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Micro Grid Operation Cost Reduction Using Particle Swarm Optimizer and Eagle Strategy

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Abstract: As a result of rapid financial development and natural disasters, energy efficiency research, and high-quality electricity alternative energy options, as well as efficient electricity sources. In particular, the use of green energy sources has become a hot issue; As a result, distributed electricity supply in the micro grid is the basis for the achievement of the vital objectives of successfully providing the customer with currency and stability. The article proposes a hybrid metaheuristic approach based on the Eagle strategy Technique (ES) and Particular Swarm Optimizing (PSO) Technology, which will minimize low-voltage running costs from a renewable energy source such as an electricity generator, solar panels, wind generators, micro turbines and fuel cells. The cost optimization problem is set up as a nonlinearly constrained problem. In order to maximize distributed generation, a mathematical problem must be solved. The proposed hybrid solution is evaluated on low-voltage micro grids, and its optimal performance is compared to that of other hybrid approaches and variety of other metaheuristic techniques
Keywords: Micro grid, PSO, Eagle Strategy Technique (ES) and Distributed Generation (DG)

I. INTRODUCTION

Alternative energy sources such as wind, biomass, solar, hydro and more have more recently become common as they generate cheaper energy with less environmental impact. Integration of these renewable sources with MG is proposed. Distributed Generation (DG) including photovoltaic (PV), micro-turbines, fuel cells and storage devices can play an important role in energy production in the future [1]. However, a higher percentage of DGs entering the grid setting could lead to new electrical system challenges. This can be partially addressed by MG, which is characterized as an aggregation of distributed generation, loads, and the distribution system interconnected between them. In this regard, the methodologies applied to handle and monitor the operation of MGs are going through continuous changing in order to make these networks configured and active structures, hence there is a strong need for more precise scheduling of energy sources in MGs considering different objectives [2].

Numerous research articles have been published on the optimum process scheduling under various environmental conditions. In the beginning, traditional economic scheduling was suggested as a solution to the optimization problem by seeking an optimal set of generators to fulfill power demands and operational constraints while being economically efficient. Due to the environmental issues, and toxins generated by conventional fossil fuel units, a multivariable optimization problem should be used in this situation.

Multi-objective optimization - based strategies have been introduced in articles to include the emission as a distinct goal in order to choose a certain number of units for serving the load in certain situations, taking account of minimum cost levels and grid emissions. DG is a technique used to produce a range of distributed resources, including renewables and fossil fuel. It can be divided into two main categories, namely, fuel supply and without fuel supply. Micro turbines and the fuel cell can be common for the form with fuel supplied. Micro turbines with integrated generators and energy electronics are scaled down turbine engines. DG has the benefit of lower emissions, greater energy efficiency, and more versatile installations; transmission and distribution resources and maintenance costs can be saved and the concentric transmission line loss minimized. It can also reduce total power grid capability, increase peak and valley quality and power supply reliability.

It supplies the power network strongly and efficiently. When the DG penetrates more and more, its inherent problems are clear. Single access costs and control issues are high. First, DG is not an easily managed source, so that large systems tend to be restrained, isolated to handle it, so that their effects on the power grid are minimized. DG has certain characteristics, on the other hand, that cause DG to connect and operate as a load [2], which would result in a very limited shape of the distributed generation.

To incorporate the distributed generation into the net and optimize the economic, energy and environment advantages of the distributed generation, the MG definition is proposed. MG consists of charges, turbines, and energy storage devices, as smaller, autonomous and decentralized device. It decreases feeder loss, increases the reliability and energy efficiency of local electricity supply. In isolated mode as well as in grid-connected mode, MG works through a point of common coupling to share power from the host grid. MG and the host grid support one another in grid-connected modes and thereby improve power supply stability.

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. 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 [3].

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 [4]

