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Optimal Sitting of PV-Wind-Energy Storage System Integrated Micro Grid Using Artificial Bee Colony Optimization Technique

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ABSTRACT*:* The proper placement of Distributed Generation (DG) in distribution system is still very challenging issue for obtaining their maximum potential benefits. This paper proposes an Artificial Bee Colony (ABC) optimization based performance model of Photovoltaic (PV), Wind Turbine Generation Unit (WTGU) and Energy Storage (ES) placement integrated with micro grid. The integration is meant for reducing line loss in radial distribution system. In order to solve the multi-objective problem the ABC is employed. The paper reflects the effectiveness of WTGU and PV array performance models in DG placement problem formulation. Energy storage device is used in this to reduce an Expectation of Energy not Supplied (EENS) to the customer. The IEEE 33-bus system is considered for solving the optimal operation of multiple DG and ES. The presented result clearly shows the effectiveness of the proposed ABC algorithm. Moreover, this implementation presents the idea of incorporating the PV-WTGU-ES in upcoming operation of Indian power system.

KEYWORDS: Distributed Generation; Artificial Bee Colony Optimization Algorithm; Photovoltaic; Wind Turbine Generation Unit; Expectation of Energy not Supplied; IEEE 33-bus system

I. INTRODUCTION

Distributed Generation units are mainly energized by wind, solar and fuel cell. There are a number of DG technologies available in the market today and a few are still at the research and development stage. The overall efficiency of the system is improved using DG units. It is important to determine the optimal sitting of DGs. The devices is strategically placed in power systems for grid reinforcement, reducing power losses, on-peak operating costs, improving voltage profiles, load factors, deferring or eliminating for system upgrades, improving system integrity, reliability, and efficiency. Most Flywheel Energy Storage (FES) systems use electricity to accelerate and decelerate the flywheel, but devices that directly use mechanical energy. Advanced FES system have rotors made of high strength carbon-fibre composites, suspended by magnetic bearing and spinning at speed from 20,000 to over 50,000rpm in vacuum enclosure.Compared to other ways of storing energy, FES systems have long lifetime with little maintenance. High specific energy [100W.h/kg, or 360-500 kJ/kg] and large maximum output. The energy efficiency of FES has high as 90%.Typical capacity range from 3kWh to 133kWh. Rapid charging of system occurs in less than 15 minutes. FES can lose energy storage using mechanical bearing is about 20% to 50% of their energy in two hours. Conversely, flywheels with magnetic bearings and high vacuum can maintain 97% mechanical efficiency and 85% round trip efficiency.Most of the radial distribution system suffers with high power losses because of high resistance to reactance ratios. In case of installation of multiple DGs, the problems of optimal placement and sizing of DGs are normally solved by some previous researchers have performed optimization and economic analysis to determine optimal allocation for DG units.

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The multi-objective planning models of DG are optimized by various methods as Simulated Annealing technique [1], Tabu Search method (TS) [2], Tabu Search method integrated with Genetic Algorithm (GA-TS) [3] and Fuzzy optimization method [4]. Recent studies about DG planning model and various algorithms is listed as follows.

Several other intelligent optimization algorithms such as Genetic Algorithm (GA) [5], Particle Swarm Optimization (PSO) [6,7], Differential Evolution (DE) [8] and Artificial Bee Colony (ABC) [9] are utilized to solve the optimization problem considering minimum costs for network upgrading, operation, maintenance and losses for handling the load growth and maximum DG penetration level. The Bacterial Swarm Optimization (BSO) [10,11] is proposed for scheduling generating system. Even though it solves the problem, steps involved in solving this algorithm are large. Inspired by geographical elements, Biogeography-Based Optimization (BBO) [12, 13] introduced to solve numerous problem in DG formulated micro grid. Sometimes the BBO struck in local optima leads towards worst optimal solution. The Ant Colony Optimization (ACO) [14] is introduced to solve the optimal power flow problem, the Ant's path takes more time to find the optimal path. The Bat Motivated Optimization (BMO) [15] involves the inspiration from social facts leads to poor solution.

