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Optimization of Energy Storage Unit Size and Location in a Radial Distribution Network to Minimize Power Loss Using Firefly Algorithm

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ABSTRACT

By strategically deploying BESS sources within a distributed generation (DG) environment, power distribution losses could be reduced. Misallocation of these units may result in under- or overvoltage, which is undesirable. The objective is to select transit locations with the lowest possible losses and the greatest potential benefits. This study describes how to use a firefly algorithm (FA) to size a battery energy storage system (BESS) in order to minimise the voltage increase in a radial distribution network that employs a hybrid solar and wind energy conversion system (WECS). This research analyses the optimal capacity and positioning of the BESSs in a radial distribution network with 33 buses and 69 buses with the goal of minimising power loss to the greatest extent feasible. Solar photovoltaic (PV) systems, wind energy conversion systems (WECS), and energy storage systems (ESSs) are only some of the distributed energy resources that might benefit from the conservation voltage reduction (CVR) architecture proposed by this study. The proposed method is assessed by simulating it in Matlab while contrasting the results to those of the Genetic Algorithm (GA) and the Ant Colony Algorithm (ACA), among others.

1. Introduction

People are more worried about the environment, the network is improving, and the government has a return program, so distributed generating units are being utilized more to generate electricity for companies and residences. Even if DG units have low pollution, having a lot of them in a distribution system could affect the quality of the power. It is common knowledge that improper DG installation and sizing may lead to significant power losses, subpar operation, and harmonic wave propagation [1- 2].

DG that use green energy sources like WECS, PV production have lately garnered a lot of attention on a worldwide scale due to their dependability, cleanliness, and environmental friendliness. The unreliability of their power supply presents a number of obstacles that must be overcome before these systems can be integrated into existing distribution infrastructure. PV and WECS rely

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significantly on natural sunshine and wind patterns. Power output increases or decreases depending on the quantity of available solar energy rather than the load demand at any one moment. When the load exceeds the DG's output capability, voltage fluctuations occur [3, 11].

Unwanted damages caused by sudden voltage rises or falls in the network might be expensive for the customers. As a result, some solutions to the problem of voltage fluctuation have been suggested in the literature. A good approach for minimizing the voltage rise problem is the BESS [4, 13]. However, each bus in the network needs to have a BESS installed, which is expensive. Therefore, locating BESS in the system's ideal location is essential. Finding the ideal BESS size is crucial because the cost of a BESS increases with its capacity. The system can achieve a suitable BESS size for maintaining voltage regulation with the help of optimal BESS sizing [5].

An updated evolutionary approach is described in [6] to better pinpoint where DG units and capacitors should be put in RDS. This change was designed to decrease active power losses while maintaining a constant voltage. The authors of [7] provide a unique technique for optimizing DG units that employs a fuzzy logic controller, the Ant-lion optimisation methodology, and particle swarm optimization. The problems of power loss and voltage fluctuations will be addressed. An innovative method for choosing the ideal number of DG penetrations is provided in [8]. This method is based on an exploration algorithm for quasi-oppositional unpredictable symbiotic organisms.

To determine the optimal size for stand-alone PV systems, the authors of [9] evaluate the likelihood of power outages for different combinations of PV and BESS capacities. For example, Arun, etc. A stochastic model [10] found the BESS's optimal storage capacity and producing outputs concurrently, taking into account wind power forecast uncertainty. [11] described scaling and regulating zinc-bromine BESS. [12] used MATLAB curve fitting to study the energy flow size curve of a stand-alone PV system and establish a formula for optimum PV and BESS sizing. [13] studied BESS positioning and size to reduce PV expansion-induced voltage fluctuations. Instead of PV siting, a bi-level GA was used to optimise the model. Analytically optimise DG or BESS unit size and location.

[14] utilised design space and chance constrained programming. The minimal BESS capacity was calculated by graphing the PV rating against it on a sizing curve. GA optimises the size of a hybrid wind-solar-BESS system [15]. This study optimises renewable energy uptake and costs using a multi-objective function. Chen *et al.* [16] optimised the investment cost model, a nonlinear objective function, to obtain the ideal energy storage size using GA.

CVR is the most effective approach to reducing feeder voltage. The CVR approach effectively saves energy by reducing voltage on the distribution network and minimizing maximum demand and losses. In order to lower peak demand and achieve significant energy savings at the lowest possible cost without disrupting consumer appliances, the primary tenet of CVR functioning is to minimize end-use voltage within standard voltage limitations. If implemented, CVR has the potential to lower both total energy use and feeder voltage.

In order to reduce power losses throughout the whole system, a unique swarm intelligence technique is proposed, in which the Firefly Algorithm (FA) is utilised to figure out the ideal size and positioning of a BESS unit in RDN with DG and CVR. FA allows the simultaneous determination of both the location and size of BESS [17, 20].

In this research, we examine three different approaches to determining the best location for and size of BESS units from a sample of buses: the FA technique, the GA, and the ACA. To demonstrate the effectiveness of the suggested technique, an in-depth analysis of an IEEE 33 and 69 bus Radial Distribution System is carried out. Proof of the algorithms' effectiveness is provided by their deployment in a variety of use cases and the dissemination of the generated solutions. Results from the simulations are used to compare the suggested approaches to GA and ACA, with power loss serving as the performance metric of choice. Based on the results, it appears that the proposed FA approach has demonstrated strong performance across a wide range of parameters. This paper will have the following outline. The under-discussion system is described in depth in section II. Section III provides an introduction to FA. In Section IV, we give the case study and our analysis of it. In Section V, the results are presented.

2. Description of The System Under Consideration

(A) Network Under Consideration

Understanding the characteristics of the supply network's predicted load is necessary for the planning phase of BESS deployment on a distribution network. This is done so that planners may choose the method of network loss computation that is most suitable for the situation. The location of the BESS's connection to the grid, as well as the amount of that connection, will determine how the totaling of DG will affect power losses. Figure 1 and Figure 2 depict the simplified network diagrams of the 33-bus and 69-bus RN, respectively, both of which adhere to IEEE standards.

