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An Approach for Optimal STATCOM Sizing and Location in Micro-Grid Based on *L*_∞ and Firefly Algorithm

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Abstract

The rise in renewable energy resource (RES) consumption has prompted academics to maximize RES performance. Many studies address the optimal placement of photovoltaic (PV) units and DSTATCOM units, as well as reconfiguration hurdles, by specifying the number of PV units used in the simulation. Optimization alone cannot improve power system operational efficiency without considering the microgrid's PV unit count. Hence, the objective of this work is to address multi-objective problems in the context of modifying radial distribution systems to operate as a microgrid (MG), with the aim of ensuring the microgrid's security and stability while achieving optimal performance. In this paper, the Firefly algorithm (FA), an optimization technique, is used to determine the size, location, and DSTATCOM within specified ranges to determine the number of PV units to install and the open network lines. The Twain 84-bus system was employed to assess the suggested method's accuracy and efficacy. The outcomes amply illustrated the approach's superiority and efficacy in enhancing MG performance. The proposed method addresses PV unit installation and DSTATCOM installation and reconfiguration in the MG. Also, it enhances the voltage profile and reduces losses of both reactive and active power.

Keywords: Firefly FA, Microgrid, Static Compensator STATCOM, Voltage regulation

1. Introduction

The reactive power compensation of the network is crucial in modern power systems to achieve an elastic, dependable, and dynamic distribution network [1]. Furthermore, the power system has experienced rapidly increasing load demand and congestion issues; therefore, the integration of photovoltaic distributed generation resources has led to greater demand for advanced activities such as MGs [2]. The similarity in the characteristics of the electric distribution systems and MGs, such as end-user locations, the radial flow of power, short line lengths, and standard acceptable limits of the voltage variation, permits the use of quite a similar approach as in the electrical distribution system [3]. Distribution system reconfiguration (DNR) refers to the change of the distribution network's map caused by changes in the state of switches, specifically sectionalizing switches that are usually closed and tie-switches that are usually open, between feeders [4]. Implementing an optimal DNR strategy with Photovoltaic Distributed Generation (PV) units can effectively minimize power losses, reduce congestion, and improve voltage profile [5]. The DNR task can be accomplished by redistributing the loads from feeders with the maximum load to lighter feeders and exploiting the PV units as PQ buses with negative P and zero Q in the grid, while ensuring that system stability requirements are not violated [6]. In addition, the reactive power required by the network and the loads can be effectively compensated by Flexible AC Transmission System (FACTS) devices [7]. Static Var Compensators (SVCs) and Static Synchronous Compensators (STATCOMs) are shunt dynamic Var compensators and have gained significant attention as viable substitutes for a stationary reactive power source [8]. A STATCOM is used to improve power system voltage stability by generating or absorbing reactive power; in this way, the voltage constraint imposed by PV connectivity can be avoided. In addition, installing a STATCOM at strategic locations within the network can enhance transfer capacity by increasing the maximum flow across transmission lines and mitigating apparent power losses, while ensuring a consistent voltage profile across various network scenarios [9]. Therefore, many works have emphasized how such a combination in today's advanced network structure can be optimized. Here, some prior work is reviewed. Jawad and Majeed [10] have used the Genetic Algorithm (GA) to determine the optimal size of Distributed Generators (DGs) and the line-flow sensitivity index equation to determine the optimal location of DGs in the distribution system to minimize losses and improve system security. Rao and Rao [11] have shown that optimizing the placement of Distributed Generators (DGs) and Static Synchronous Compensators (STATCOMs) is crucial for reducing distribution system losses and enhancing the voltage profile, and that this requires a thorough optimization approach. Salkuti [12] used the loss-sensitivity factor to determine where DGs would be most effective. The voltage stability index was used to determine the optimal placement of the STATCOM. To tackle the optimization problem, the Artificial Fish Swarm Optimization Algorithm (AFSOA) was employed. In prior work, such as that by Halacli and Demirore [13], the STATCOM was employed to improve voltage stability and mitigate the risk of power system failure due to voltage fluctuations in the Bursa City Transmission System in Turkey. The study primarily examines the adjustment of the STATCOM dynamic equations' gains using the PSO method. The objective is to reduce oscillations and enhance the STATCOM's response. Al-Wazni and Al-Kubragyi [14] employed a hybrid method, Hybrid Firefly and Particle Swarm Optimization (HFPSO), to determine the optimal sizing of DGs and Static Synchronous Compensators (STATCOMs). In the case of an islanded network, Kumar et al. [15] performed an analysis on the IEEE 15-bus system to find optimal STATCOM location and sizing using Genetic Optimization to enhance the voltage profile and reduce losses. Unlike the previous work mentioned above, this work presents a Static Synchronous Compensator (D-STATCOM) used to inject reactive power into the MG. In addition, ideal network reconfiguration and the sizes of the PVs and D-STSTCOMs were determined using the Firefly optimization algorithm (FA). The results of simulations conducted on the radial distribution network of the modified Taiwan Power Company (TPC) 84-bus test system, operated as an MG, demonstrate a noticeable improvement in total power losses and a reduction in the system's voltage variation.

