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Dynamic optimal distributed resource planning for renewable energy based interconnected microgrids using teaching learning algorithm

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Abstract. Distributed Generating (DG) units, Energy Storage Systems (ESS), Distributed Reactive Sources (DRS), and resilient loads make up the microgrid (MG), which can operate in both connected and isolated modes. Because the amount of power generated by Renewable Energy Sources (RES) such as Wind Energy Systems (WES) and Photovoltaic Energy Systems (PVES) is unpredictable, it becomes difficult for MGs planners to make judgments. In this article, the uncertainties caused by RES are resolved through the successful application of a hybrid optimization approach and the integration of hybrid DGs. The Teaching Learning Algorithm (TLA) is used in this study to determine the best site for DGs and reconfiguration, and heuristic fuzzy has been merged with TLA to handle multi-objectives such as total generation and emission cost minimization, and bus voltage deviation. In addition, the impact of replacing RES with hybrid DGs on RES performance is investigated. The ideal structures are determined by solving four different scenarios with the suggested approach, allowing DSO to make decisions with greater flexibility. The proposed technique is validated using a benchmark IEEE 33 bus system that has been converted into a microgrid. WES, PVES, and hybrid DGs are validated using a 24-hour daily load pattern with 24-hour load dispatching characteristic behaviors.

Keywords: Renewable energy sources, radial distribution system, wind energy systems, photovoltaic energy systems, teaching learning algorithm

Nomenclature:

Notations	Description
VD	Bus Voltage Deviation
nb	Total number of load buses present in the system
V_{feeder}	Voltage at the feeder
P_L	Real power Transmission losses
Q_L	Reactive power transmission losses
P_D	Real power Demand
Q_D	Reactive power Demand
TEC	Total Emission Cost
TGC	Total Generation Cost
DE	Diesel Engine
$E_{SB}{}^{t.s}$	Stored Energy
$E_{SB}{}^{min}$	Minimum Stored Energy
E_{SB}^{max}	Maximum Stored Energy
$P_{SB,ch}^{max}$	Charge Rate
$P_{SB,dis}^{max}$	Discharge Rate
η_{ch}	Charge efficiency
η_{dis}	Discharge efficiency
r_m^{up}	Ramp up
r_m^{down}	Ramp down
Δt	Time period

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1. Introduction

The power system is undergoing significant changes in all areas of design, configuration, operation, and control in the context of global energy infrastructures. The demand for installing Distributed Energy Resources (DER) and Energy Storage Systems (ESS) is fast expanding as a result of increased awareness of environmental issues and deregulation of the power industry, with more and more DG units being adopted and deployed near homes. DGs and ESSs placed near loads provide significant benefits, including increased system reliability, improved energy quality, reduced power loss, and lower power generation and emission costs. Nonetheless, the diversification of this paradigm shift necessitates the coordination and collaboration of distribution and control systems, which poses certain challenges in energy system design, operation, and control. Power distribution firms are faced with the difficult task of developing a reliable and cost-effective distribution infrastructure. Various energy management and control methodologies, as well as heuristic optimization methods connected to microgrids, have recently evolved, each providing quality and trustworthy support to ensure microgrids operate optimally. A distribution system [1] suggested at a complete assessment of the intelligent control methodologies that has been applied as well as future development. For successful management of MG with RESs based DGs optimization algorithms such as harmony search algorithm [2], stochastic optimization [3], resilient optimization algorithm for mixed integer programming [4], and cuckoo search algorithm [5] have been established. The hierarchical structures of microgrid control methods were described in [6], and it's managed to the microgrid optimal operation and control. In MG, one purpose of energy distribution is to reduce costs and losses. A hybrid grey wolf and particle swarm optimization approach for minimizing power losses in the distribution system by selecting the best site for DGs [7]. An evaluation of the optimization approach is used for the combined reconfiguration and optimal DG placement successfully conducted [8].

However, the particle swarm optimization (PSO) with a fitness function based on the microgrid, it has been benefit to load response and WES [9]. In addition to that for executing optimal generation scheduling (OGS) and distribution feeder reconfiguration (DFR) using Mixed-Integer Second-Order Cone Programming (MISOCP) recommended on a short-term forecast basis it's evaluated the lowering total microgrid operating costs under various DG and utility system [10]. To address the distribution system optimization problem under dynamic load conditions, an improved hybrid fuzzy-genetic approach was developed in [11]. Using the Interval Optimization approach, [12] presented a Multi-objective Optimal Dispatch Model of Microgrid (MODMG) under power system uncertainty. In [13], a hybrid optimization technique based on fuzzy theory was developed to increase the speed of convergence and better handle operational constraints along with the objective function in order to achieve the goal of lowering the total fuel cost and real power loss of MG. To minimize economic and emission costs, an effective scenario-based stochastic programming approach was presented in [14], which decomposes the problem into deterministic problems. Table 1 shows a detailed analysis of the remaining literature that proposes solutions to the microgrid optimization challenge.

The majority of the studies in Table 1 solved the optimization problem by using optimal DG placement as the objective function. The need of controlling CO2, NO2, and SO2 emissions has been recognized by most developing countries, resulting in the use of renewable energy sources for power generation. Based on different variables such as efficiency, lifetime, payback period, installation and maintenance costs, power generation through WES and PVES is the most recommended among all other RES. However, the power generation of these renewable energy sources is mostly dependent on environmental conditions, resulting in seasonal and time-varying power generation. Furthermore, many studies ignore the ambiguities associated with WES and PVES. As a result, the suggested position for the DGs for optimal functioning displays inadequate power delivery performance for the majority of the hours of the day. The cost co-efficient of hybrid DG is discussed in the papers [31]. The appropriate replacement of standalone RES-based DGs with hybrid DGs can address this key issue [32]. Based on the modeling of the problem, the technique applied for DG placement, and the assumptions made to achieve the answer, the mathematical complexity of the solution process is classified as small, moderate, or big in the literature review. The impact of WES and PVES on the microgrid is investigated using a hybrid Fuzzy and TLA algorithm to solve the optimization issue in the microgrid while taking into account their unpredictability. The system's distinctive data can be found from [33].