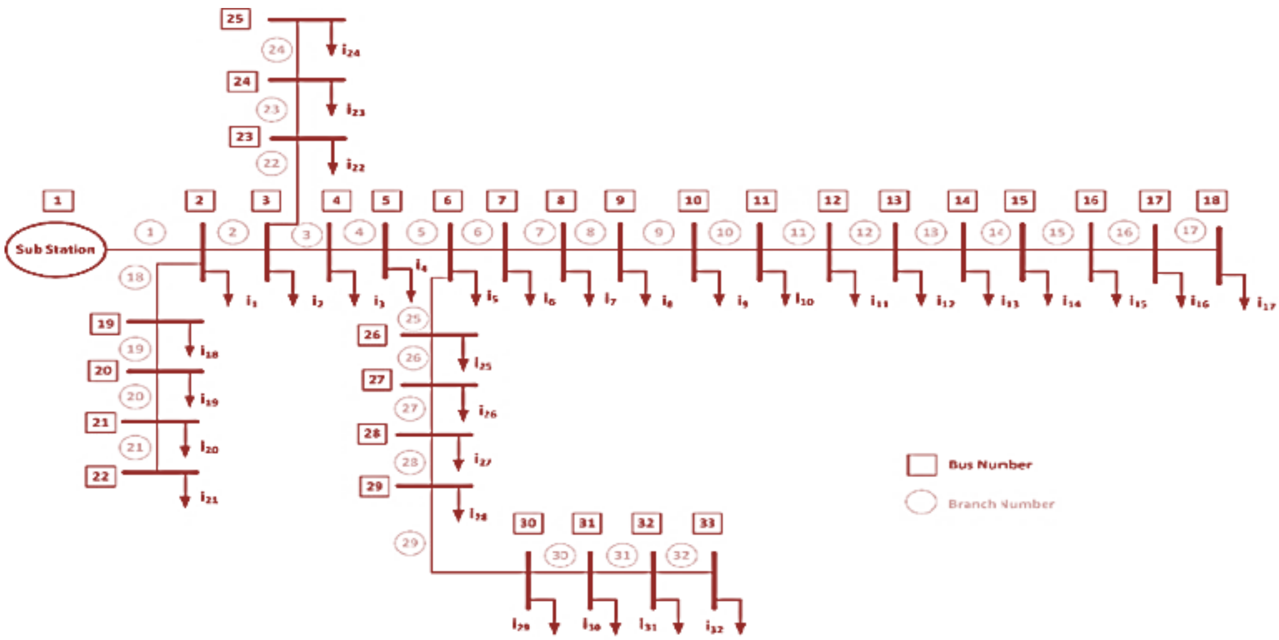

Fig. 1. Line diagram of IEEE 33-bus RN

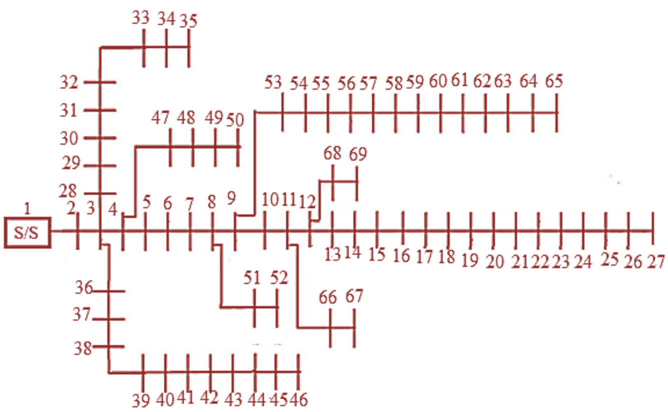

Fig. 2. Line diagram of 69-bus RN

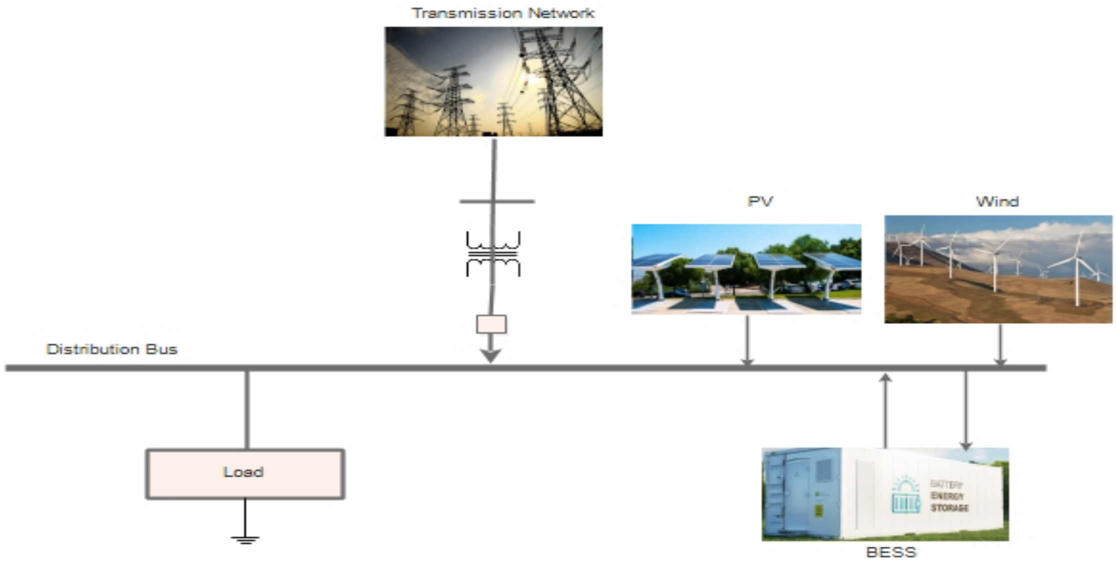

Fig. 3. Fundamental Block Diagram of PV, WECS and BESS integrated into the Distribution Network

The diagram presented in Figure 3 illustrates a simplified configuration for a combined photovoltaic and wind energy conversion system, which employs a distribution grid alongside a battery-based energy storage mechanism. In this analysis, solar arrays, WECS, batteries, and loads are the four primary models that are combined with the distribution network. The instability of PV and WECS systems is a big problem because it upsets the equilibrium between electricity demand and supply. In such instances, the majority of specialists hold the view that utilising BESS to furnish or stockpile electric power as per demand is the optimal strategy. Energy losses may be minimised by decreasing network current flow by locating DG systems and BESSs near demand centres. However, the power losses in a distributed system may be reduced even more with the correct BESS distribution within the network.

(B) Formulation of the Objective Function

This section counsels FA to determine the ideal DG unit size and placement in the distribution system in order to minimize system loss. The reduced losses should lead to a better voltage profile at each bus. The material that follows demonstrates how to color-code elements that influence the distribution of distributed generation (DG):

$$a = [(a_{1l}, a_{1b}), \ldots..(a_{nl}, a_{nb})] \tag{1}$$

where 'l' denotes the BESS's location, 'b' denotes its size, and n is the quantity of BESS units that must be deployed in the system. The algorithm is then executed to determine the system's overall loss once these variables are added to the data for the load flow. Algorithm must be performed repeatedly to attain the best BESS allocation. It is terminated after the best BESS location and size have been achieved concurrently. The system's overall loss, P_{loss}, which must be minimized, is represented by the objective function, f(a) as follows:

$$f(a) = min(\sum_{i=1}^{m} \quad P_{loss}) \tag{2}$$

where 'm' denotes the quantity of distribution system transmission lines.

(C) Concept of CVR

The CVR approach relies on the demand minimization and peak trimming principles to reduce voltage without directly hurting consumers in order to save energy and enhance dynamic stability. As a result of lowering the grid voltage, energy consumption is cut down in direct proportion to the voltage sensitivity of the loads. As a result, it immediately equalizes the energy use at a dynamic time scale, enhancing grid stability. Figure 4 shows the CVR use throughout various time periods.