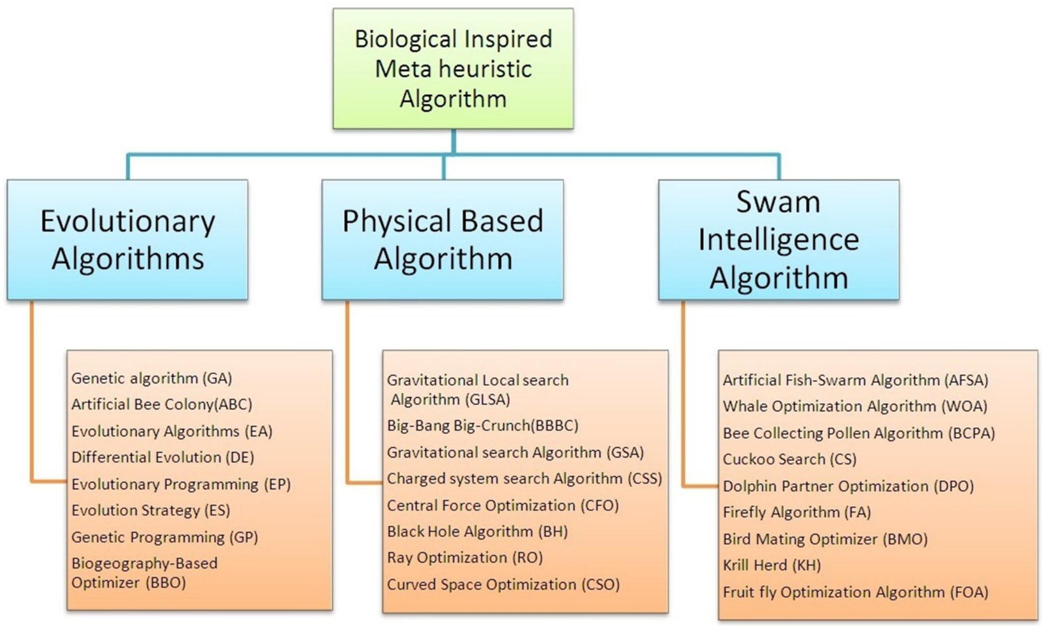

Fig.1 Biology Inspired Optimization Algorithm

III. PROBLEM FORMULATION

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 at finding OPFs from energy sources to load centres for a definite period of time in an economical manner. Such objective function can be formulated as below:

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

where $B_{Gi}(t)$ 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:

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

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

$$n = N_g + N_s + 1 \tag{2}$$

where, n is number of state variables, N_g and N_s are the total number 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:

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

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

$$P_s = \left[P_{s1}, P_{s2}, \ldots P_{s,Ns} \right]$$

$$P_{sj} = \left[P_{sj}(1), P_{sj}(2), \ldots, P_{sj}(t), \ldots, P_{sj}(T) \right]; j = 1, 2 \ldots, N_s \tag{3}$$

Where T represents 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.

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

$$u_k = \left[u_k(1), u_k(2), \ldots, u_k(t), \ldots, u_k(T) \right]; k = 1, 2, \ldots, n \tag{4}$$

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

A. *Constraints*

1) *Power Balance*

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

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

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

2) *Real Power Generation Capacity*

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

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

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

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

Where $P_{G,min}(t)$, $P_{s,min}(t)$ and $P_{grid,min}(t)$ are the minimum active powers of i^{th} DG, j^{th} storage and the utility at the time t. In a similar manner, $P_{G,max}(t)$, $P_{s,max}(t)$ and $P_{grid,max}(t)$ are the maximum power generations of corresponding units at hour t.

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

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

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

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 of time (Δt), η_{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 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.

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IV. EAGLE STRATEGY WITH PSO ALGORITHM

By operating and sizing the micro grid as economically as possible, optimisation techniques are needed. The low voltage Micro grid ES-PSO algorithm minimizes the running costs. Many algorithms have been used to minimize low-voltage grid operating costs. The presented hybrid solution is evaluated on micro grids with low voltage and best performance is compared with other metaheuristic approaches.