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Table 1
Comparison of literature

	PV	WT	Hybrid DGs	DG location identification	Optimi-zation	VD	Demand uncertainty	Mathematical complexity
Gazijahani, Farhad Samadi et.al., [15]	√			√	√	√	√	Middle
Kavousi-Fard et.al., [16]	√	√		√	√	√	√	Simple
Dall'Anese et.al., [17]	√	√		√		√	√	Middle
Nikmehr et.al., [18]	√	√		√	√		√	Middle
Golshannavaz et.al., [19]	√	√		√		√		Middle
M.Hemmati et.al., [20]		√				√	√	Complex
Mosayeb Bornapour et.al., [21]	√	√		√	√	√		Middle
Maulik, Avirup et.al., [22]	√			√		√	√	Complex
Neeraj Kanwar et.al., [23]	√	√		√	√	√	√	Simple
Hamed Nafisi et.al., [24]	√	√			√	√	√	Simple
Gazijahani, Farhad Samadi et.al., [25]	√	√			√	√		Middle
C. Chen et.al., [26]	√	√			√			Middle
Mohammadi et.al., [27]	√	√		√	√			Middle
Jithendranath et.al., [28]	√			√	√	√	√	Middle
Gabbar, Hossam A et.al., [29]	√	√			√	√		Middle
Jian Chen et.al., [30]			√				√	Simple
Ed McKenna et.al., [31]			√				√	Simple
Proposed	√	√	√	√	√	√	√	Simple

1.1. Contributions and organization

For the best placement of renewable energy-based DGs in the microgrid, this paper presents a hybrid Fuzzy-TLA algorithm. The following are some of the paper's contributions:

i. Optimal solution based on overall generating cost, emission cost, and system bus voltage variance.
ii. For simultaneous reconfiguration and DG placement, a single algorithm is used.
iii. Performance analysis of the two most popular RES and their many combinations.
iv. Performance improvement is realized by replacing RES with hybrid DGs.

The best daily dispatch investigation with genuine RES and load uncertainty features. The following are the six sections that make up this document. The considered scenarios of the work are described in section II. Section III introduces the considered objectives as well as the operational constraints. The proposed algorithm's step-by-step method is detailed in Section IV. Section V describes the test system and examines the various case study outcomes. Finally, section VI summarizes the findings of the current study and introduces potential future research fields.

2. Considered scenarios

2.1. Optimal dispatch under wes integration

This scenario is realized by assuming that the microgrid is only augmented by the WES. The WES's generating cost is calculated based on its installed capacity, life expectancy, and installation, operation, and maintenance costs. For WES [34], the generation cost functions are as follows:

$$WE_{\cos t} = c_{WE}^{g} * \left(\frac{C_{WE,IN}}{K_{WE}} \right) + c_{WE}^{g} * C_{WE,OM} \quad (1)$$

Where c_{WE}^{g} an installed capacity of WES, K_{WE} is a designed lifetime of WES, $C_{WE,IN} and C_{WE,OM}$ represents the installation, and operation and maintenance cost of the WES, respectively.

2.2. Optimal dispatch under pves integration

Only PVES-based DGs are replenished together with the grid in this situation. Although the operational costs of PVES plants are low when compared to other renewable energy plants, the installed capacity, life time, and installation, operation, and maintenance costs of each plant are all taken into account when determining the per KW power output cost. The cost of electricity generation per unit fluctuates with plant capacity, which is stated as,

$$PV_{\cos t} = c_{PV}^{g} * \left(\frac{C_{PV,IN}}{K_{PV}} \right) + c_{PV}^{g} * C_{PV,OM} \quad (2)$$

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Where c_{PV}^{g} an installed capacity of PVES, K_{PV} is a designed lifetime of PVES, $C_{PV,IN} and C_{PV,OM}$ represent respectively the installation, and operation and maintenance cost of the PVES.

2.3. Optimal dispatch under combined PVES and WES integration

The combined effect of PVES and WES integration into the microgrid is examined in this scenario. In this situation, it is considered that the indicated optimal placement for the DGs has sufficient environmental support and is located in excellent conditions for their respective power generation. Equations (1) and (2) are used to compute the overall cost of power generation based on the number of PVES and WES connected to the microgrid.

2.4. Optimal dispatch under hybrid PV-diesel and WE-diesel integration

This situation is being considered in order to better understand the advantages of hybrid DGs. It is well known that wind and photovoltaic electricity generation differs depending on environmental factors. Even in the proposed optimal sites, renewable energy-based DGs perform poorly. By replacing stand-alone PVES and WES systems with hybrid systems, the efficiency of such circumstances can be increased. The hybrid DGs are designed to provide a steady power output despite environmental variables. The benefits of both controllable and uncontrollable DGs are combined in the hybrid DG. The Diesel Engine is assumed to be hybrid in this study, with PVES and WES operating separately. The cost function of the Diesel engine [34] is shown in equation (3),

$$DE_{\cos t} = a_{DE} + b_{DE}P_{DE} + c_{DE}P_{DE}^{2} \quad (3)$$

Where a_{DE}, b_{DE} and c_{DE} are the cost coefficients of DE. As this work addresses the total emission cost reduction of the microgrid along with generation cost reduction, the emission cost estimation of the Diesel Engine (DE) and grid are taken care. The emission cost of the plants is expressed in terms of CO_2, NOx and SO_2. The generalized equation for estimating the emission cost of the DE per kW power generation are expressed as,

$$EM_DE = \left(CO_2^{DE} + NO_x^{DE} + SO_2^{DE}\right) \times P_{DE} \quad (4)$$

Similarly, the emission by the grid for per kW power generation is determined using the Equation (5).

$$EM_Grid = \left(CO_2^{grid} + NO_x^{grid} + SO_2^{grid}\right) \times P_{grid} \quad (5)$$

3. Objective functions and constraints

The following subsection discusses the three objective functions and along with the operational constraints [34] considered in this paper.