Equation (1) defines the CVR.

$$CVR^f = \frac{\Delta E\%}{\Delta v\%} \quad (3)$$

where E and V represent the percentage of overall energy saved as a result of the feeder's reduced voltage. The load configuration changes periodically. Consequently, the fixed load example may not adequately validate the suggested CVR approach. Because commercial and residential customers depend more on voltage than industrial loads do, adopting the dependent load configuration results in greater energy savings for these customers. As a result, the CVR factor is determined by categorizing clients into several groups as follows:

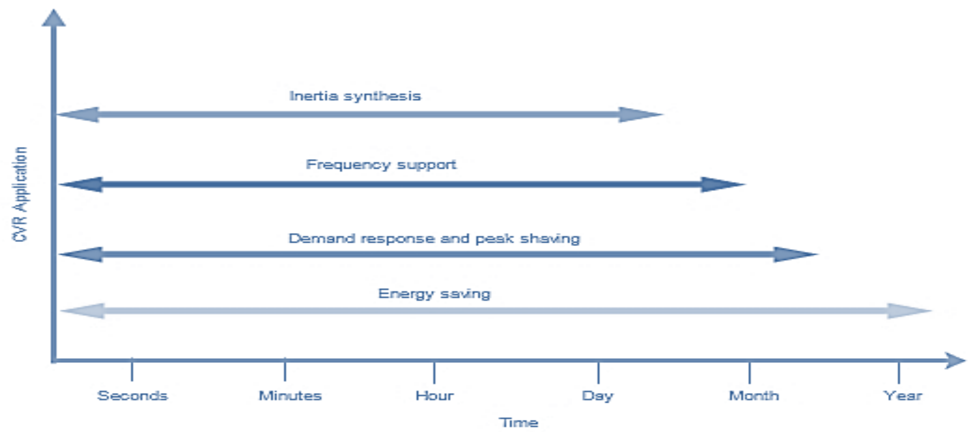

Fig. 4. CVR's Utilization Chart

where ΔE and Δv are the percent of total energy saved as a result of the feeder voltage drop. There are frequent shifts in the load arrangement. Therefore, the proposed CVR approach may not be adequately validated in the fixed load situation. Industrial loads, commercial/residential clients with greater voltage dependencies, and hence larger amounts of energy savings from reducing voltage, are grouped together in the dependent load configuration. Therefore, the CVR factor is determined by categorising clients as follows:

$$CVR_f = R \cdot CVR_{fR} + I \cdot CVR_{fI} + C \cdot CVR_{fC} \quad (4)$$

where $R \cdot CVR_{fR}$, $I \cdot CVR_{fI}$, and $C \cdot CVR_{fC}$ are the CVR factor coefficients that, respectively, indicate the load shares of the residential, industrial and commercial client classes.

$$P_{li} = P_{ni} \left(\frac{v_i}{v_n}\right)^{k_p} \quad (5)$$

$$Q_{li} = Q_{ni} \left(\frac{v_i}{v_n}\right)^{k_q} \quad (6)$$

where the system's rated voltage and the bus voltage, respectively, are v_i and v_n; P_{li}, P_{ni}, the ith bus's active power and active load; Q_{li}, Q_{ni} are the ith bus's reactive power and reactive load; Exponential parameters are represented by k_p and k_q .

3. Firefly Algorithm (FA) Proposed For Optimization

The Firefly Algorithm (FA) was inspired by the behavioural and blinking patterns of fireflies, as noted by Xin-She Yang [29]. The primary feature that distinguishes this system is its utilisation of stochastic variables and reliance on inter-particle communication within a swarm of fireflies. Hence, it appears to be a more efficacious approach in attaining objectives related to multiobjective optimisation. FA adheres to three primary regulations. Initially, it is noteworthy that fireflies do not exhibit any sexual attraction towards their conspecifics, irrespective of their gender. It has been observed that there exists a direct correlation between the aesthetic appeal and luminosity of an object, whereby both attributes tend to diminish as the distance from the observer increases. Therefore, the duller firefly will fly over to the brighter one. If there is no clear winner, the firefly will just go off in a direction at random. Thirdly, the target function's landscape influences a firefly's brightness. The light intensity L(d) is monotonically and exponentially decreasing with increasing distance 'd'.

$$L = L_O e^{-\gamma d} \tag{7}$$

where 'γ' is the light absorption coefficient and L_O is the initial light intensity. The attractiveness of a certain area of light, which is related to the goal function, affects the number of fireflies present. The allure of fireflies may be described as follows, as it decreases with increasing brightness:

$$\beta = \beta_O e^{-\gamma d^2} \tag{8}$$

where β_O represents attractiveness when d is equal to 0. It is important to note that the exponent γd can be replaced by d^m when m is greater than 0. Without knowing the spacing between fireflies, it is impossible to produce the light intensity and allure of a firefly. The following expression can be used to calculate the d_{ij} between two fireflies.

$$d_{ij} = \sqrt{\left(p_i - p_j\right)^2 + \left(q_i - q_j\right)^2} \tag{9}$$

where the positions of fireflies i and j are represented by (p_i,q_i) and (p_j,q_j), respectively. When a firefly i is drawn to another more alluring (brighter) firefly j, its movement is given as below:

$$p_i^{k+1} = p_i^k + \beta_O e^{-\gamma d_{ij}^2}\left(p_j^k - p_i^k\right) + \delta_k \omega_i^k \tag{10}$$

where the attraction amongst fireflies i and j is represented by the second term. The randomization is represented by the third term, $\delta_k \omega_i^k$. Figure 5 depicts the procedure for including the FA in the best BESS allocation.