Besides, several sensitivity analysis methods of DG allocation are proposed in [16–17]. In case of multiple conflicting objectives, solution not obtained is the best compromise for all objectives.Therefore, a "tradeoff" solution is needed instead of a single solution in multi-objective optimization. Multi-Objective Optimization approach based on genetic algorithm [18] is proposed to maximize savings in system upgrade investment deferral, cost of annual energy losses and cost of interruption.Multi-Criteria Planning model [19] aiming to minimize the cost and maximize the reliability of generating units is proposed. A multi-objective performance index-based size and location determination of DG is presented with different load models in [20] and a new approach using improved Harmony Search (HS) algorithm is presented in [21]. This paper deals with Artificial Bee Colony (ABC) is an optimization algorithm based on intelligent foraging behaviour of honeybee swarm, proposed by Karaboga[22]. This colony consists of three groups of bees: employed bee, onlookers, and scouts.The main advantages of the ABC algorithm are simplicity, flexibility, robustness, use of fewer control parameters compared to many other search techniques and ease of hybridization with other optimization technique. In this paper,the ABC technique is used to achieve the optimal placement and sizing of distributed generation of photovoltaic and wind reduces the expectation of energy not supplied by adding energy storage device and to achieve the minimum loss with maximum output by the distributed generation.

II. PROBLEM FORMULATION

A. *Multi Objective Method for Optimal Placement:*

Now a days DG's are very popular because of less pollution, less costly and source is free. The different types of resources of distributed generation are the wind, solar, bio-mass, bio-gas and tidal. Which are abundantly available in nature.Especially the wind and solar considered because these energies are easily converted into electrical energy. So this formulation of wind and PV are optimally allocated to improve the power quality and to reduce the energy not supplied to the consumer.

$$F(x) = \sum_{i=1}^{k} w_{ti} . f(x)_i \tag{1}$$

Where w_{ti} non negative weight of PV and wind

$$\sum_{i=1}^{k} w_{ti} = 1 \tag{2}$$

Here F(x) indicates the optimal formulation of PV and wind. Where the optimization is minima so low VSF obtained bus is used for placement of DG. Here the weights reasonable to change from 0 to 1 during the whole optimization.

B. *Performance Modeling of Wind and Solar Generation System:*

Power generation of Wind Turbine Generation Unit (WTGU), PV array depends on their model and resource such as wind speed, solar radiation. In this section,modelling of WTGU and PV array is discussed to understand wind and solar-based DG placement technique in better way.

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Performance Model of WTGU:

Depending on the rotational speed, WTGUs is broadly categorized into two types namely fixed speed WTGU and variable speed WTGU. Fixed speed WTGU consists of direct grid coupled induction generator. In variable speed WTGU class, a wind turbine and an induction generator is connected with grid through back to back voltage source converter. Commonly variable speed WTGU is used in which real power output varies wind speed. For a typical WTGU, the output electrical power generation is given by

$$P_w = \begin{cases} 0 & v_w < v_{cin} \quad or \quad v_w > v_{cout} \\ P_{rated} \dfrac{v_w - v_{cin}}{v_N - v_{cin}} & v_{cin} \le v_w \le v_N \\ P_{rated} & v_N \le v_w \le v_{cout} \end{cases} \tag{3}$$

Where v_{cin}, v_{cout}, v_{cout} are cut-in speed, cut-out speed and nominal speed of wind turbine, respectively; v_w is the average wind speed.

P_{rated} is the rated output power of turbine and is represented as

$$P_{rated} = 0.5\rho A v_w^3 C_p \tag{4}$$

Where A is the swept area of rotor; ρ is the density of air; v_w is wind speed and C_p is the power co-efficient.