2. Method of the Research

2.1 Problem Statement

The challenge of improving the voltage profile and minimizing power losses in connected-mode MG is addressed by formulating a solution that combines the use of a STATCOM, reconfiguration, and PV allocation. The formulation of this solution involves the following phases [16].

2.1.1 Total Active Power Losses

Equation (1) is mathematically represented by Total active power losses (Tapl), which can be defined as follows [17].

$$T_1 = Tapl = \sum_{n=1}^{N_{br}} i_n^2 \, r_n \tag{1}$$

This equation consists of only two parameters: the corresponding line current and reactance. The power loss and its magnitude are directly affected by the line current, as long as the line's reactance is unchanged, regardless of how the radial distribution system scheme is set up. As a result, the nodal voltage equations can be used to find the line currents. Assume that the incidence matrix is represented by matrix A for the node-branch of the radial distribution system. The following is a vector representation of the nodal voltage and current equations:

$$a^T.v = z.i \tag{2}$$

$$i = a^T.v.z^{-1} \tag{3}$$

The vector representation of all power losses is as follows:

$$Tapl = i^T.r.i^* \tag{4}$$

By inserting (2) and (3) into (4), the overall power losses can be calculated as:

$$Tapl = v^T.v.z^{-T}.r.z^{-*}.a^T.v^* \tag{5}$$

Where:

$z_n = r_n + jx_n,\ v_n = e_n + je_n$

And

$$a_{n*m} = a_{0(n*m)} * s_m \tag{6}$$

The s_m in (6) is a regulated switch which is found in each branch in the network to have the exchanging capability and can be defined as follows:

$$s_m \begin{cases} 1 & closed\ mode\ of\ m \\ 0 & open\ mode\ of\ m \end{cases}$$

The nodal incidence matrix can be derived from a radial distribution network by defining it as follows:

$$a_{n,m} = \begin{cases} +1 & branch\ n\ leaves\ node\ m \\ 0 & branch\ n\ does\ not\ touch\ m \\ -1 & branch\ n\ enters\ node\ m \end{cases}$$

Let the matrix h_{n*n} be defined as follows, where: n represents the total number of nodes.

$$h = a.z^{-T}.r.z^{-*}.a^T \tag{7}$$

The final expression of Tpl can be derived by substituting (6) and (11) into (4) [5].

$$Tapl = \sum_{j=1}^{n} \left(v_j^* \sum_{n=1}^{n} \left(v_i \sum_{c=1}^{m} \left(\frac{a_{ic}^0 a_{jc}^0 S_c^2 r_c}{|z_c|^2} \right) \right) \right) \tag{8}$$

2.1.2 Congestion Lines Determination

The contingency ranking method can be utilized to find the maximum congestion line. The first criterion utilized for system ranking is the performance index. To quantify the extent of line overloads, the network current-based index is employed, as in (9) [18].

$$J_c = \sum_j w_j \left(\frac{i_j}{i_{n,j}} \right)^{2*n} \tag{9}$$

Where:

j represent the number of lines, w_j represent the weighing factor such that $0 < w_j < 1$, $i_{n,j}$represents the limit imposed by the adaptation of the thermal limit criteria of the line current, i_j

represents the actual current flowing in the circuit j, and n is the exponent factor.