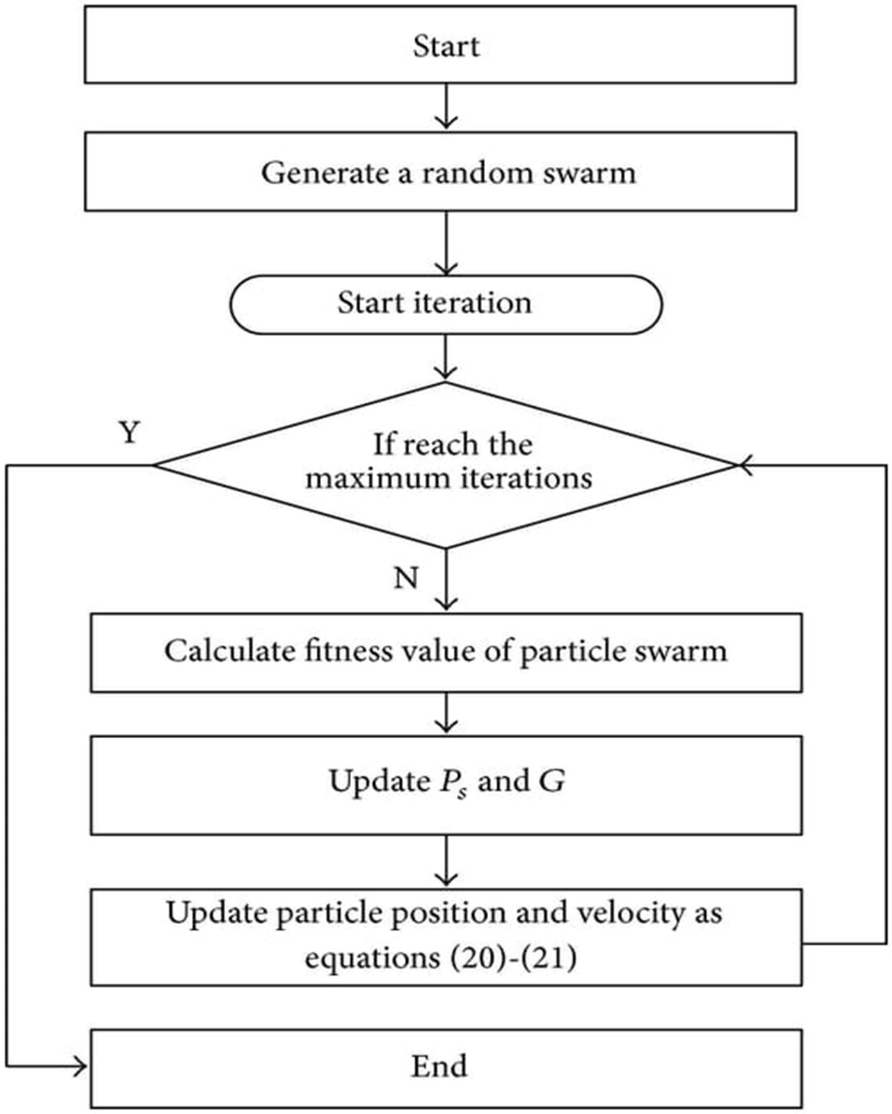

Fig.2 ES-PSO Algorithm flow chart

The high performance and versatility of particle swarm optimization (PSO) is one of the most commonly used methods for cost optimization. It is a basic definition, a fast implementation, stable parameters of monitoring, and computer performance compared to mathematical algorithms and other techniques of heuristic optimization.PSO is a computational method which optimizes a problem by attempting iteratively to improve the applicant solution in terms of a given quality measurement. It solves a problem by a population of candidate solutions known as particles in the search space and by moving certain particles around the position and velocity of the particles in accordance with a basic mathematical formula using flowchart as shown in fig.2. The movement of a particle is influenced by the best known location but is also oriented to the most known search area positions that are modified as other particles find better positions. This will drive the swarm to the best solutions.

V. RESULT AND DISCUSSIONS

In this part of the work the proposed ES PSO algorithm is implemented to solve the multi-operation management problem for a typical MG as shown in Fig.3.

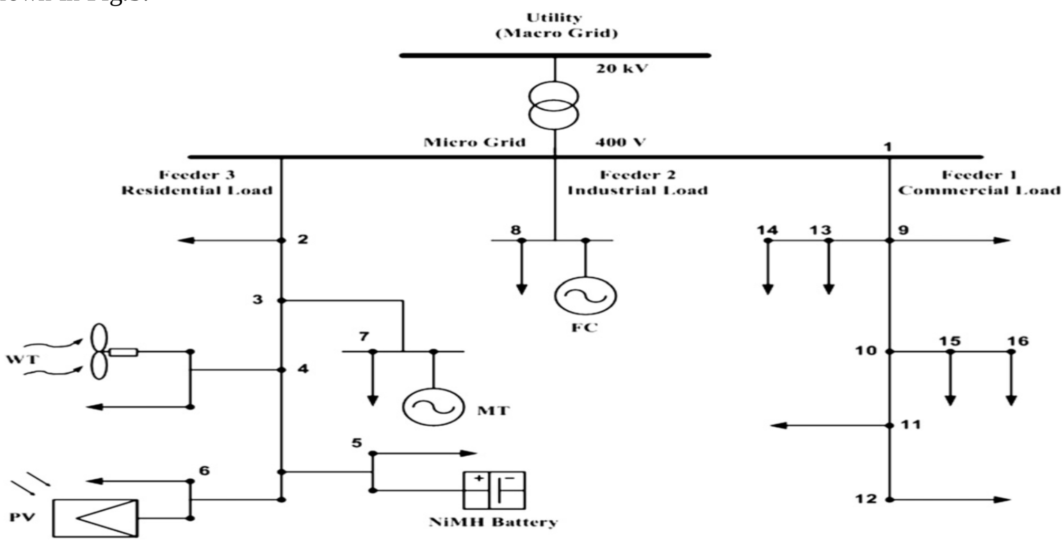

Fig.3 A typical L.V micro-grid

A. Grid Connected Mode

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 159.02$ and 815.90 $ respectively as shown in Table 2.