Performance Model of PV Array:

Solar radiation and ambient temperature are the main governors for sizing of PV module. PV module cannot generate bulk amount of electrical power. So, large numbers of PV modules are connected in series and parallel to design PV array. Series and parallel connection of PV modules boost up voltage and current to tailor PV array output. For a PV array consist of $N_S * N_P$ PV modules, maximum output power is,

$$P_{pv} = N_s N_p P_{md} \tag{5}$$

P_{md} Is the maximum electrical power generated by PV module, which is formulated as

$$P_{md} = FF * V_{oc} * I_{sc} \tag{6}$$

Where V_{oc}, I_{sc} and FF are the open circuit voltage, short circuit current and fill factor of PV module. V_{oc}, I_{sc} and FF are the function of solar irradiance and PV module temperature; and these are obtained as follows

$$V_{oc} = \frac{V_{Noc}}{1 + c_2 * \ln \dfrac{G_N}{G_a}} \left(\frac{T_N}{T_a} \right)^{c_1} \tag{7}$$

$$I_{sc} = I_{Nsc} \left(\frac{G_a}{G_N} \right)^{c_3} \tag{8}$$

$$FF = \left(1 - \frac{R_s}{V_{oc} / I_{sc}} \right) \frac{\dfrac{V_{oc}}{nKT / q} - \ln \left(\dfrac{V_{oc}}{nKT / q} + 0.72 \right)}{1 + \dfrac{V_{oc}}{nKT / q}} \tag{9}$$

Where R_s is the series resistance of module; c_1, c_2, c_3 are the three different constant which are introduced to show non-linear relationship between solar irradiance, photo-current and cell temperature n is density factor (n = 1.5). T is

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the PV module temperature (in Kelvin); K is Boltzmann constant $(1.38*10^{-23} J/K)$ and q is the charge of electron $(1.6*10^{-19} c)$.

C. *Energy Storage Device:*

Since FES is used to absorb or release electrical energy, such device may be sometimes incorrectly. Advanced FES system have rotors made of high strength carbon-fibres composites, suspended by magnetic bearing, spinning at speed from 20,000 to over 50,000rpm in vacuum enclosure. Compared to other ways of storing energy, FES systems have long lifetime with little maintenance.High specific energy $[100W.h/kg]$ or 360-500 $[kJ/kg]$, large maximum output. The energy efficiency of FES has high as 90%. Typical capacity range from 3kWh to 133kWh is choosed. Rapid charging of system occurs in less than 15 minutes. Flywheels with magnetic bearings and high vacuum is maintained by 97% mechanical efficiency and 85% round trip efficiency.

$[J]$ - Kinetic energy of the rotor.

$[kg.m^2]$ - The rotor moment of inertia

$[Kg/m^3]$ - The material density

D. *Expected Energy Not Supplied:*

The second optimal objective is to minimize the EENS. It is defined as one of the reliability indices. EENS includes the value of power outages inside micro grid and the one outside micro grid. The probability of EENS in MG is expressed as follows:

$$P_{IN} = P_{line,in} + P_{ES} * P_{island} \tag{10}$$

Where power line is the line fault probability inside MG power ES is the fault probability of ES device, p-island is the probability of MG to be island. For the EENS outside MG, the load outside MG will lose power when there is line fault between UG and MG, and the DG units outside MG may have fault and stop working.
The probability of power outage outside MG is expressed as follows:

$$P_{OUT} = P_{line,out} + P_{UG} * P_e \tag{11}$$

Where, p_{IN} is the line fault probability outside the MG, P_{OUT} is the probability of ES when distribution power system has outage and ES capacity cannot support the DG units outside MG. UG is the fault probability of the system, in the case that UG cannot provide power to users.Multiple constraint conditions are considered in the optimization model, which includes constraints of power flow equations, design capacity, line thermal limits, nodal voltage, DG capacity, etc.Then the minimal load loss expectation is shown as follows:

$$Min\ f(x) = \{P_{in} * P_{L.MG} + P_{OUT} * (P_{TL} - P_{L,MG})\} \tag{12}$$

Where,

P_{in} , P_{OUT} = Power input and power output

$P_{L.MG}, P_{TL}$ = power load with Micro grid and power with total load.

E. *Minimum Loss*

The third objective is to minimize the system line loss after DG/MG injection into U

$$Min\ f(x) = Min\sum_{i,j}^{n} g_{i,j} - (2v_i + v_i) \tag{13}$$

Where $g_{i,j} - 2v_i + v_j$ is the difference between generation and voltage on iteration.