3.1. Minimization of total generation cost

The optimization has been approached by simultaneously implementing the reconfiguration and optimal DG placement on the microgrid. Therefore, the minimization of Total Generation Cost (TGC) is viewed as a function of per KW generation cost by the Grid, WES, and PVES.

Minimize;

$$TGC = Grid_{cost} + \sum_{i=1}^{nWE} WE_{\cos t,i} + \sum_{j=1}^{nPV} PV_{\cos t,j} \quad (6)$$

Where nWE and nPV represent the total number of WES and PVES integrated in the microgrid, respectively. Also, Grid cost refers the per kW power generation cost by the grid which is expressed in (7),

$$Grid_{cost} = P_{grid} * K_{grid} \quad (7)$$

Where K_{grid} represents the cost co-efficient constant which is assumed as 0.044 $/kW-hr[34].

3.2. Minimization of bus voltage deviation

In order to ensure the operational security and voltage quality to the customer ends, the minimization of bus Voltage Deviation (VD) is considered as an additional objective with the TGC reduction. The minimization of the bus voltage deviation with the set reference voltage for all the load buses of the system is expressed as [35],

$$VD = \sqrt{\frac{\sum_{i=1}^{nb}\left(\left|V_i\right| - \left|V_{feeder}\right|\right)^2}{nb}} \quad (8)$$

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Where V_{feeder} is the voltage at the feeder bus, V_i is the ith bus voltage and the term 'nb' refers to the total number of load buses present in the system.

3.3. Minimization of total emission cost

The Total Emission Cost (TEC) of the system is determined through summing the emission produced by the diesel engine expressed in (4) and emission by the grid. This cost function is considered during the integration of hybrid DGs to the microgrid.

$$\mathrm{TEC} = \mathrm{EM_DE} + \mathrm{EM_Grid} \tag{9}$$

3.4. Operational constraints

The considered operational constraints are as follows:

$$\sum_{i=1}^{NG} \mathrm{PG_i} - \mathrm{P_L} = \mathrm{P_d} \tag{10}$$

$$\sum_{i=1}^{NG} \mathrm{QG_i} - \mathrm{Q_L} = \mathrm{Q_d} \tag{11}$$

$$\max\left(P_i^{min}, P_i^0 - DR_i\right) \leq P_i \leq \min\left(P_i^{max}, P_i^0 + UR_i\right) \tag{12}$$

$$P_i \in \begin{cases} P_i^{min} \leq P_i \leq P_{i,1}^l \\ P_{i,j-1}^u \leq P_i \leq P_{i,j}^l \\ P_{i,n_i}^u \leq P_i \leq P_i^{max} \end{cases}, \; j = 2, 3, ..., n_i, \; i = l, ..., m. \tag{13}$$

$$P_{G_i}^{min} \leq P_{G_i} \leq P_{G_i}^{max} \quad 1 \leq i \leq N_G \tag{14}$$

$$\mathrm{Q_{G_i}^{min}} \leq \mathrm{Q_{G_i}} \leq \mathrm{Q_{G_i}^{max}} \quad 1 \leq \mathrm{i} \leq \mathrm{N_G} \tag{15}$$

$$\mathrm{Q_{C_i}^{min}} \leq \mathrm{Q_{C_i}} \leq \mathrm{Q_{C_i}^{max}} \quad 1 \leq \mathrm{i} \leq \mathrm{N_C} \tag{16}$$

$$|\mathrm{S_k}| \leq \mathrm{S_k^{max}} \quad 1 \leq \mathrm{k} \leq \mathrm{N_E} \tag{17}$$

$$0.95 \leq Vi \leq 1.05, i = 1, 2, ..., nbus \tag{18}$$

$$0.8 \leq PF \leq 1 \tag{19}$$

$$P_{\mathrm{gen},i,s} \leq P_{\mathrm{gen},i,max}, \quad \forall i \in N_{\mathrm{droop}} \tag{20}$$

$$Q_{\mathrm{gen},i,s} \leq Q_{\mathrm{gen},i,max}, \quad \forall i \in N_{\mathrm{droop}} \tag{21}$$

$$0 \leq P_{\mathrm{gen},i,max} - P_{\mathrm{gen},i,s} \perp \frac{1}{m_{p,i}}\left(\omega_i^* - \omega_s\right) - P_{\mathrm{gen},i,s} \geq 0, \forall i \in N_{\mathrm{droop}} \tag{22}$$

$$0 \leq Q_{\mathrm{gen},i,max} - Q_{\mathrm{gen},i,s} \perp \frac{1}{n_{p,i}}\left(|V_k|^* - |V_{k,s}|\right) \quad Q_{\mathrm{gen},i,s} \geq 0, \forall i \in N_{\mathrm{droop}} \tag{23}$$

$$\sqrt{\left(\mathrm{P_{gen,i,s}}\right)^2 + \left(\mathrm{Q_{gen,i,s}}\right)^2} \leq \mathrm{S_{gen,i,max}}, \quad \forall \mathrm{i} \in \mathrm{N_{droop}} \tag{24}$$