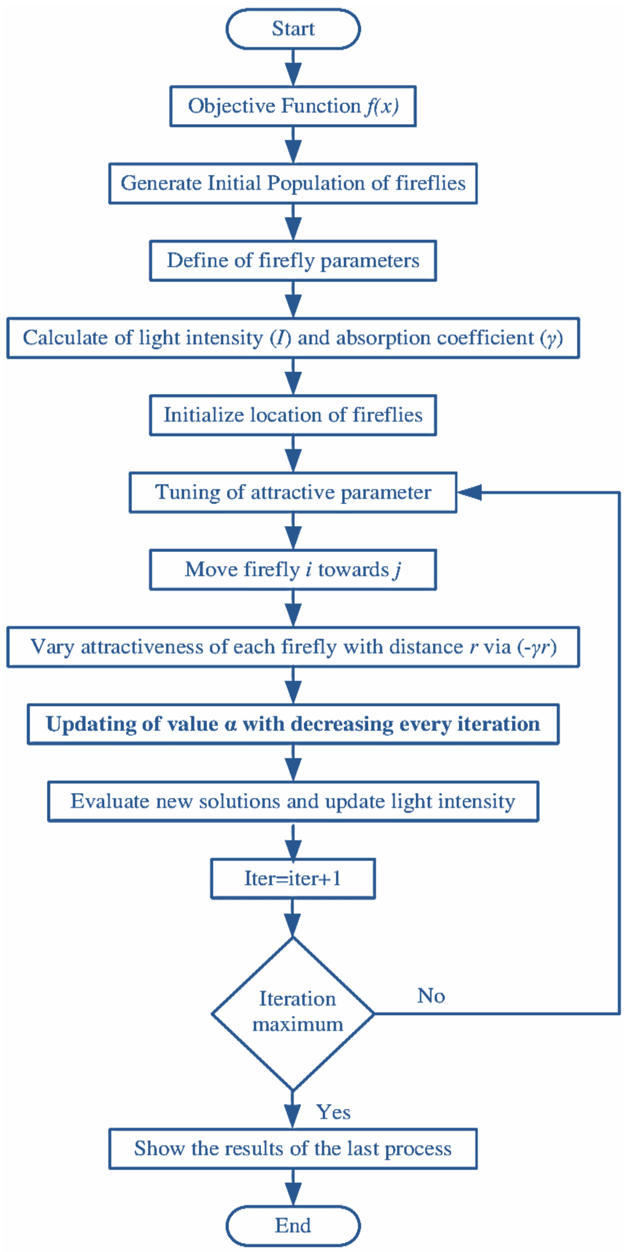

Fig. 5. FA's Flowchart

4. Results and Discussion

The techniques employed to arrange BESS units in the MATLAB platform were the IEEE 33 bus as well as 69 bus distribution test systems, as depicted in Figures 1 and 2. The distribution network is equipped with six DG units, comprising of four PV systems and two wind energy systems, with a capacity of 100 kW each. These units have been placed at random locations, namely bus stops 3, 9, 16, and 25 for the PV units, and buses 7 and 13 for the wind units. The findings are accessible and confirmed. The GA, ACA, and FA algorithms determine the optimum locations and sizing of BESS units.

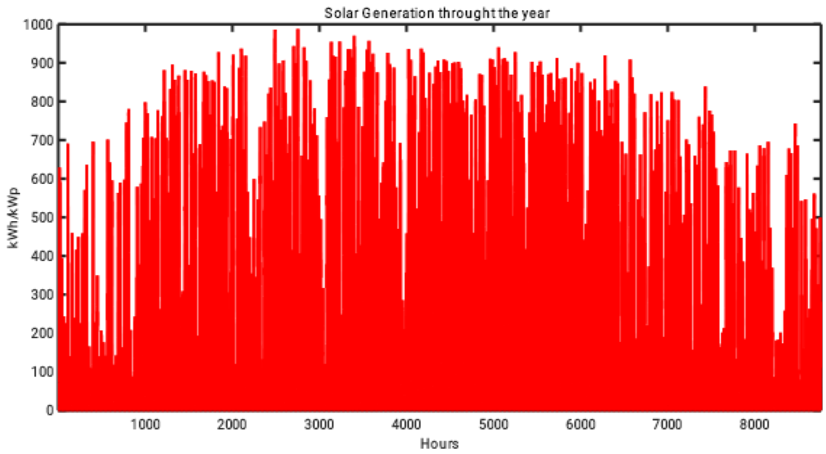

Fig. 6. Solar Power Generation Curve for one year

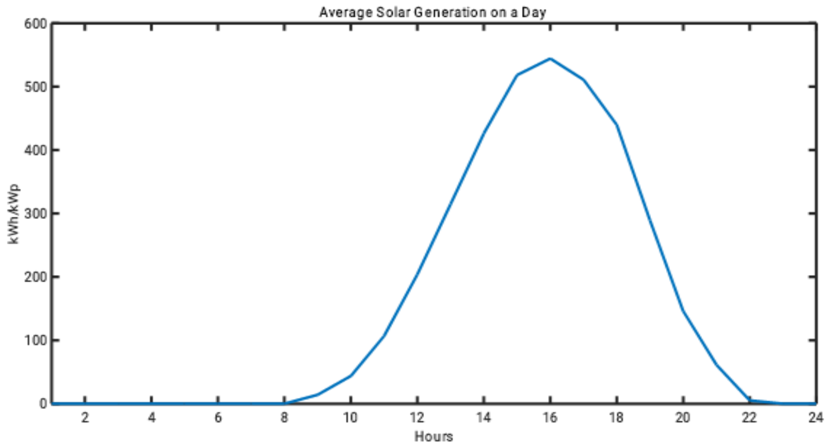

Fig. 7. Solar Power Generation Curve for one day

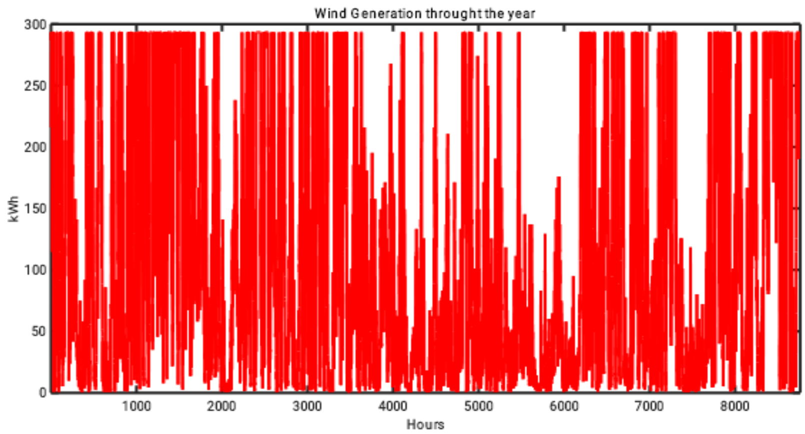

Fig. 8. Wind Power Generation Curve for one year

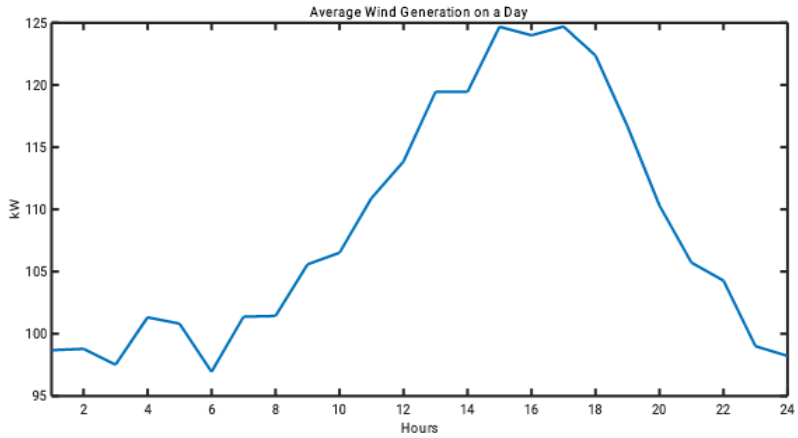

Fig. 9. Wind Power Generation Curve for one day

Figures 6 and 8 show the observed and presented annual PV and wind generation. Figures 7 and 9 show the hourly PV and wind power generation.

(A) Simulation Results of 33-bus System

The IEEE-33 bus system is utilised to bring the recommended approaches into effect. Indicators of efficacy are shown in Figures 10 through 17. The implementation of BESS is shown in a flowchart in Figure 5, which finally results in the determination of the ideal cost function.