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III. ARTIFICIAL BEE COLONYOPTIMIZATIONALGORITHM

In the ABC algorithm, the colony of artificial bees contains three groups of bees: employed bees, onlookers and scouts. A bee waiting on the dance area for making decision to choose a food source is called an onlooker and a bee going to the food source visited previously is named an employed bee. The bee carrying out random search is called scout bee. In the ABC algorithm, first half of the colony consists of employed artificial bees and the second half constitutes the onlookers. For every food source, there is only one employed bee. In other words, the number of employed bees is equal to the number of food sources around the hive. The employed bee whose food source is exhausted by the employed and onlooker bees becomes a scout.

F. .*ABC Algorithm Stages:*

i) At the initialization stage, a set of food source positions are randomly selected by the bees and their nectar amounts are determined. Then, these bees come into the hive and share the nectar information of the sources with the bees waiting on the dance area within the hive.
ii) In the second stage, after sharing the information, every employed bee goes to the food source area visited by herself at the previous cycle since that food source exists in her memory, then chooses a new food source by means of visual information in the neighbourhood of the present one.
iii) On the third stage, an onlooker prefers a food source area depending on the nectar information distributed by the employed bees on the dance area. As the nectar amount of a food source increases, the probability with which an onlooker chooses food sourcegets increases. Hence, the dance of employed bees carrying higher nectar recruits the onlookers for the food source areas with higher nectar amount.

G. *ABC Algorithm Steps:*

The Detailed pseudo-code of ABC algorithm is given below. The flow chart of the considered algorithm is presented in Fig.1.

[1] Initialize the population of solutions x_{ij} , $i = 1,2,......SN$.

a) Set randomly distributed initial population P of SN solutions(food source positions)
b) Here number of employed bees= onlooker bees
c) Number of worst bees= scout bees
d) Each solution x_{ij} , $i = 1,2,......SN$ is a D dimensional vector.

[2] Evaluate the population
[3] cycle=1
[4] repeat
[5] Produce new solutions v_{ij} for the employed bees and evaluate them

$$v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{kj})$$

Where $K = 1,2,....SN$, $j = 1,2,....D$, ϕ_{ij} is the random number between [1,-1] and $(x_{ij} - x_{kj})$ is the difference between old solution and new solution.

[6] Apply the greedy selection process.
[7] Calculate the probability indexof Bees

$$p_i = \frac{fit_i}{\sum_{n=1}^{SN} fit_n}$$

[8] Produce the new solutions v_{ij} ,In the onlookers*j* from the solution x_I , This selection depends on p_{ij} and evaluate the corresponding.
[9] Apply the greedy selection process

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[10] Determine the abandoned solution for the scout, if exists, replace it with a new randomly produced solution x_{ij}.

[11] Memorize the best solution achieved so far

[12] Until cycle=MCN(maximum cycle number)

IV. IMPLEMENTATION OF ARTIFICIAL BEE COLONY OPTIMIZATION ALGORITHM TO PV AND WIND PLACEMENT PROBLEM

STEP 1: Initialize the parameters such as n-number of buses, α -angle, x-number of panels.

STEP 2: Determine the power loss with respect to nodal reactive power and determine the candidate buses where the panels to be placed by sensitivity analysis. The buses are numbered in descending order and top two or three buses are selected in each lateral branch.

STEP 3: Randomly generate the variables x and t, the population size is based on the number of selected buses and load levels. The randomly generated values must be within the limits.

STEP 4: Evaluate $eval(v)$using the randomly generated variables.

$$eval(v) = f(x,t) + PN(x,t)$$

STEP 5: Each solution in the initial randomly created population is evaluated and selected by rank. The selected solution is based on the probability value.

$p_i = \frac{fit_i}{\sum_{n=1}^{SN} fit_n}$ Where fit_i is the fitness value of the solution i evaluated by bees (randomly generated values).

STEP 6: If maximum number of iteration is satisfied. If not create a new solution v_{ij} by the following equation.

$v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{kj})$Where $k = 1,2,...SN$ and $J = 1,2,....D$.

ϕ_{ij} - Random number between $[1,-1]$

STEP 7: The newly created population is evaluated; this generational process is repeated until a termination condition has been reached.