The inclusion of the highest congestion line in the fitness function relies on the comparison between the real current flowing into the network and the thermal limit of the related line, which is determined by the current, as expressed in (10).

$$x = \max\left(\frac{i_j}{i_{n,j}}\right) \quad (10)$$

Let define variable u as follow

$$u = \begin{cases} 0, & x < \propto \\ \frac{x}{\propto}, & x \geq \propto \end{cases}$$

Where $\propto < 1$

Finally, the current-based index can be derived as in (11).

$$T_2 = f(n) = 1 - \frac{1}{e_u} \quad (11)$$

In this work, the L_∞ technique is introduced as a solution to enhance the profile of the voltages and address the issue of PVs in the distribution system, as explained in the next section. The technique utilizes an optimal algorithm to determine the most suitable size and location for STATCOM and PVs.

2.1.3. The $\mathbf{L}_\infty$ technique

The positive impact of the PV system penetration on the network is technically limited by the voltage rise. Therefore, many previous studies have proposed optimization techniques to determine optimal sizing and location to avoid voltage rise. In this study, STATCOM is also included to increase PV system connectivity. As stated in the previous section, utilizing L_∞ with an optimization technique can enhance total system performance. The L_∞ is defined in (12), [19].

$$\|x\|_\infty = sup_t|x(t)| \quad (12)$$

To get the highest value of the vector v, denoted as $v(i)$ with i representing the number of nodes in the MG, it can use (13) and (14).

$$V = \{v(1), \ldots . v(i), \quad v(N_{bus})\}^T \quad (13)$$

$$\|V\|_\infty = sup_i|v(i)| \quad (14)$$

Where $i = 1,2, \ldots, N_{bus}$

The distribution system's target voltage value is expressed in per unit. pu quantity that is supposed to be equal 1 pu. Hence, (15) denotes the percentage variation of the voltage level in the distribution system:

$$V_p(i) = (v(i) - 1) * 100\% \quad (15)$$

Therefore,

$$V_p = \left(v_p(1), \ldots, v_p(N_{bus})\right)^T \quad (16)$$

The supremum of the V_p vector, which depicts the voltage change at each bus in the MG system, is found using the L_∞ norm as in (17).

$$T_3 = \left\|V_p\right\|_\infty = sup_i\left|v_p(i)\right| \quad (15)$$

The recommended method's main goal is to reduce the difference between the desired value of 1 pu and the voltage vector v_p, while ensuring that the power system security constraints are not violated. As

$$\| V \| \infty \to 1, \| Vp \| \infty \to 0, ander \to 0$$

The multi-objective function can therefore be written as in (18)

$$T = (K_1 * T_1) + (K_2 * T_2) + (K_3 * T_3) \quad (16)$$

T in (18) represents the objective function that needs to be reduced to avoid congestion problems, reduce power losses, and enhance the voltage profile.

2.2. Constraints

The objective function in (18) is constrained by a series of conditions, as explained below:

2.2.1. The Current and Voltage Limits

The optimal higher and lower limits of voltage in the MG (84-bus TCP) are 1.05 pu and 0.95 pu respectively [20].

$$v_{min} \leq |v_i| \leq v_{max} \quad (17)$$

Equation (20) imposes a restriction on the maximum current that can flow through the line between buses. i and j in MG networks.

$$i_{ij} \leq i_{ij}^{max} \quad (18)$$

2.2.2. Capacity Limits of PV System.

The power provided by the PV units and the selection of multiple PV units are limited to a specified range, as indicated below.

$$P_p^{min} \leq P_p \leq P_p^{max} \quad (19)$$

$$N_p^{min} \leq N_p \leq N_p^{max} \quad (20)$$

2.2.3. System Configuration

Radial MG network reconfiguration in power systems is limited by the simplicity in protection system schemes that are compatible with the radial structure. The limitations imposed by the protection system should be avoided by ensuring radiality during MG reconfiguration; otherwise, a sophisticated protection scheme is required. To ensure this limitation on network reconfiguration, (23) is adopted [21].

$$N_{bus} - S_L = \sum_{n=1}^{N_{br}} |S_k| \quad (21)$$

Each loop in the system must adhere to the equation that requires the absolute values of entire sectionizing and tie switch states to be met [22].

$$N_{busL} - 1 = \sum_{n=1}^{N_{brL}} |S_{KL}| \quad (22)$$

MG system with DNR should be such that all loads are serviced without disconnections. This can be done using the rank of A as in (25)

$$rank(A) = Q \quad (23)$$

2.2.4. STATCOM Capacity Limits.

The reactive power injected or observed by the STATCOM units and the selection of multiple STATCOM units are limited to a specified range, as indicated below [12].