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
1	6	14	0	0	30	1	1	0	0	1	6.9	6.858
2	14.5	3	0	0	30	1	1	0	0	1	5.7	7.509
3	26.08	30	0	0	-8.58	1	1	0	0	1	-1.081	20.738
4	6	30	21.51	0	-9.01	1	1	1	0	1	-0.973	67.151
5	28.33	30	0	11.11	-15.95	1	1	0	1	1	-1.722	33.695
6	7.19	30	0	0	24.31	1	1	0	0	1	4.86	12.105
7	15.28	3	19.23	0	30	1	1	1	0	1	6.9	57.542
8	29.96	25.3	0	0	17.25	1	1	0	0	1	6.553	21.128
9	30	30	20.93	13.1	-20.52	1	1	1	1	1	-27.703	90.652
10	29.93	29.93	24.91	7.74	-15.02	1	1	1	1	1	-54.065	95.156
11	30	30	20.9	14.92	-20.82	1	1	1	1	1	-74.962	92.55
12	30	30	17.35	14.82	-19.67	1	1	1	1	1	-70.804	83.257
13	27.53	14.94	0	0	27.53	1	1	0	0	1	41.296	16.974
14	30	30	17.04	12.98	-20.03	1	1	1	1	1	-72.099	80.504

15	30	30	18.11	14.89	-19.51	1	1	1	1	1	-35.113	85.318
16	23.39	24.12	0	0	29.98	1	1	0	0	1	58.47	17.783
17	27.92	27.55	0	0	28.03	1	1	0	0	1	16.817	20.859
18	30	30	14.29	0.01	11.69	1	1	1	1	1	4.795	59.479
19	28.63	29.18	0	0	29.18	1	1	0	0	1	10.215	21.664
20	28.77	27.45	0	0	28.77	1	1	0	0	1	12.373	21.221
21	19	28.15	0	0	28.85	1	1	0	0	1	33.759	16.957
22	30	25.33	0	0	14.77	1	1	0	0	1	7.975	21.127
23	20.57	30	0	0	11.43	1	1	0	0	1	3.429	18.22
24	6.61	16.89	0	0	30	1	1	0	0	1	7.8	7.988

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	159.02 $
Cost of DG	554.55 $
Start-up/Shutdown cost	0.9600 $
Maintenance Cost of DG	100.409 $
Operation cost MG	815.90 $

Table 3
Comparison results

Algorithm	Worst solution ($/day)	Average ($/day)	Best solution($/day)
ES-PSO	815.2627	815.1776	815.158
DE	875.2234	858.2814	852.12
BA	1106.986	989.3718	933.814
PSO	1241.745	1081.8351	968.019
GA	1361.243	1196.3251	1041.83

The overall operation cost of MG obtained using ES-PSO is compared with other techniques like DE, BA, PSO and GA as shown in Table 3.It is seen that WOA results is better minimization of operating cost.

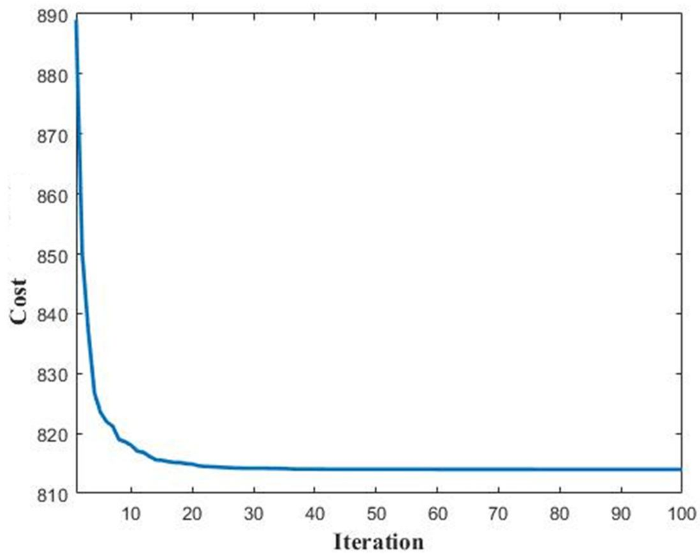

Fig.4 Convergence property of PSO algorithm – Grid Connected Mode

The convergence characteristic of PSO-GA algorithm for grid connected mode is shown in Figure 4. From Figure 4, it is clearly seen that the optimal result is achieved within 38th iterations hence the proposed approach is much faster in obtaining the results.

VI. CONCLUSION

In this Paper, A EG-PSO algorithm is proposed and implemented to solve the multi-operation management problem in a typical MG with RESs. To evaluate the performance of the proposed algorithm several test cases are introduced and the simulation results are gathered subsequently. The numerical results indicate that the proposed method not only demonstrates superior performances but also shows dynamic stability and excellent convergence of the swarms. The proposed method also yields a true and well distributed set of optimal solutions giving the system operators various options to select an appropriate power dispatch plan according to economic considerations.

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