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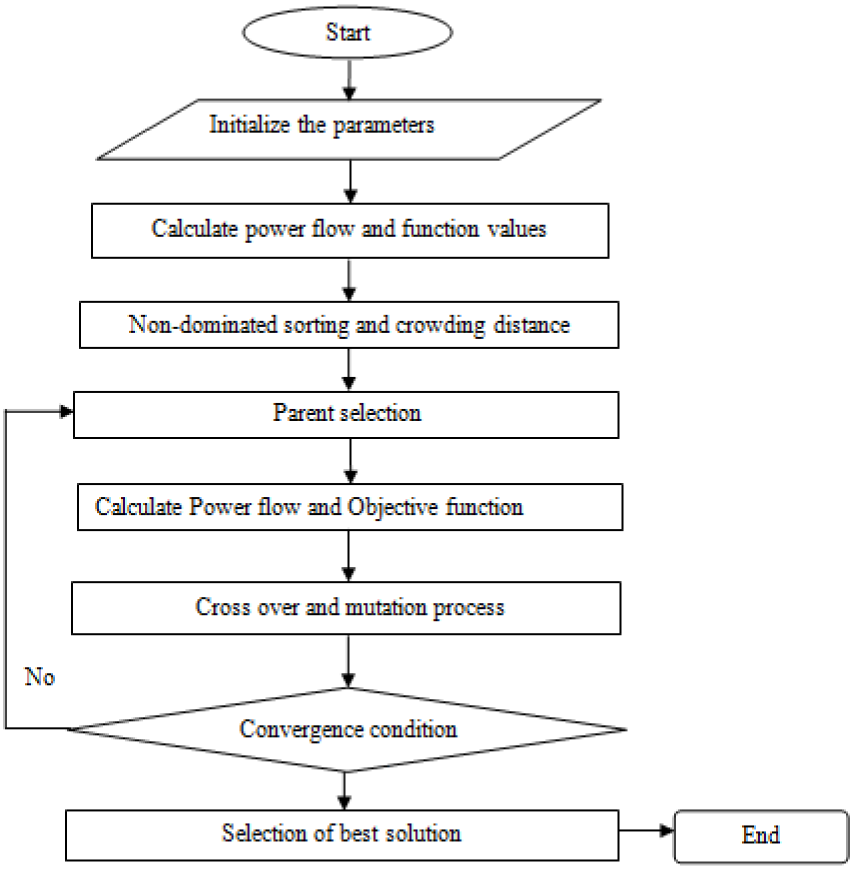

Fig.1.Flow chart of ABC Algorithm

V. RESULT AND DISCUSSIONS

H. *Experiment Setting:*

To demonstrate the effectiveness of the proposed method, the algorithm is implemented to obtain solution for optimal grouping and planning. The algorithm is implemented, evaluated and compared in the following environments: The proposed ABC algorithm isimplemented in MATLAB and run on an Intel i3-4010U 1.70 GHz with 4 GB RAM. In the implementation of ABC algorithm, Population number NP = 250, maximal iteration number $T_{max} = 50$, the mutation factor F=0.8, the crossover factor CR = 0.8, penalty factor w1, w2 and w3 are all set to 6.0, w4, w5 and w8 are set to 1.0×0.001, w6 and w7 are set to 7.0×0.001.

I. *Experiments On IEEE 33-Bus System:*

To demonstrate the proposed method, the algorithm is applied to obtain solution for an optimal grouping allocation on the area from node 5 to node 17. The single line diagram of IEEE 33-bus system is shown in Fig.2. And the load design capacity from node 5 to node 17 is 1.0 MW.