$$Q_{STATCOM}^{Min} \leq Q_{STATCOM} \leq Q_{STATCOM}^{Max} \quad (24)$$

$$N_{STATCOM}^{Min} \leq N_{STATCOM} \leq N_{SATCOM}^{Max} \quad (25)$$

2.3. Firefly Optimization Technique.

One of the main tasks, with significant technical and economic implications, is the planning of STATCOM and PV in the radial MG network, along with optimal reconfiguration. With the increasing use of PV units in the MG and the widespread use of the STATCOM compensator, many approaches have been adopted to address optimization issues, considering various objective functions and constraints, by installing STATCOM with PV and determining optimal MG performance. PV can act as a power source supplying active power to the load, while the STATCOM can act as a reactive power source supplying reactive power to the load, and together they play a very important role in reducing congestion in MG networks. In this section, the Firefly optimization method (FA) is applied to determine optimal PV units and a STATCOM, as well as optimal reconfiguration, so that congestion problems can be avoided and total power loss is minimized. Firefly FA is a meta-heuristic algorithm introduced by [23]. Fireflies are nocturnal insects that belong to the beetle family and have the ability to emit light through bioluminescence. In particular, they employ the flash light to attract potential mates or potential prey. Additionally, the flash light serves as a protective warning mechanism, reminding fireflies of the potential dangers they face [24]. The entire procedure of using the FA algorithm for the optimal location of PV units, RDN, and STATCOM in a radial MG power system is explained in more detail as follows:

Step1**:** Initialization:

(a) Set the Variable range x_min and x_max.

(b) Enter system data that contains bus data as well as line data of the radial MG network.

(c) Determine a problem constraint.

Step2: Determine the optimum position right now by forcing the position to satisfy a fitness function. Then the fitness function will be calculated as follows:

(a) Subject the solution containing PV position, size, STATCOM position and size, and DNR to the MG distribution system.

(b) Conduct a power flow to acquire every variable.

(c) Conduct an analysis of contingencies.

(d) Compute H_∞.

(e) Find TRPL, then compute the fitness function using (18)

Step 3: Apply the Firefly algorithm

(a) Objective function $f(x)$, where

$$x = (x_1, \dots, x_d)^T$$

(b) Produce the initial population of fireflies such that $x_i (i = 1, 2, \dots n)$

(c) $f(x_i)$ determines the light intensity L_i at x_i.

(d) Describe the light absorption coefficient (γ).

(e) While t < Max Generation

(f) For $i = 1{:}n$ for all n fireflies

(g) For $j = 1{:}n$ for all n fireflies (inner loop)

(h) If $I_i < I_j$ move firefly i towards j ; end if

(i) The attractiveness varies with distance r via ex $[-\gamma r]$

(j) The new solutions were evaluated and updated to the light best g ; end while

Postprocess results and visualization

Step 4: If the latest solution outperforms the previous step.

Then, a global best, which is a new best.

End If

End for

End

3. Results

The FA for MG with STATCOM and PV in the distribution network of the Taiwan Power Company is applied in Fig.1. The 84-bus power distribution system and all the important technical system data are given in [17]-[21]. The distribution system used in this case study is 28350 kW ,00 $kVAR$, d 11.4 kV network. For simplicity of calculations, the base voltage capVsub b a. s e and the base power cap P sub b a. s e are equal to 11 kV and 100 MVA, respectively. Furthermore, integrating the L∞ technique increases the effectiveness of the FA algorithm and enhances the cconvergence process. In this procedure,FA runs 40 times, and each run has 200 iterations. As a result, the FA algorithm has converged to the optimal solution. Table 1 tabulates the FA algorithm's convergence properties for voltage profile, line congestion, and total active power loss. The results have shown a noticeable power loss minimization which is reduced from 531.994 kW to 195.9 kW which gives the PV system more space to inject more power without violating the network thermal limit, furthermore, the voltage profile has effectively improved as can be seen in Fig.2, so that the per unit pu value increase from 0.9285 pu to 0.98471838 pu which is due to the inclusion of STATCOMs in the network. STATCOMs have compensated for all reactive power needed by the network. Besides, the current magnitude at all lines is significantly reduced, as indicated from 364.37 A to 198.73 A in lines (1-2) Fig.1. However, the harmonic contains were not included, however, it is expected to be noticeable due to a number of PV and STATCOM otherwise filter requirements cannot be avoided unless a more advanced power electronic converter could be used such as multi-level inverter technology instead. Therefore, the power losses due to the system converter can be included to obtain more precise and accurate results. Far from harmonic and other hidden losses, Table 1 clearly shows that after using DNR, STATCOM, and PVs, a significant minimization in the flow of currents in the modified distribution system MG lines is observed, such that every current has decreased by more than 50% below the values of its limits. This positively affects power loss as well as congestion in the MG under test (the real current originally was (364.37) A of the line (1-2), and the critical limit is (364.37) A, and then after applying the proposed method with DNR, STATCOM, and PV reduced to 198.73 A). Fig.3 shows the convergence of the FA optimization method to the optimal solution in run number (11) from 40 runs with 200 iterations.