$$\begin{cases} \mathrm{P_m^{t,s}} - \mathrm{P_m^{t-1,s}} \leq \mathrm{r_m^{up}}\Delta t \\ \mathrm{P_m^{t-1,s}} - \mathrm{P_m^{t,s}} \leq \mathrm{r_m^{down}}\Delta t \end{cases} \tag{25}$$

$$\mathrm{E_{SB}^{t,s}} = \begin{cases} \mathrm{E_{SB}^{t-1,s}} - \mathrm{P_{SB}^{t,s}}\Delta t\eta_{\mathrm{ch}} & \mathrm{P_{SB}^{t,s}} < 0 \\ E_{\mathrm{SB}}^{t-1,s} - P_{\mathrm{SB}}^{t,s}\Delta t/\eta_{\mathrm{dis}} P_{\mathrm{SB}}^{t,s} \geq 0 \end{cases} \tag{26}$$

$$P_{\mathrm{SB,ch}}^{max} \leq P_{\mathrm{SB}}^{t,s} \leq P_{\mathrm{SB,dis}}^{max} \tag{27}$$

$$E_{\mathrm{SB}}^{min} \leq E_{\mathrm{SB}}^{t,s} \leq E_{\mathrm{SB}}^{max} \tag{28}$$

Equations (10) and (11), respectively, indicate the microgrid's actual and reactive power balances. (12) and (13) show the generating capacity of distributed generating units (13). Equations are used to express the capacity limits of electrical power equipment (14–17). In (18) and (19), the DGs' minimum and maximum bus voltage limits, as well as their power factor limits, are defined. The DG units' actual and reactive power handling capacity are expressed in (20) and (21, respectively. A set of constraints (22) and (23), respectively, are used to solve the DG units' actual and reactive power handling capacities. The apparent power handling limits obtained from the real and reactive power handling limits is shown in (24). The expression for the ramp up and down rate constraint is shown in (25), where $\mathrm{r_m^{up}}$ and $\mathrm{r_m^{down}}$ represent ramp up and down limits, respectively; Δt is the time period. The constraints related to storage battery are expressed in equations (26–28), where $E_{\mathrm{SB}}^{t,s}$, E_{SB}^{min} and E_{SB}^{max} are the stored, minimum and maximum energy in SB, respectively. $P_{\mathrm{SB,ch}}^{max}$, and $P_{\mathrm{SB,dis}}^{max}$ are the charge and discharge rate of the SB; η_{ch} and η_{dis} are the charge and discharge efficiency.

Equations (6), (8), and (9) express three objective functions in this optimization problem (9). The recommended method shall deliver the most compromised solution among the assessed goal functions

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under certain system operating conditions. To merge the objective functions into a single objective function, a fuzzy decision set method is introduced. The membership functions are introduced in this regard for each objective function. The membership functions produced fuzzifier values for the specified configuration, which are utilized in the fuzzy decision set to make decisions. For each fitness function, fuzzy membership functions with maximum and minimum limitations are used. The developed fuzzy functions can be modified according to the contribution of the fitness functions according to the problem needs. The membership functions are defined as follows,

$$\mu_{TGC} = \begin{cases} 1 & TGC \le TGC_{\min} \\ \frac{TGC_{\max} - \mathrm{TGC}}{TGC_{\max} - TGC_{\min}} & TGC_{\min} < TGC < TGC_{\max} \\ 0 & TGC \ge TGC_{\max} \end{cases} \tag{29}$$

$$\mu_{TEC} = \begin{cases} 1 & TEC \le TEC_{\min} \\ \frac{TEC_{\max} - \mathrm{TEC}}{TEC_{\max} - TEC_{\min}} & TEC_{\min} < TEC < TEC_{\max} \\ 0 & TEC \ge TEC_{\max} \end{cases} \tag{30}$$

$$\mu_{VD} = \begin{cases} 1.0 & for\ VD_x \le VD_{max} \\ \frac{VD_{max} - VD_x}{VD_{max} - VD_{min}} & for\ VD_{min} < VD_x < VD_{max} \\ 0.0 & for\ VD_x \ge VD_{max} \end{cases} \tag{31}$$

During the arrival of each new configuration, the values of TGC, TEC, and VD are calculated, which are defined as the ratio between the prior best solution and the current solution in the preceding equations. From the membership values found in each feasible solution, the decision fuzzy set (32) is used to discover the compromised solution.

$$\mu \mathrm{D} = \min\left(\mu_{\mathrm{TGC}}, \mu_{\mathrm{TEC}}, \mu_{\mathrm{VD}}\right) \tag{32}$$

4. Teaching learning algorithm for optimal searching

For optimal searching, the Teaching Learning Algorithm (TLA) [36] is used, which is one of the nature-inspired, well-proven, population-based optimization algorithms. It searches for the best answer using a population of solutions, avoiding the need for algorithm-specific parameters for convergence. When compared to other population-based algorithms like GA, ABC, PSO, HS, DE, and others, this trait is regarded a major strength for the TLA. Importantly, this method ensures a worldwide optimal solution for problems of various scales and characteristics. It is based on the data collected throughout the teacher and learner phases of each iteration. In every iteration, the best learner becomes the teacher as teacher is the most experienced, knowledgeable and highly learned person in the community. In this problem, in every iteration, the teacher is the optimal location of DGs and tie-switches based on the objectives. The learners learns the course according to the quality of the teacher and the quality of the learners present in the class for each course. The learners get the course input from the teachers and the interaction between the co-learners of the class. In this problem, every learner has a set of DG locations and tie-switches. The suggested algorithm's step-by-step approach is depicted in Fig. 1 as a flowchart. The following is the pseudocode and technique for the proposed calculation:

Step 1: Initialization the values

Set Max Iteration (MIT), Courses Offered (C = Number of DGs+Number of MGs), Total learners (L), gen_count = 0

