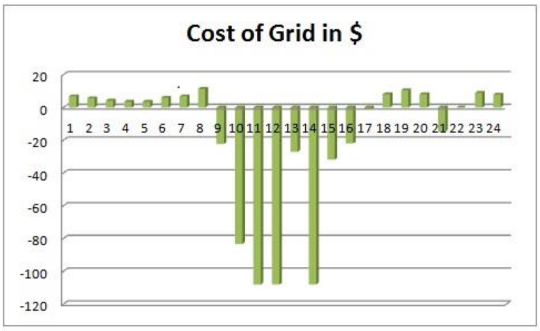

Fig. 5 A Cost of Grid in $ over 24 Hours

TABLE X. OPTIMAL COST – GRID MODE

Cost of Grid	-434.24651 $
Cost of DG	617.16944 $
Start –Up /Shutdown Cost	0.96000 $
Maintenance Cost of DG	73.51447 $
Operation Cost of MG	258.35740 $

TABLE XI. COMPARISON RESULTS

Algorithm	Worst solution ($/day)	Average ($/day)	Best solution($/day)
GSO	**625.235**	**618.142**	**617.169**
ES-PSO	815.2627	815.1776	815.158
PSO	1141.745	1071.8351	958.019
GA	1261.243	1096.3251	986.83

The overall operation cost of MG obtained using GSO is compared with other techniques like ES-PSO [7], PSO [2] and GA as shown in Table 4. It is seen that GSO results is better minimization of operating cost.

The convergence characteristic of GSO algorithm for grid-connected mode is shown in Fig. 6. From Fig. 6. it is seen that the optimal result is achieved within 20th iterations; hence the proposed approach is much faster in obtaining the results.

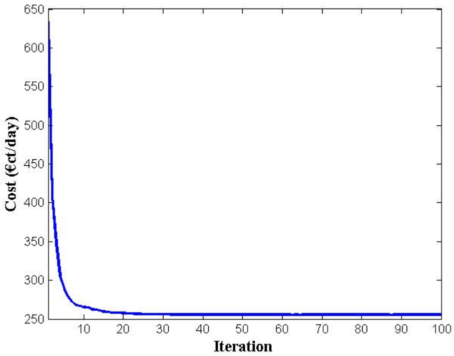

Fig. 6 Convergence property of glowworms swam algoritham

VI. CONCLUSION

A GSO technique is presented and implemented in this study to handle the multi-operation management problem in a typical MG with RESs. To assess the effectiveness of the proposed algorithm, the microgrid has been activated, and the findings have been collected. The numerical results show that the suggested method outperforms other methods and has dynamic stability and excellent swarm convergence. The proposed method also produces an accurate and well-distributed set of optimal solutions, providing system operators with various options for selecting an appropriate power dispatch plan based on economic considerations.

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REFERENCES

[1] M. Mansour-lakouraj and M. Shahabi, "Comprehensive analysis of risk-based energy management for dependent micro-grid under normal and emergency operations", *Energy*, vol. 171, pp. 928-943, Mar. 2019.

[2] Amjad anvari moghaddam,Ali Reza Seifi, taher Niknam, and Mohammad Reza Alizadeh Pahlavani,"Multi-objective operation management of a renewable MG (micro-grid) with back-up micro turbine /fuel cell/battery hybrid power source ", *Energy* ,vol.1,pp. 6490-6507, 2011.

[3] J. Deepak Vasanth, N. Kumarappan, R. Arulraj, T.Vigneysh, "Minimization of operation cost of a microgrid using firefly algorithm", *in Proc. of the IEEE Intl. Conference on Intelligent Techniques in Control, Optimization and Signal Processing (INCOS)*, Peradeniya, Sri Lanka, Aug 9-11, 2007, pp. 517-522.

[4] Seyedali Mirjalili, Seyed Mohammad Mirjalili, Andrew Lewis "Grey Wolf Optimizer" *Advances in Engineering Software* vol. 69, pp. 46-61, 2014.

[5] K.N. Krishnanand, D. Ghose.D, "Detection of multiple source location uses a glowworm metaphor with applications to collective robotics," *in IEEE swarm Intelligence Symposium, Pasadena*, CA, June 2005, pp. 84–91.

[6] B. Bahmani-Firouzi and R Azizipanah-Abarghooee, "Optimal sizing of battery energy storage for micro-grid operation management using a new improved bat algorithm", *Int. J. Electr. Power Energy Syst.*, vol. 56, pp. 42-54, Mar. 2014.

[7] Gnanaprakash M and Mangaiyarkarasi S.P "Multi-Objective Management of A Renewable Micro-Grid with Grid Connected and Island Mode Operations" *International Conference on Sustainable Development in Technology for 4th Industrial Revolution (ICSDTIR-2021)* on March 12-13, 2021 at Port City International University, Chattogram, Bangladesh.. pp 142-147.