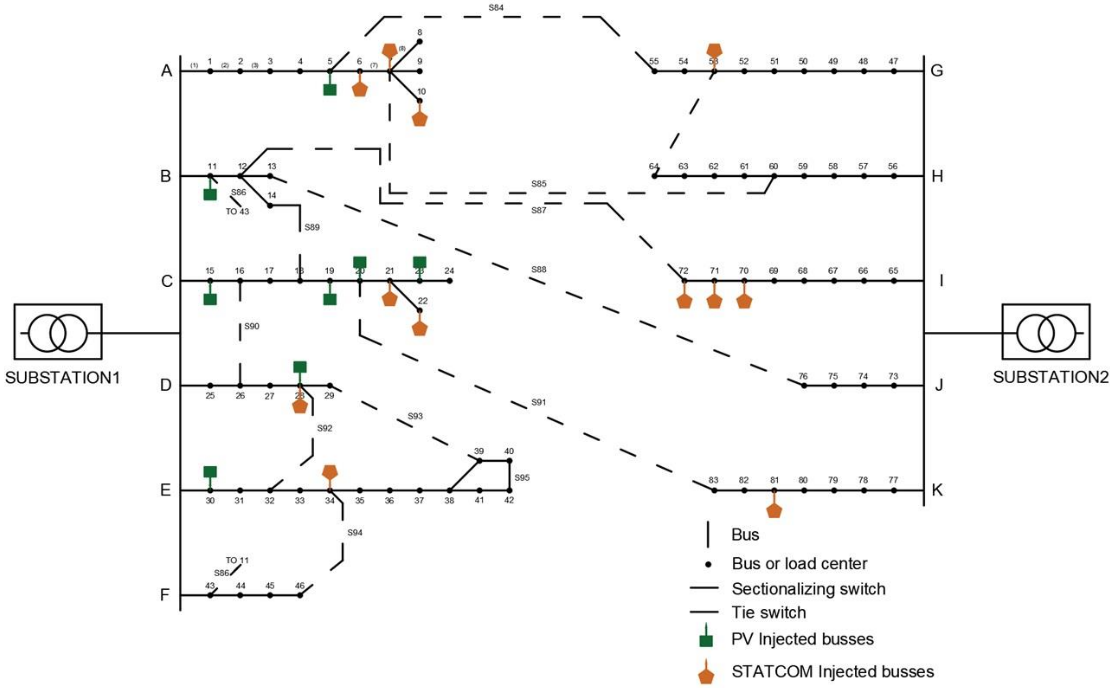

Figure 1. A practical-scale Taiwan power company (TPC) 84-bus test system.

Table 1. Result of optimization process.