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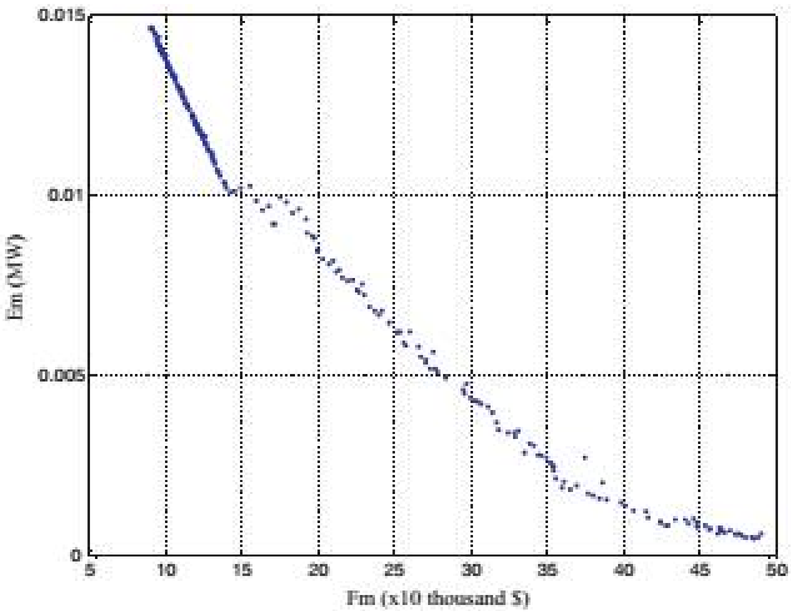

Fig.2. Relation between objective function

The parameters of multi objective optimization are listed in Table 1. The Pareto set form the 3-D curve corresponding to three objectives, which is illustrated in Fig.3. As shown in Fig.3, there is no dominated relation among the candidate solutions in Pareto set.It further shows that the proposed ABC algorithm has powerful searching capacity and convergence performance.

Type	Position	Capacity (MW)
PV	6	0.4182
PV	16	0.1413
WT	9	0.0162
WT	16	0.2306
Load	16	0.3602
Load	6	0.4117
ES	10	0.1986

Table.1. Optimal configuration of DG units, load and ES

The relations among different objective functions are illustrated in Figs 2–3. It shows that the increase of investment cost is efficiently decrease the value of EENS. When there is lower EENS demand, the corresponding investment cost will be improved.EENS and line loss does not have the strictly collaborative or mutual exclusion relation, since the load capacity to be grouped is larger than the total capacity of DG units. By importing energy storage, the difference of power is balanced between DG units and load, which will lead to better load balancing and decrease the current on the lines. Further, the line loss is reduced.Because the ES cost is nearly proportional to the investment cost the line loss will be deceased to a stable value when there are more ES devices are integrated into system. The best compromise solution from Pareto-optimal set got as the optimal configuration scheme in MG planning.

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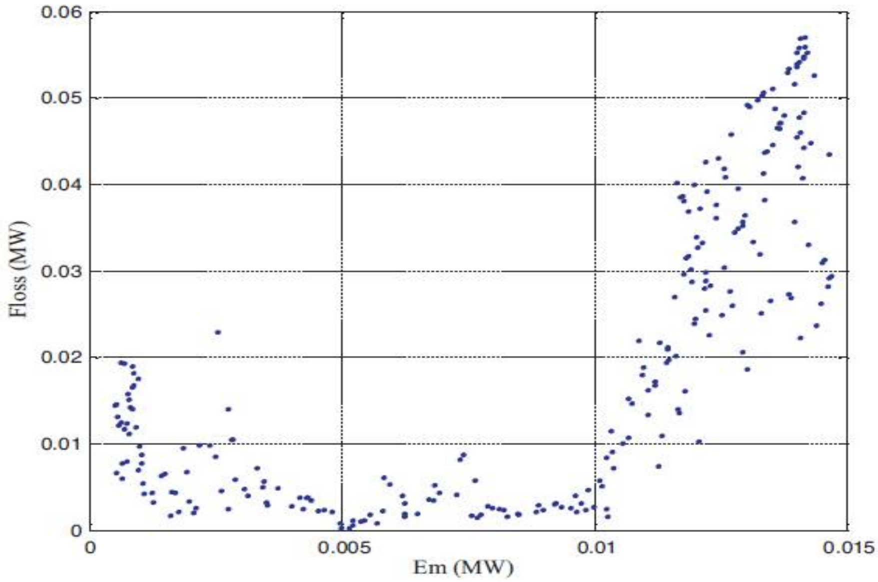

Fig.3. Relation between loss and efficiency

The optimal configuration of DG units, load and ES are shown in Table 1. The optimal MG allocation in the modified IEEE 33-bus test system is show in Fig.4.Because the ES cost is nearly proportional to the investment cost the line loss will be deceased to a stable value when there are more ES devices are integrated into system. The best compromise solution from Pareto-optimal set got as the optimal configuration scheme in MG planning. The optimal configuration of DG units, load and ES are shown in Table 1. The optimal MG allocation in the modified IEEE 33-bus test system is show in Fig.4.