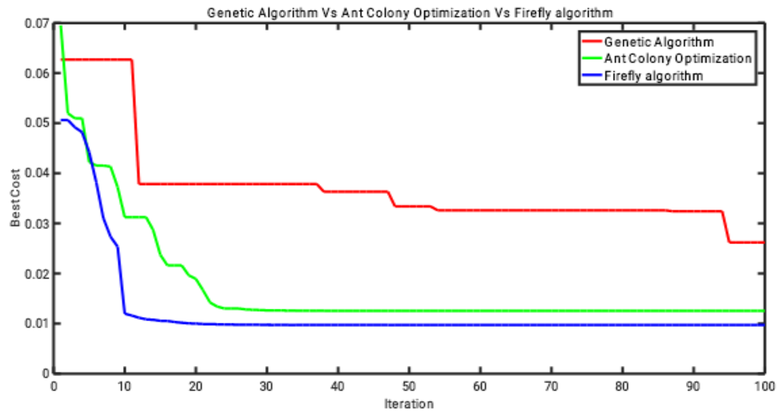

Fig. 10. Comparison of Fitness values for the proposed methods

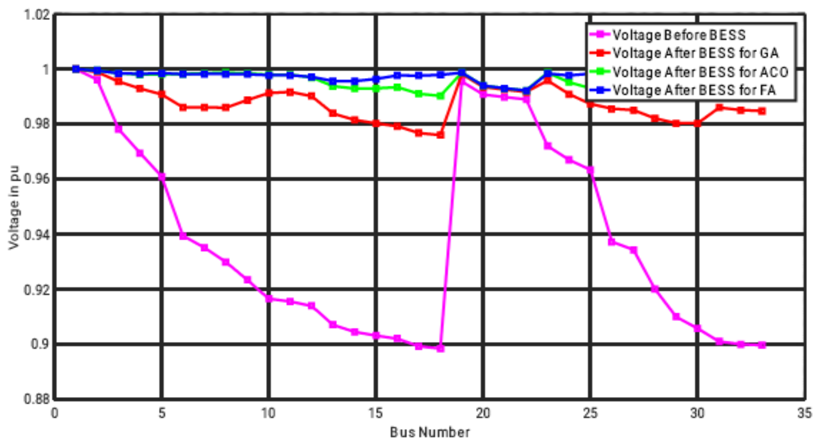

Fig. 11. Comparison of p.u. Voltage with and without BESS for the proposed methods

As demonstrated in Figure 10, the recommended FA is unquestionably more economical than the ACA and GA. Figure 11 displays the voltage using all three techniques both before and after the BESS was placed. The 33-bus system's actual and reactive power losses are shown in Figure 12 for comparison. Figure 12 depicts the power losses for the FA, GA, and ACA methods prior to and following the BESS installation.

There is no question that the suggested FA algorithm reduces losses in comparison to the conventional method. Figure 12 makes this very evident. Figure 13 displays the ideal BESS dimensions and placement for the proposed FA technique.

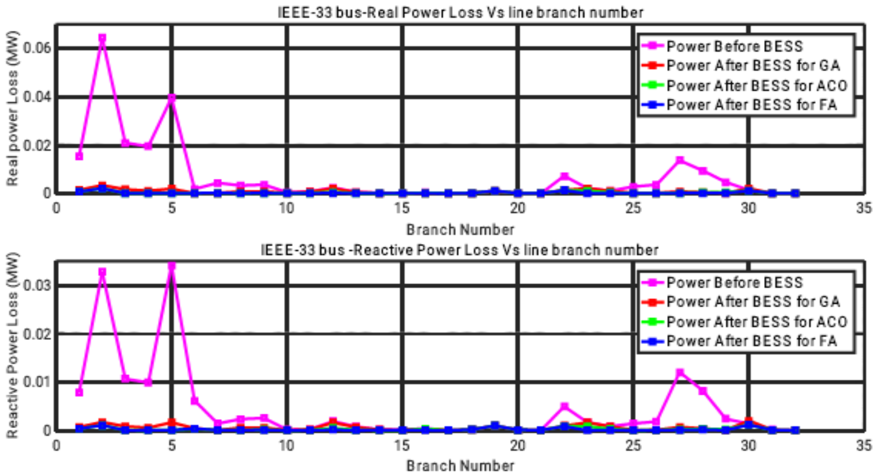

Fig. 12. Loss Comparison for the proposed methods with and without BESS

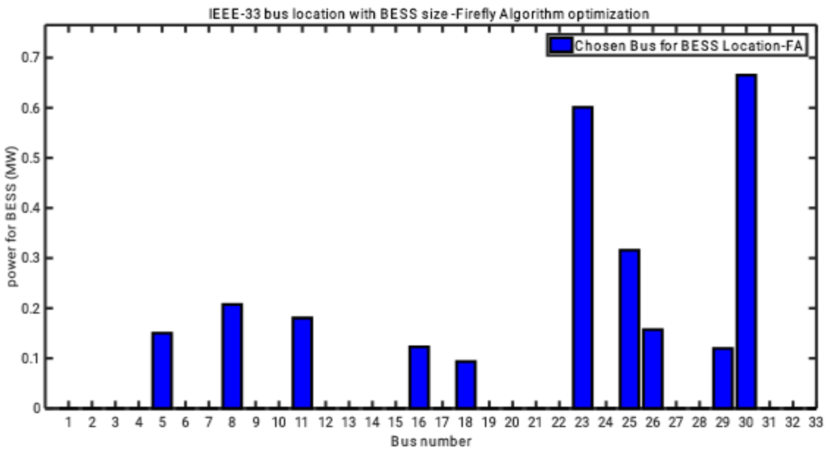

Fig. 13. Location and Power of BESS for the prosed FA technique

The impact of CVR implementation is evaluated through system simulations, both with and without its implementation, to ensure accurate comparison. The voltage drop, actual power loss, and reactive power loss are depicted in Figures 14-16, both with and without the implementation of CVR. The graphical representation depicted in Figure 14 illustrates the gradual decrease in voltage that is uniformly observed across all distribution feeders. The present study displays Figures 15 and 16, which exhibit the real and reactive power losses of the 33-bus system, both with and without CVR.