Methods	FA	Original system data
P losses (kW)	195.9	531.994
min node per unit voltage	0.98471838	0.9285
Open Lines	[7,10,14,16,26]	[84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96]
Total P(MVA)	4.3400449	-
PV Injected buses	[5, 11, 15, 19, 20, 23, 28, 30]	-
PV injected (kVA)	[372.6642, 520.8022, 388.8884, 188.29, 251.1134, 14.03, 1159.7445, 1444.5125]	-
STATCOM (kVAR)	[-300, 300, 300, -300, 300, 300, -300, 300, 300, 300, -300, 300]	-
STATCOM Injected buses	[6, 7, 10, 22, 21, 28, 34, 53, 70, 71,72, 81]	-
Cost	1.797546	-
Mean cost	2.177852	-

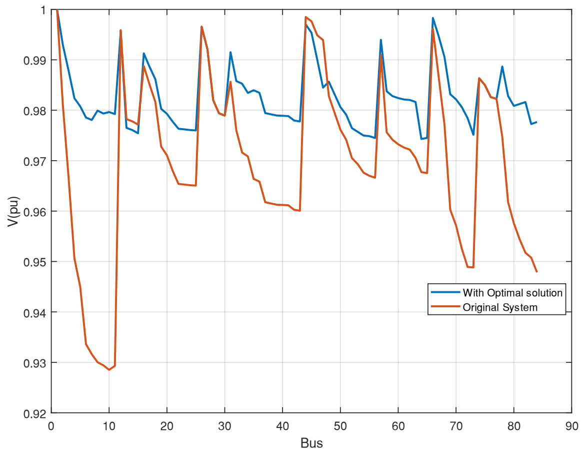

Figure 2. Bus Voltage Variation before and after Optimized System.

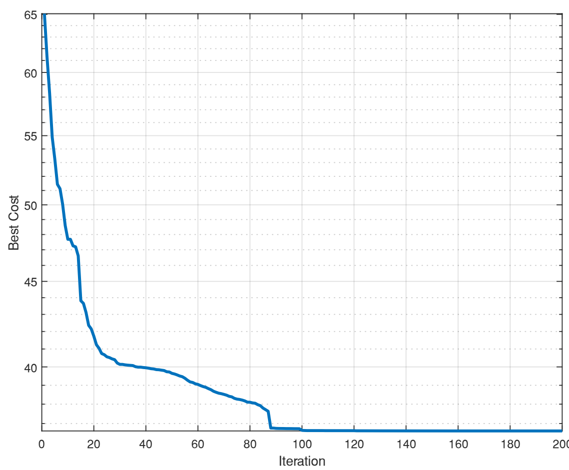

Figure 3. Convergence of optimization for 40 runs and 200 iterations.

4. Discussion

The results show that optimizing the distribution network reconfiguration (DNR) and the placement and allocation of photovoltaic (PV) systems and STATCOMs (S) are substantial for microgrid operation when using the Firefly Algorithm (FA). The proposed multi-objective framework can achieve significant gains in overall system performance by simultaneously coordinating active power generation, reactive power compensation, and network topology, compared with conventional approaches that optimize only one of the three.

The total active power loss has been reduced from 531.994kW in the original system to 195.9kW, a 63.2% reduction achieved through the optimization process. This major enhancement is primarily due to the optimal positioning of the PV units, which reduces reactive power consumption via long feeders, and to the STATCOM units providing compensation for local reactive power consumption, which reduces feeder current. Again, due to network reconfiguration, the power distribution is redistributed, which alleviates the heavily loaded branches and reduces the resistive losses.

The voltage profile was also significantly improved. The minimum bus voltage rose from 0.9285 p.u. to 0.9847 p.u., and all buses are kept well within the acceptable operating range. This enhancement suggests that the combined control of PV generation and STATCOM compensation is effective at reducing voltage drops in a highly loaded radial distribution system. Operating within typical voltage ranges will improve power quality and increase the reliability of microgrid operation.

Another major benefit is reduced line congestion. The highest rated feeder current was reduced from 364.37 amps down to 198.73 amps (about 45%). Reduced line currents lowers the amount of thermal stress on conductors, provide for more capacity for future conductor growth, and enhance overall network security. This shows that besides reconfiguration of the network, proper coordination of distributed generation/DP and reactive power support is also necessary for congestion mitigation.

From Fig. 3, it can be seen that the Firefly Algorithm has stable optimization characteristics. The algorithm has converged in 200 iterations on 40 independent runs, indicating that the solution obtained is reliable and stable in computation. The value of the objective function decreases quickly in the early iterations, showing that the search space is being explored effectively; the convergence in later iterations shows that the search is effective in exploiting the global optimum.