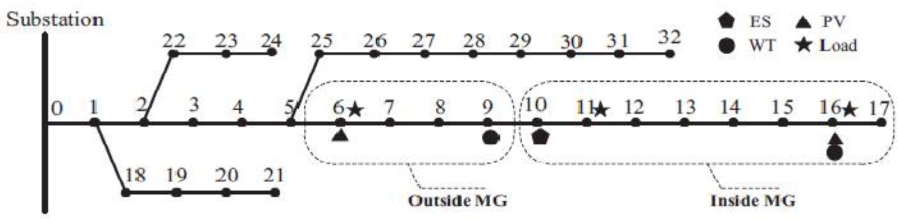

Fig.4. Schematic diagram of modified IEEE-33 bus system

J. *Comparison With Different Load Volume In MG:*

In order to investigate the relation between load level in MG and MG planning result, the load in MG will be set from 0.1, 0.3, 0.5, 0.7 and 0.9 respectively to get the optimal solution. As shown in Table 2, the investment cost will increase and the EENS will decrease with the size of load in MG.

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Load (MW)	Investment ($)	EENS (MW)	∆Em/∆Fm
0.1	17.67	93	NA
03	10.85	74	0.8636
0.5	25.17	61	0.5652
0.7	27.83	50	0.5625
0.9	32.67	38	0.4138

Table.2. Relation between losses and objective function

The increment ratio between the EENS and investment cost is gradually decreasing with the size of load. It means the increasing margin of power delivery reliability deriving from unit investment cost is reducing.

K. *Comparison With Different ES Cost:*

To investigate the ES cost influence on the optimal solution, the ES cost are selected with nearly 10% increase respectively. Through the proposed optimal MG planning method, the optimal result is got and the comparison result is shown in Table 3. As shown in Table 3, the different grouping load and DG units are also listed corresponding to the inside MG and outside MG.

ES Cost ($/MW)	ES Position	ES Capacity (MW)	Load inside MG (MW)	DG inside MG (MW)	Load outside MG (MW)	DG outside MG (MW)
18.33	9	0.2470	0.7882	0.5655	0.2108	0.2345
20	13	0.2309	0.7163	0.4779	0.2837	0.3221
21.67	10	0.1986	0.5796	0.3719	0.4204	0.4281

Table.3. Optimization results with different cost of energy storage

With the ES cost increasing, the planning capacity about load and DG units inside MG is also deceased, which shows the proposed hybrid scheme is sensitive to the ES cost. The comparison result also provides usefulevidence that efficient ES cost.

L. *Result Comparison And Analysis:*

The preference parameters of the three objective functions are set to the same when selecting the best solution using membership function. The optimization result for optimal allocation in hybrid integration scheme is shown in Table 4.As shown in Table 4, the location and capacity of each group DG, ES and Load are listed. ES is located at node 5 with 30 kW capacity.

PV is divided into two groups, one group at node 9 inside MG, the other group at node 5 outside MG. WT is divided into3 groups; the three groups are located at node 4, 10 and 11respectively. The first load group at node 6 is outside MG while the other load group at node 9 is inside MG. The Load at node 9inside MG is 150 kW while 50 kW at node 6 outside MG region.

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Type	Position	Capacity (kW)
PV	9	80
PV	5	30
WT	11	10
WT	4	30
WT	10	10
Load	9	150
Load	6	50
ES	7	50

Table.4.Optimization result of DG-MG-UG hybrid integration scheme

The placement and group sizing of DG, ES and load are illustrated at Fig.5. To investigate the difference between centralized integration scheme and hybrid integration scheme, further comparisons have been carried out. Centralized integration scheme refers to that ES located at the first node of the investigation area;all of the DG and load are involved in the MG area. Table 5 shows the allocation result for centralized integration scheme.