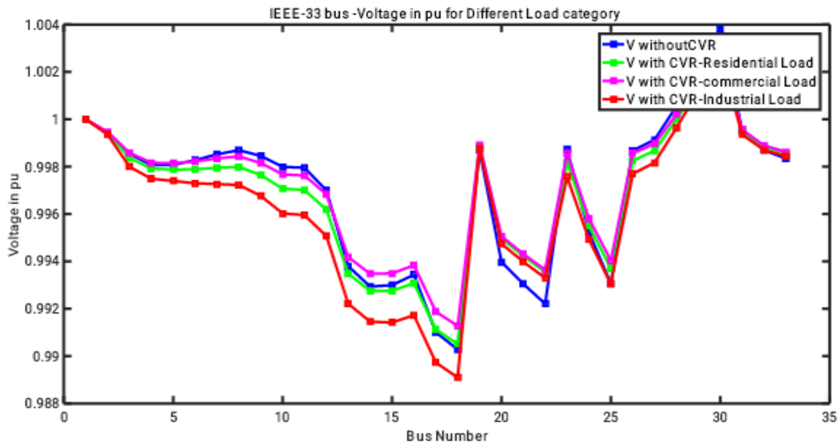

Fig. 14. Voltage profile of various loads with and without CVR

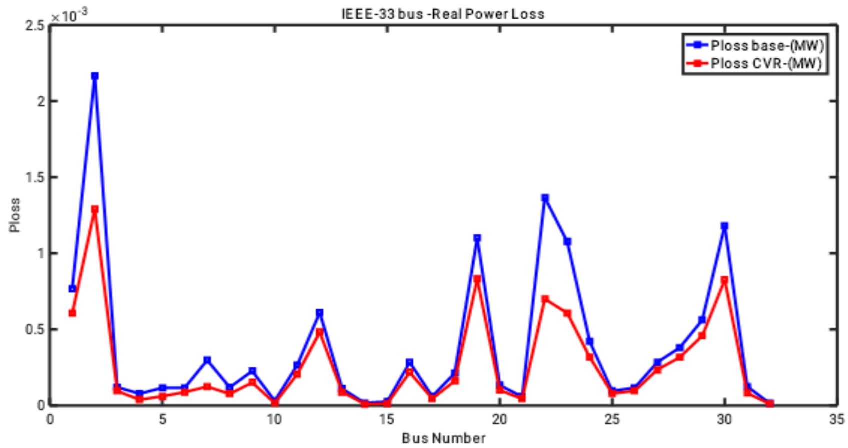

Fig. 15. Real power loss using FA Algorithm with and without CVR

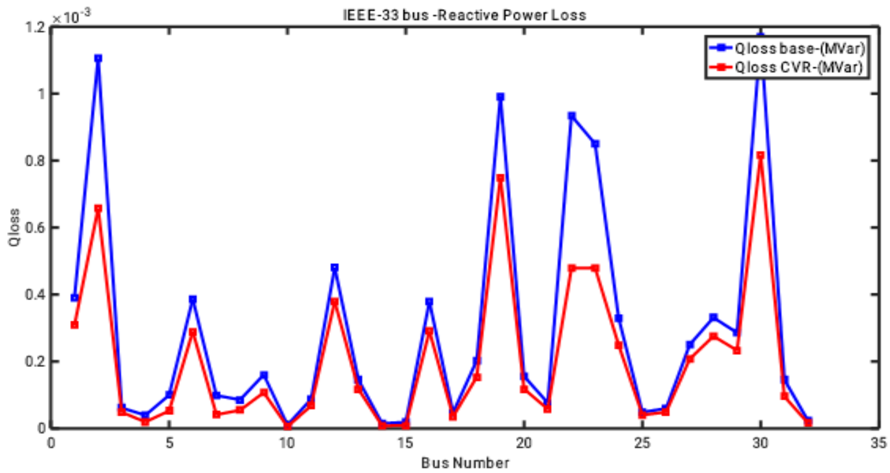

Fig. 16. Reactive power loss using FA Algorithm with and without CVR

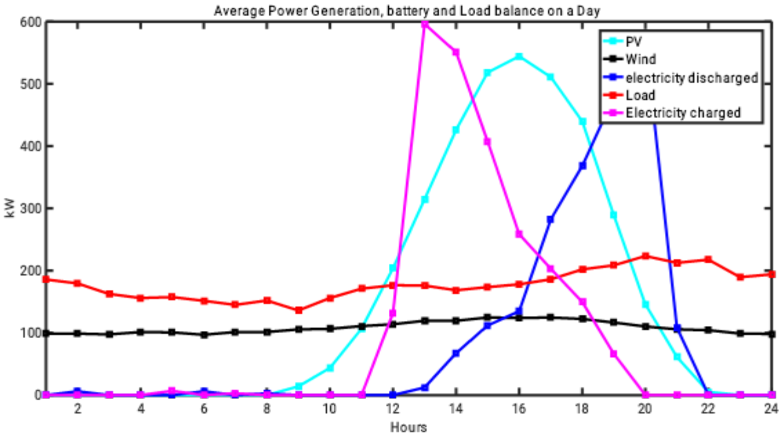

Fig. 17. Energy Management Profile of the System Under Consideration

Figure 17 shows the average power production over a 24-hour period, including wind, solar, and BESS charging and discharging.

(B) Simulation Results of 69-bus System

Similar to the above procedure the proposed methodology is also tests on a 69 bus system shown in figure 2. Figures 18 to 25 display the performance metrics of the 69 bus system.

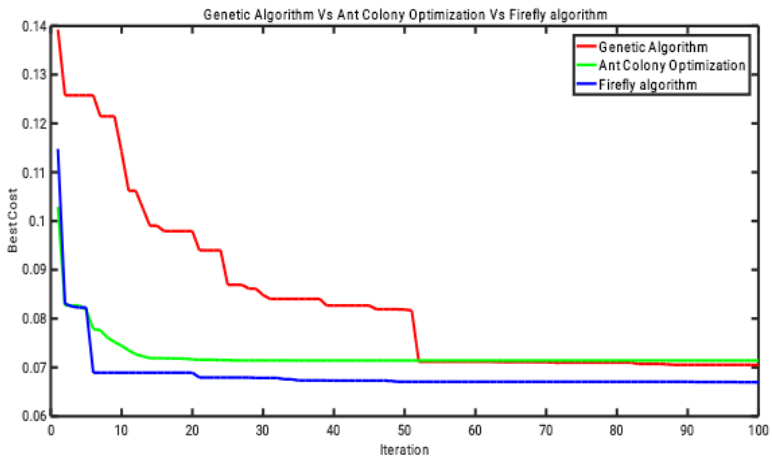

Fig. 18. Comparison of Fitness values for the proposed methods

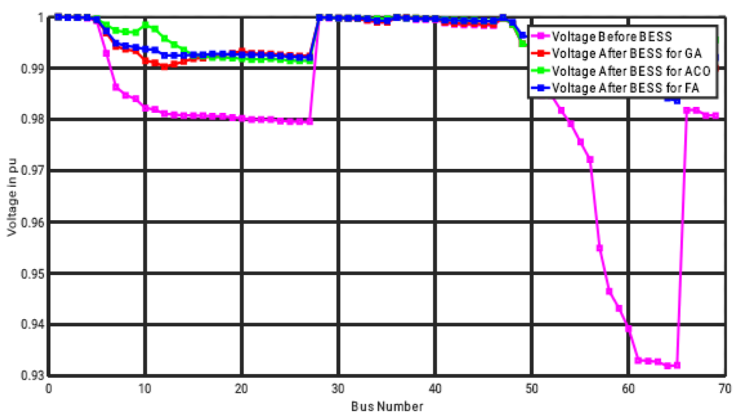

Fig. 19. Comparison of p.u. Voltage with and without BESS for the proposed methods

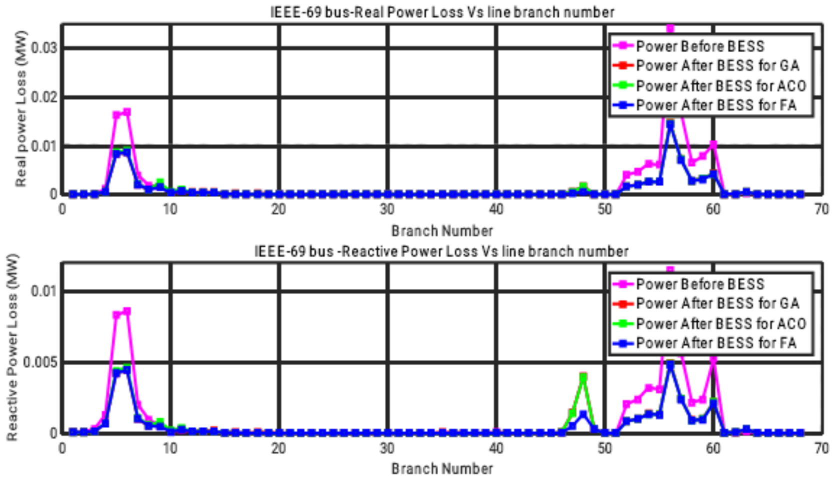

Fig. 20. Loss Comparison for the proposed methods with and without BESS

The optimal cost function for a 69-bus system is discovered after a predetermined number of repetitions, according to the flowchart shown in figure 5 using BESS. The proposed FA is clearly less expensive than the ACA and GA approaches, as shown in Figure 18. The p.u. voltage in Figure 19 before and after the BESS installation is shown using each of the three ways. The 69-bus system's actual and reactive power losses are shown in Figure 20. The power losses for the FA, GA, and ACA methods are shown in Figure 20 both prior to and following the BESS installation.