The proposed method is not only an integration of the three optimization variables, but also brings in an optimization approach that optimizes all three variables together, while previous studies optimize DG placement, STATCOM allocation, and network reconfiguration separately. The coordinated strategy offers greater flexibility in controlling both active and reactive power flows, resulting in improved voltage regulation and/or power-loss reduction compared with optimization methods that control a single variable. The findings consequently reinforce the tendency of optimizing active distribution networks and renewable-energy-based microgrids, in an integrated manner, for modern power systems.

Practical issues are outside the scope of the present study, despite the proposed framework demonstrating excellent technical performance. The potential for harmonic distortion from inverter-based PV systems and STATCOM devices was not considered, nor were converter losses, communication delays, and uncertainties in renewable generation. Moreover, the simulations were conducted under steady-state operating conditions using only one benchmark network. Further research is required to examine the practical feasibility of the proposed framework in future under the following conditions: dynamic operating conditions, stochastic renewable generation, integration of battery energy storage, multi-objective economic optimization, and hardware-in-the-loop or real-time validation.

5. Conclusions

In this paper, a coordinated optimization method for PV unit allocation, STATCOM optimal size and placement, and distribution network reconfiguration in a microgrid with the Firefly Algorithm (FA) is presented. The proposed multi-objective approach achieved the goal of minimizing active power losses, reducing feeder congestion, and improving the voltage profile while maintaining the operational constraints of the radial distribution network.

The effectiveness of the proposed methodology was demonstrated by simulation results obtained from the Taiwan Power Company 84-bus test system. The total active power loss decreased from 531.994 kW to 195.9 kW, a 63.2% reduction, and the minimum bus voltage increased from 0.9285 p.u. to 0.9847 p.u. Also, the peak feeder current dropped from 364.37A to 198.73A, indicating a substantial reduction in line congestion and improved utilization of network capacity. The convergence characteristics also showed that the Firefly Algorithm converged to a stable solution after 200 iterations across 40 independent runs.

The main novelty of this work is the development of a new optimization framework that integrates PV allocation, STATCOM planning, and network reconfiguration, thereby enabling simultaneous control of active and reactive power flows. This synergistic approach offers greater operational flexibility and improves the technical performance of renewable-energy microgrids.

However, the present study makes the following assumptions: steady-state operation; no consideration of harmonic distortion, converter losses, renewable generation uncertainty, or communication delays; and no consideration of the dynamic behavior of the systems. The authors recommend exploring the feasibility of stochastic optimization, integrating battery energy storage, enabling real-time applications, and conducting economic evaluation under different operating scenarios in future studies.

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Abbreviations

ACA	Ant Colony Algorithm
CR	Converge Rate
DG	Distributed Generation
DNR	The Distribution Network Reconfiguration
FA	Firefly Optimization Algorithm
HSOA	Harmony Search Optimization Algorithm
ICSA	Improved Cuckoo Search Algorithm
MG	Microgrid
PSO	Particle Swarm Optimization
PV	Photovoltaic
STATCOM	Static Synchronous Compensator
Tapl	Total active power loss

List of Symbols

a	The branch incidence matrix
a_0	The matrix of node branch incidence
$a_{n,m}$	The (A) matrix element
$a^o_{n,m}$	The (A) node matrix element
E_d^{itr}	Endurance
itr	Iteration
i	a branch of the current vector
i_n	the nth branch's current magnitude.
$i_{N,j}$	A critical thermal limit of the line depends on current.
$i_{i\,j}^{max}$	highest current at thermal limit of (*i,j*) line
i_j	real current magnitude through circuit j.
$K_{1,2,3}$	the penalty factors in the objective function
L_p	p-norm
L_∞	∞-norm
max	the maximum number.
min	the minimum number.
n	positive integer parameter.
N_{br}	number of branches in the system.
N_{bus}	number of buses
N_P	the number of the PV
P_P	the power of the i^{th} PV
r_n	the resistance of the n^{th} branch
r	the resistance vector.
T	the fitness function
T_{min}	Lowest possible temperature
T_{max}	highest possible temperature
$v(i)$	Voltage at bus (i) was measured.
v	The vector of nodal voltage
v_d^{itr}	velocity
v_{min}	lowest voltage possible
v_{max}	highest voltage possible
V_p	vector of voltage changes
x_d^{itr}	Location
z	the matrix of branch reactance

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Author Contributions

Dawood Saleem developed the theory and performed the computations.

Ali F. Marhoon verified the analytical methods and investigated and supervised the findings of the work.

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