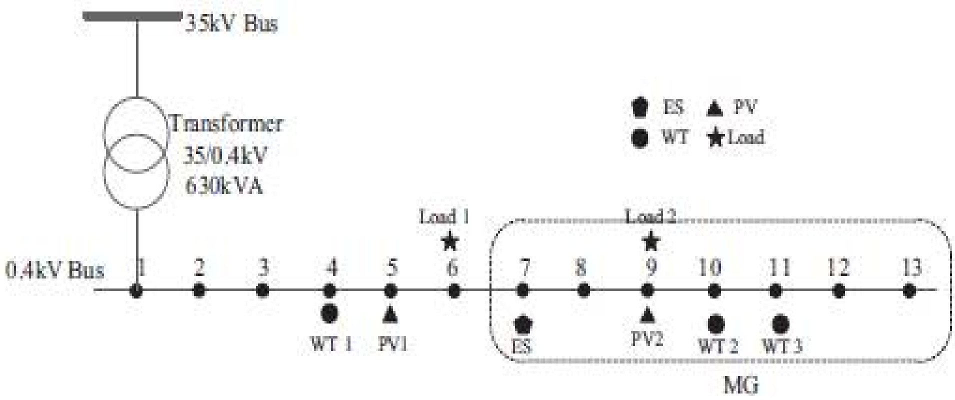

Fig.5. Energy Storage, DG, load allocation and location solution

Table 5 shows the allocation result for centralized integration scheme. The comparison of objective function values for the two integration schemes are shown in Table 5. Comparing with hybrid integration scheme, the EENS value in the centralized integration scheme is decreased by 4.4%, while the investment cost is increased by 17.78%.

Type	Position	Capacity (kW)
PV	8	30
PV	12	60
WT	8	20
WT	10	10
WT	6	40
Load	8	90
Load	7	20
ES	12	90

Table.5. Allocation schemes for MG centralized allocation scheme

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The comparison has been made between the proposed planning scheme and the real implementation scheme for MG planning. The proposed planning scheme involves three objective functions, while only investment cost is considered in the real implementation scheme. The comparison on two different configurations is shown in Table 6.

Type	Hybrid scheme position		Real scheme capacity	
	Position	Capacity (MW)	Position	Capacity (MW)
PV	9	80	5	50
PV	5	30	7	30
WT	11	10	6	30
WT	4	30	10	20
Load	9	150	1	100
Load	9	50	11	100
ES	7	50	8	50

Table.6. Comparison between Hybrid scheme and Real scheme

Substituting the result of the proposed theoretical optimization model with the actual position and capacity of DG, ES, load in the MG engineering implementation, the three objective function values is takenfor comparison. The comprehensive comparisons on three objective function values of investment cost, EENS and line loss are shown in Table 7.

Situation	Investment cost ($)	EENS (kW)	Line loss (kW)
Actual construction	6.83	9.6	14.8
GA [20]	7.5	9.1	0.68
ABC (Proposed)	**8.2**	**8.7**	**0.45**

Table.7.Comparison between Theoretical Calculation and Actual Calculation

Based on the comparison between the proposed planning and actual construction result, it is seen that the proposed theoretical optimization model is consistent with the actual construction project. The proposed DG/MG planning and grouping method provides theory complement to the practical construction project.The Proposed ABC algorithm is capable of reducing the line loss with reasonable DG/MG and ES allocation. Even though the investment cost is improved by using an ABC method, the line loss is reduced by 33.82% and the EENS is reduced by 4.3% when compared with GA. Similarly, When Compared with actual construction, GA is reduced with 52% of line loss, 5.2% of EENS and ABC is reduced with 96.95% of line loss, 9.3% of EENS. This comparison is clear from Table.7.

VI. CONCLUSION

This paper investigates the typical hybrid integration scheme. In order to quantify the integration capacity for DG units and ES, an optimal allocation method for PV-Wind-ES is proposed with the three optimal objectives. The three objectives have been formed with the consideration of minimal investment cost, EENS and line loss. Then the ABC is utilized to solve the multi-objective planning problem. Experiments have been made on the IEEE 33 bus system using the proposed method. Numerical results clearly show that the hybrid integrated scheme with ABC produces optimum results of renewable resources allocation. In addition, it minimizes the investment cost

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and maintains the system reliability. This makes the low cost merit of DG direct power delivery and turns the microgrid more reliable.

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