Initial set of Learners

f(L,C)=random()

Step 2: Find the mean for all the courses offered

Find Mean (C)=f(L,C)

Step 3: Find the fitness for initial population

Find Obj(f(L))

Step 4: proceed the following iteration till (gent_count < MIT)

Find the teacher from the best individual of the generation

$V_{teacher}$ = Min(f(L))

F_{best} = f($V_{teacher}$)

Step 5: Find the teaching factor

TF=(1 + random()*(2-1))

Step 6: Production of improved learners and teachers

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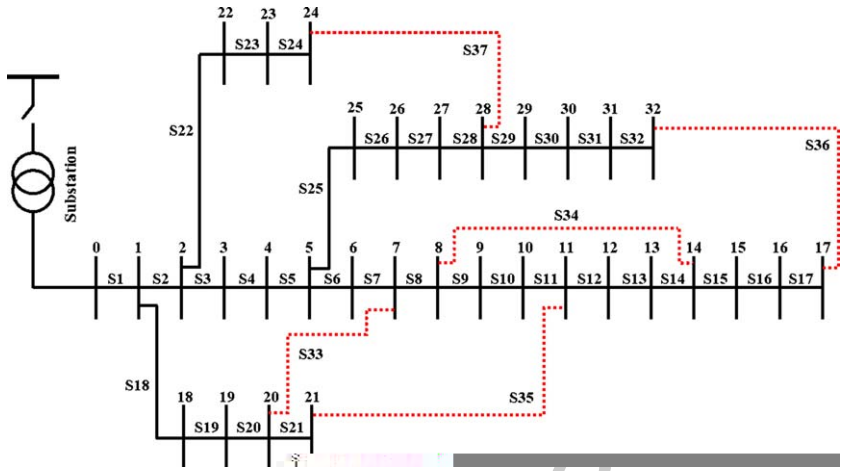


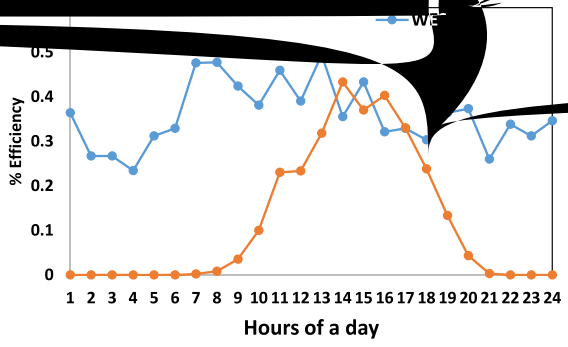
Fig. 2. Single-line diagram of IEEE 33 bus RDS.

5. Simulation and results

5.1. Test system data

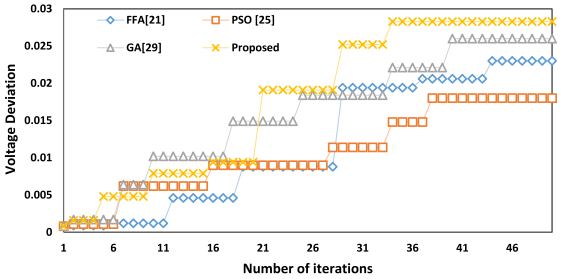
For the simulation investigation, a conventional IEEE 33-bus Radial Distribution System (RDS) is used. As indicated in Fig. 2, the system is served by 32 load buses with five tie-lines. The system's electrical specifications are as follows: 12.66 base KV, 100

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WE
0.5
0.4
0.3
0.2
0.1
0
% Efficiency
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours of a day

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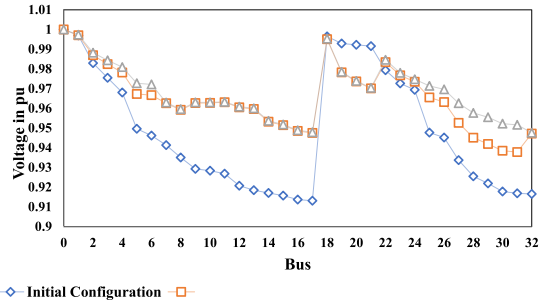


Fig. 9. Convergence of the Different Algorithms for VD.

5.2.2. *PVES integrated with microgrid*

Only PVES are present in the microgrid in this test instance. Only five PVES, each with a 100 kW installed capacity, are available for power generation, as in the prior test case. The suggested hybrid algorithm is optimized using the same boundary conditions as before. The lifetime, installation cost, and maintenance cost parameters for the WES cost function are assumed to be 20 years, 7000 dollars per kW, and 712.92 dollars per kW-year, respectively. After the proposed technique was successfully implemented, the optimal solution was found in the 33rd iteration. In the presence of PVES, results are achieved for the microgrid. Table 3 shows the power loss reduction, ideal configuration, optimal PVES placements, and the configuration's minimal voltage [37, 38].

The bus voltages and branch currents achieved in the optimal design are compared to the other system configurations depicted in Figs. 10 & 11. In comparison to the other two configurations, the bus voltages are better, and the branch current loading is lowered, according to the figures. Cons was in charge of the optimization procedure.

The acquired findings under varied load situations are summarized in Table 4. Table 4 shows that the optimal PVES sites are 16, 17, 18, 31, and 32 in the majority of the found solutions, with the NO's for the optimal structure being S7, S9, S14, S32, and S37.