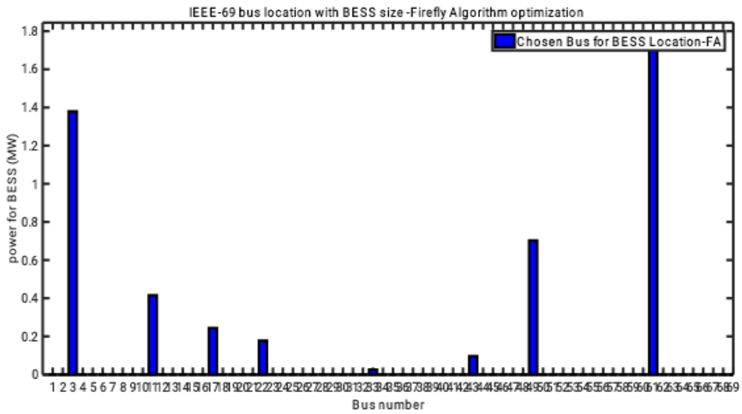

Fig. 21. Location and Power of BESS for the prosed FA technique

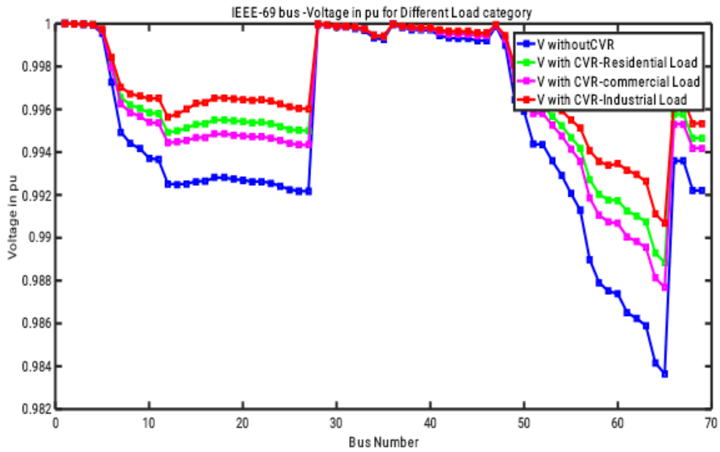

Fig. 22. Voltage profile of various loads with and without CVR

There is no question that the suggested FA algorithm reduces losses in comparison to the conventional method. Figure 20 makes this very evident. Figure 21 displays the ideal BESS dimensions and placement for the proposed FA technique.

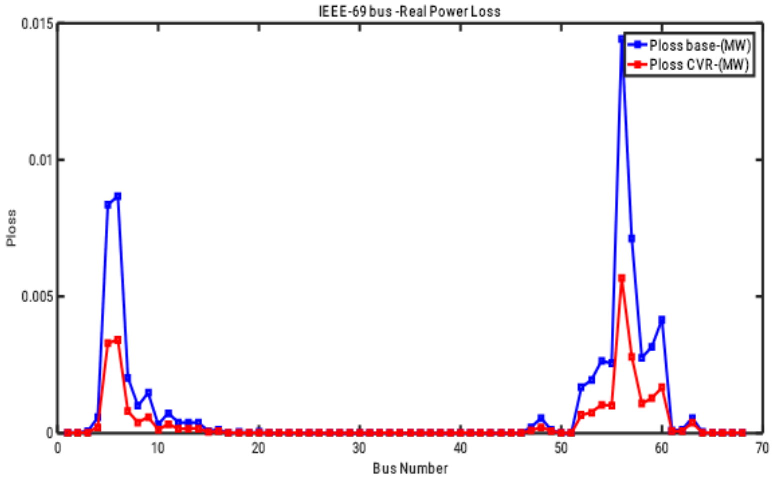

Fig. 23. Real power loss using FA Algorithm with and without CVR

The 69-bus system is simulated with and without CVR implementation in order to accurately measure the CVR effect for comparison. Figures 22–24 display the voltage and actual and reactive power loss with and without CVR for a 69-bus system. As seen in Figure 22, it is evident that all distribution feeder voltage profiles decline to some degree. For the 33-bus system taken into consideration in this study, Figures 23 and 24 note and plot the actual and reactive power losses both with and without CVR.

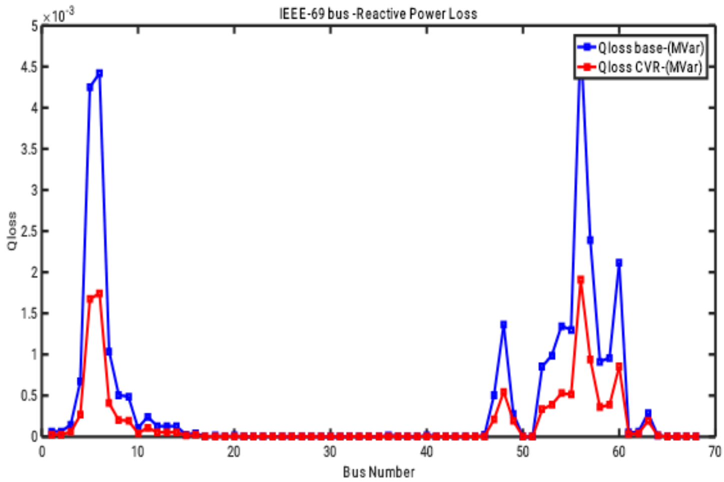

Fig. 24. Reactive power loss using FA Algorithm with and without CVR

Figure 26 shows the average power production of 69-bus network over a 24-hour period, including wind, solar, and BESS charging and discharging. Figure 27 depicts the comparison of the total power losses without BESS and with BESS using the proposed three methods. It can be observed that the FA methodology clearly gives the minimum losses as compared with the other techniques.