5.2.3. *Combined WES and PVES Integration with microgrid*

The various combinations of WES and PVES are studied in this test scenario by constraining a total

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Table 4
Summary of results with PVES under daily load pattern

Hrs.	% Efficiency of PVES	Total Load in MW	Configuration	Optimal PVES location	P_{PVES} in MW	P_{Grid} in MW	TGC in $/hr	Loss in kW	Min. Voltage in p.u	Bus
1	0.000	3.5293	7,9,14,28,36	29,27,32,32,17	0.0000	3.6304	227.3270	101.1755	0.9523	32
2	0.000	3.3435	7,9,14,28,36	32,32,32,16,11	0.0000	3.4319	218.5910	88.3783	0.9549	17
3	0.000	2.9720	9,14,28,33,36	18,17,31,26,16	0.0000	3.0404	201.3638	68.3517	0.9613	17
4	0.000	2.7863	9,14,28,33,36	29,32,30,12,32	0.0000	2.8453	192.7812	59.0420	0.9618	17
5	0.000	2.6005	9,14,17,28,33	24,13,10,29,8	0.0000	2.6508	184.2233	50.2951	0.9672	17
6	0.000	3.6407	7,9,14,32,37	32,32,10,32,32	0.0000	3.7465	232.4324	105.7571	0.9474	32
7	0.002	3.5293	7,9,14,28,36	32,32,32,32,32	0.0010	3.6293	227.2796	101.0982	0.9524	32
8	0.008	3.4550	7,9,14,28,36	32,32,32,32,32	0.0040	3.5471	223.6625	96.1910	0.9541	32
9	0.035	3.7150	7,9,14,32,37	31,31,31,31,32	0.0175	3.8062	235.0599	108.6726	0.9476	32
10	0.100	4.0865	7,9,14,28,36	17,17,16,17,32	0.0500	4.1714	251.1311	134.9264	0.9421	17
11	0.230	3.1578	9,14,28,33,36	17,32,17,16,32	0.1150	3.1114	204.4917	68.6907	0.9626	17
12	0.233	3.3435	7,9,14,28,32	32,32,17,17,32	0.1165	3.3076	213.1236	80.6191	0.9567	32
13	0.318	2.9720	9,14,28,33,36	31,17,32,17,32	0.1590	2.8724	193.9739	59.3993	0.9654	17
14	0.433	3.5293	7,9,14,32,37	31,31,32,17,31	0.2165	3.3983	217.1146	85.5739	0.9535	32
15	0.370	3.6407	7,9,14,32,37	31,32,31,32,31	0.1850	3.5476	223.6836	91.9197	0.9528	32
16	0.403	2.9720	9,14,28,33,36	32,17,32,31,17	0.2015	2.8277	192.0086	57.2335	0.966	17
17	0.330	3.3435	7,9,14,28,32	32,32,31,17,17	0.1650	3.2561	210.8573	77.6123	0.9578	32
18	0.238	2.7863	9,14,28,33,36	16,32,17,17,16	0.1190	2.7199	187.2650	52.6733	0.9672	17
19	0.133	4.4580	7,9,14,28,36	32,32,17,17,32	0.0665	4.5404	267.3662	148.9057	0.9431	17
20	0.043	4.0865	7,9,14,28,36	16,32,17,17,17	0.0215	4.2024	252.4961	137.4499	0.9405	17
21	0.003	3.7150	7,9,14,32,37	31,31,31,31,31	0.0015	3.8235	235.8211	109.9725	0.9474	32
22	0.000	3.3435	7,9,14,28,36	32,11,32,24,14	0.0000	3.4319	218.5910	88.3783	0.9549	17
23	0.000	2.6005	9,14,17,28,33	31,11,32,32,12	0.0000	2.6508	184.2233	50.2951	0.9672	17
24	0.000	2.6005	9,14,17,28,33	29,23,31,32,13	0.0000	2.6508	184.2233	50.2951	0.9672	17

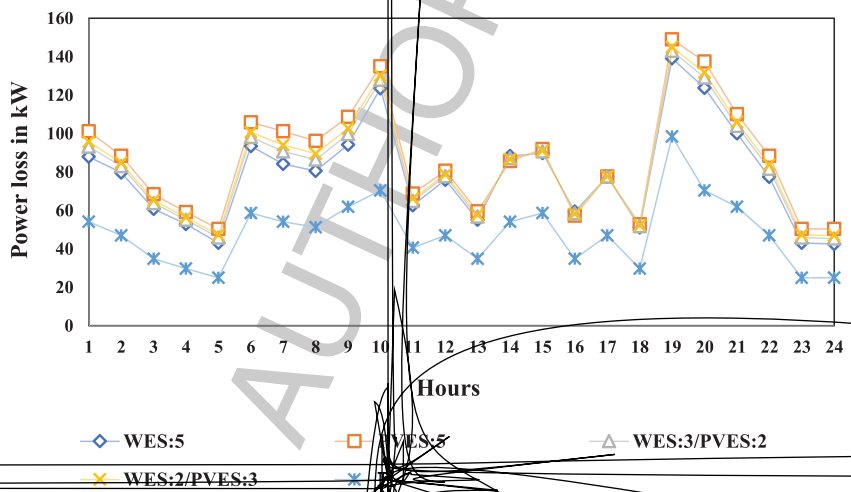
Table 5
Summary of results under combined WES and PVES integration

Hrs.	(WES:4, PVES:1)			(WES:3, PVES:2)			(WES:2, PVES:3)			(WES:1, PVES:4)		
	Loss (kW)	TGC ($/hr)	Min. Voltage in p.u	Loss (kW)	TGC ($/hr)	Min. Voltage in p.u	Loss (kW)	TGC ($/hr)	Min. Voltage in p.u	Loss (kW)	TGC ($/hr)	Min. Voltage in p.u
1	90.4450	195.5043	0.9526	93.0794	203.4579	0.9500	95.7262	211.4120	0.9526	98.3647	219.3657	0.9500
2	81.2321	188.6332	0.9560	82.9850	196.1211	0.9567	84.7318	203.6088	0.9567	86.5383	211.0992	0.9567
3	62.1899	171.4493	0.9645	63.6802	178.9257	0.9631	65.1886	186.4029	0.9629	66.7549	193.8827	0.9625
4	53.9276	163.4936	0.9660	55.1014	170.8109	0.9659	56.3435	178.1312	0.9645	57.6568	185.4546	0.9632
5	44.4257	153.5297	0.9708	45.8211	161.1999	0.9699	47.2326	168.8709	0.9697	48.7218	176.5452	0.9685
6	95.7087	201.2557	0.9522	98.1131	209.0452	0.9498	100.5823	216.8375	0.9498	103.1584	224.6345	0.9498
7	87.3356	193.3875	0.9541	90.6370	201.8544	0.9509	94.0366	210.3257	0.9508	97.4709	218.7984	0.9508
8	83.3870	189.9006	0.9577	86.4000	198.3328	0.9542	89.5586	206.7714	0.9541	92.7972	215.2136	0.9546
9	96.8975	202.7513	0.9507	99.6706	210.8209	0.9510	102.5826	218.8967	0.9504	105.5833	226.9764	0.9484
10	125.6109	220.8314	0.9482	127.8717	228.4034	0.9482	130.1807	235.9774	0.9446	132.5208	243.5528	0.9440
11	63.7022	175.2977	0.9644	64.8959	182.5938	0.9643	66.1525	189.8928	0.9629	67.3974	197.1912	0.9629
12	76.7658	185.2467	0.9584	77.6960	192.2144	0.9573	78.6631	199.1838	0.9573	79.6365	206.1535	0.9562
13	55.8670	165.7767	0.9674	56.7357	172.8254	0.9665	57.6054	179.8741	0.9665	58.4973	186.9238	0.9661
14	87.6753	193.6357	0.9531	87.1453	199.5052	0.9530	86.6156	205.3747	0.9535	86.1035	211.2450	0.9530
15	90.2002	197.5550	0.9535	90.6263	204.0870	0.9531	91.0551	210.6191	0.9531	91.4870	217.1513	0.9528
16	58.8968	168.5808	0.9659	58.4769	174.4376	0.9659	58.0586	180.2944	0.9660	57.6455	186.1515	0.9664
17	77.6488	185.9323	0.9576	77.6304	192.1631	0.9578	77.6244	198.3945	0.9578	77.6183	204.6259	0.9578
18	51.4278	161.1220	0.9672	51.7440	167.6579	0.9670	52.0539	174.1936	0.9680	52.3654	180.7294	0.9676
19	141.0064	238.0089	0.9448	142.9366	245.3462	0.9447	144.8914	252.6847	0.9438	146.8809	260.0246	0.9431
20	126.3178	221.2541	0.9482	129.0053	229.0604	0.9481	131.7361	236.8686	0.9445	134.5194	244.6791	0.9428
21	101.9069	205.9989	0.9493	103.8470	213.4511	0.9493	105.8517	220.9061	0.9492	107.8988	228.3630	0.9475
22	79.4729	187.3062	0.9557	81.5796	195.1221	0.9557	83.7909	202.9426	0.9572	86.0674	210.7661	0.9571
23	44.4257	153.5297	0.9708	45.8197	161.1999	0.9698	47.2326	168.8709	0.9697	48.7218	176.5452	0.9685
24	43.8336	152.9052	0.9713	45.3610	160.7309	0.9701	46.9191	168.5579	0.9700	48.5554	176.3883	0.9686

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Table 6
Summary of results under hybrid WES and PVES integration

Hrs.	(WES:3, PVES:2)				(WES:2, PVES:3)			
	Loss (kW)	TGC ($/hr)	TEC (lb./hr)	Min. VD	Loss (kW)	TGC ($/hr)	TEC (lb./hr)	Min. VD
1	54.06	194.22	5403.56	0.00355	54.06	198.51	5458.15	0.00355
2	46.96	185.74	5067.30	0.00324	46.96	194.05	5118.49	0.00324
3	34.80	168.87	4313.45	0.00272	34.80	177.17	4357.02	0.00272
4	29.64	160.48	3947.09	0.00235	29.64	168.78	3986.96	0.00235
5	24.95	152.10	3545.19	0.00241	24.95	160.40	3581.00	0.00241
6	58.64	199.32	5650.53	0.00375	58.64	207.63	5707.61	0.00375
7	54.06	194.22	5375.39	0.00355	54.06	202.53	5429.69	0.00355
8	51.14	190.83	5218.54	0.00346	51.14	199.13	5271.25	0.00346
9	61.83	202.73	5737.27	0.00390	61.83	211.03	5795.22	0.00390
10	70.35	219.44	6442.45	0.00432	70.35	227.75	6507.53	0.00432
11	40.60	177.30	4407.98	0.00288	40.60	185.60	4452.50	0.00288
12	46.96	185.74	4804.12	0.00324	46.96	194.05	4852.64	0.00324
13	34.80	168.87	3935.32	0.00272	34.80	177.17	3975.07	0.00272
14	54.06	194.22	5000.14	0.00355	54.06	202.53	5050.65	0.00355
15	58.64	199.32	5261.84	0.00375	58.64	207.63	5314.99	0.00375
16	34.80	168.87	3909.07	0.00272	34.80	177.17	3948.55	0.00272
17	46.96	185.74	4730.48	0.00324	46.96	194.05	4778.26	0.00324
18	29.64	160.48	3696.39	0.00235	29.64	168.78	3733.73	0.00235
19	98.38	237.00	7170.05	0.00536	98.38	245.30	7242.47	0.00536
20	70.35	219.44	6499.76	0.00432	70.35	227.75	6565.42	0.00432
21	61.83	202.73	5820.51	0.00390	61.83	211.03	5879.31	0.00390
22	46.96	185.74	5044.57	0.00324	46.96	194.05	5095.52	0.00324
23	24.95	152.10	3545.19	0.00241	24.95	160.40	3581.00	0.00241
24	24.95	152.10	3534.30	0.00241	24.95	160.40	3570.00	0.00241



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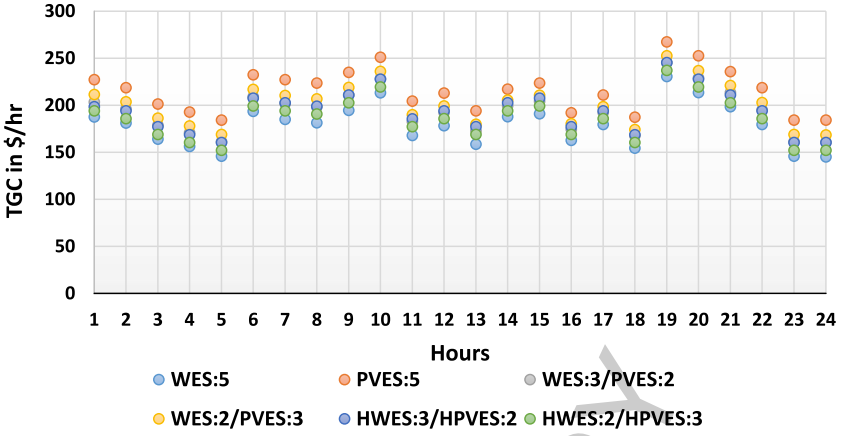


Fig. 13. Comparison of generation cost between case 4 and case 5.

evidenced by the results of the previous cases. PVES generates no electricity for roughly 12 hours a day and has a 25 percent efficiency for the remaining 8 hours of the day. PVES, on the other hand, would be far more efficient than WES during the summer months. In terms of WES, the installation necessitates a minimum appropriate wind velocity at the locations at all times of the day.

Overall, the RES' delivery performance is subpar, despite the fact that they are installed in the best possible sites. When it comes to global warming and the depletion of traditional energy sources, however, renewable energy sources are the best option. As a result of these factors, the best way to improve performance while maintaining the benefits of RES has been determined. Many research projects involving hybrid DGs have recently been completed. The hybrid DG is made up of controllable DGs and renewable energy sources, and it ensures a consistent power supply at the Point of Common Coupling (PCC). When RES power generation is insufficient to meet demand, controlled DGs are used to provide the necessary supply. The performance of the RES can be improved in this way with the help of controllable DGs. The choice of the appropriate controlled DG is determined by the RES's installed capacity. To test the performance improvement, the RES is replaced by hybrid DGs in this scenario. With the replacement, the hybrid DG ensures 100 kW of power generation throughout the day, regardless of the RES' power supply performance. The studied two possible combinations of the preceding example are investigated with hybrid DGs for a better comparison of the solutions. The proposed method makes use of the identical boundary conditions as the previous example. The fitness function (32) is created using the equations (3–9) and all of the operational restrictions stated in equations (10–28) are included in the solution process along with the objectives.

The implementation is done for a 24-hour variable load pattern, and the results are shown in Table 6, which shows the power loss, total generating cost, total emission cost, and minimum bus voltage deviation of the best configuration. Under variable load situations, the compromised solution among the examined objectives is ensured. The collected results of all of the situations are compared in order to verify the performance boost of hybrid DGs. The incorporation of hybrid DGs into the grid, most critically, increases the penetration of DGs. The microgrid's performance is improved due to the increased penetration of DGs. Figure 12 depicts the power loss of the final configuration achieved by the various examples over the course of a day.

The replacement of RES by hybrid DGs provides the best option with the least amount of power loss at all times of the day. Furthermore, even at the best setups, all of the remaining situations are useless due to the RES's low delivery performance. In Fig. 13, the overall producing cost of the scenarios is compared. When hybrid DGs are linked with an interconnected microgrid, the total generating cost is significantly reduced. In particular, the hybrid WES has a lower generating cost than the hybrid PVES, which can be reversed for plants with higher capacity. Additionally, because hybrid DGs emit dangerous gases, which is unavoidable when addressing global warming issues, this work analyzes the optimization of the total emission cost of the microgrids. The relative performance benefits of WES and PVES are assessed using the

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predicted daily load curve for the next day and the forecasted daily power generation curve of WES and PVES. The annual anticipated power generation of WES and PVES, which varies seasonally, can be used to analyze this study.

6. Conclusion and future work

In this research aspect to integrate hybrid DGs performance level and reconfiguration microgrid has been improved. The detailed analysis was carried out with the three key objective functions of total generation cost minimize, total emission cost minimize, and voltage deviation minimize in this manuscript. The fuzzy is integrated with TLA to deal with multi-objective issues. It is used to optimize and reconfigurable location of DGs. At present the investigation on IEEE 33 buses configured in four categories such as microgrid incorporate with WES, microgrid incorporate with PVES, microgrid incorporate with WES / PVES, and microgrid incorporate with hybrid DGs.

In addition to that, a 24-hour load dispatch energy system is under operating, an hour-to-hour shifting daily pattern was investigated. The simulation results show that the proposed method achieves the best outcome, and the optimized structure is clearly enhanced to the present structure. In additionally taken as various combinations of DGs in order to determine the optimum solutions. Most crucially, the value of hybrid DGs over stand-alone DGs was realized. This work can be improved by taking into account the microgrid's non-linear and unbalanced load situations. Also, a hybrid DG framework used to block-chain technology can be elevated through maximizing customer benefits. The impact of other controllable DGs, as well as renewable energy sources can also be investigated. DGs are used to examine the solution to the microgrid under abnormal situations.

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