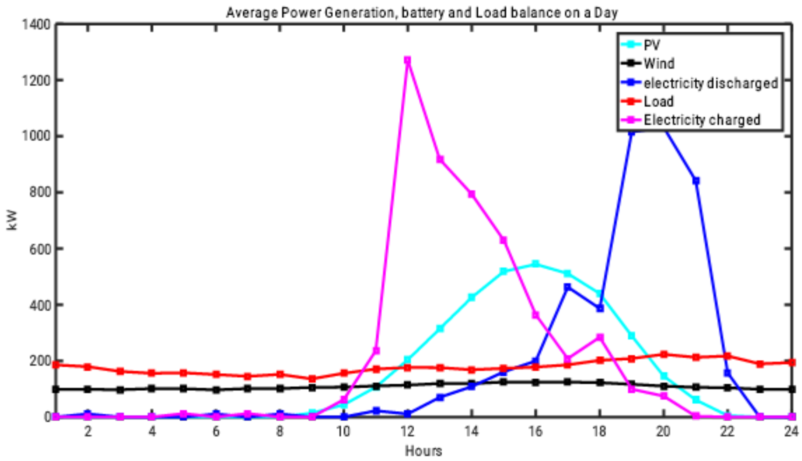

Fig. 25. Energy Management Profile of the System Under Consideration

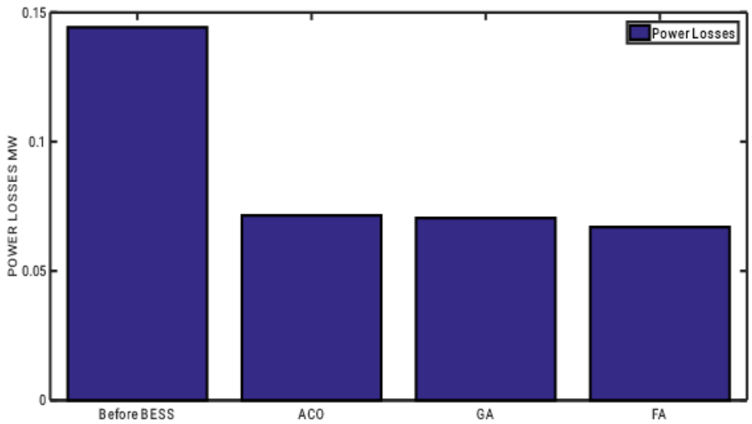

Fig. 26. Comparison of Total Power Losses for the proposed methods

Table 1
Comparison of Results for the proposed methods of 33-bus system

Parameters	Using GA	Using ACA	Using FA
Power Losses including PV, WECS & BESS (MW)	0.026196	0.012541	0.0097224
Average voltages of buses in p.u.	0.98774	0.99701	0.99727
Reduction in real power loss (%)	88.4302	94.4612	95.7061

Table 2
Comparison of Results for the proposed methods of 69-bus system

Parameters	Using GA	Using ACA	Using FA
Power Losses including PV, WECS & BESS (MW)	0.070487	0.071423	0.066967
Average voltages of buses in p.u.	0.99469	0.99627	0.99479
Reduction in real power loss (%)	51.11	50.4606	53.5513

Table 3
Operation results comparison – Power loss

Parameters	33-bus system	69-bus system
P_{loss} without CVR in MW	0.012541	0.066967
P_{loss} with CVR-Residential Load in MW	0.0083279	0.027843
P_{loss} with CVR-commercial Load in MW	0.0081728	0.034426
P_{loss} with CVR-Industrial Load in MW	0.0090482	0.019451

The pertinent parameters for the proposed FA, ACA and GA techniques are shown and contrasted in Tables 1, 2 and 3. It effectively illustrates how effective the proposed GA approach is compared to other techniques. Table 1 and Table 2 compare the output parameters generated by the different optimisation algorithms considered in this study for a 33-bus and 69-bus system, respectively. Table 3 displays the power losses with and without CVR. Energy efficiency is a realistic target, as shown by several studies. CVR reduces power losses to a minimum. The CVR factors are larger under peak load conditions, making the BESS an appropriate unit for voltage regulation.

5. Conclusion

This study determines the best position and size for a BESS in the IEEE 33-bus and 69-bus systems, both of which exhibit irregular load distributions due to CVR and BESS effects. The results of this study shed light on the optimal quantity and placement of BESS in radial power grids. The various load configuration models classify the allocation BESS as a speculative optimisation problem. These changes aim to lower annual running expenses in terms of energy loss BESS installation by combining FA, ACA and GA optimisation methodologies. The observation and findings demonstrate that using CVR with BESS achieves a significant power decrease. The utility saves more energy by using CVR and batteries together, solving the issue of rising load demand, and achieving dynamic stability. The suggested methods are successfully built in Matlab using m-file coding to determine the proper BESS sizing and location as well as loss minimization. Results are subjected to exploration, investigation, and output evaluation. Along with the findings are the conclusions that were reached. In light of this, it can be said that the output of the suggested approach outperformed the GA and ACA methods in terms of power losses from tables 1 and table 2. Dynamic stability is attained via the CVR approach.

References

[1] Wong, Ling Ai, Hussain Shareef, Azah Mohamed, and Ahmad Asrul Ibrahim. "Optimal battery sizing in photovoltaic based distributed generation using enhanced opposition-based firefly algorithm for voltage rise mitigation." *The Scientific World Journal* 2014 (2014). https://doi.org/10.1155/2014/752096

[2] Scott, Nigel C., David J. Atkinson, and James E. Morrell. "Use of load control to regulate voltage on distribution networks with embedded generation." *IEEE transactions on Power Systems* 17, no. 2 (2002): 510-515. https://doi.org/10.1109/TPWRS.2002.1007926

[3] Kakimoto, Naoto, Qin-Yun Piao, and Hiroo Ito. "Voltage control of photovoltaic generator in combination with series reactor." *IEEE Transactions on Sustainable Energy* 2, no. 4 (2011): 374-382. https://doi.org/10.1109/TSTE.2011.2148181

[4] Cappelle, Jan, Johan Vanalme, Stijn Vispoel, Thomas Van Maerhem, Bart Verhelst, Colin Debruyne, and Jan Desmet. "Introducing small storage capacity at residential PV installations to prevent overvoltages." In *2011 IEEE international conference on smart grid communications (SmartGridComm)*, pp. 534-539. IEEE, 2011. https://doi.org/10.1109/SmartGridComm.2011.6102380

[5] Zhang, Cuo, Yan Xu, Zhao Yang Dong, and Jin Ma. "Robust operation of microgrids via two-stage coordinated energy storage and direct load control." *IEEE Transactions on Power Systems* 32, no. 4 (2016): 2858-2868. https://doi.org/10.1109/TPWRS.2016.2627583

[6] Shen, W. X. "Optimally sizing of solar array and battery in a standalone photovoltaic system in Malaysia." *Renewable energy* 34, no. 1 (2009): 348-352. https://doi.org/10.1016/j.renene.2008.03.015

[7] Arun, P., Rangan Banerjee, and Santanu Bandyopadhyay. "Optimum sizing of photovoltaic battery systems incorporating uncertainty through design space approach." *Solar Energy* 83, no. 7 (2009): 1013-1025. https://doi.org/10.1016/j.solener.2009.01.003
[8] El-Khattam, Walid, Y. G. Hegazy, and M. M. A. Salama. "An integrated distributed generation optimization model for distribution system planning." *IEEE Transactions on power systems* 20, no. 2 (2005): 1158-1165. https://doi.org/10.1109/TPWRS.2005.846114
[9] Vrettos, Evangelos I., and Stavros A. Papathanassiou. "Operating policy and optimal sizing of a high penetration RES-BESS system for small isolated grids." *IEEE Transactions on Energy Conversion* 26, no. 3 (2011): 744-756. https://doi.org/10.1109/TEC.2011.2129571
[10] Ekren, Orhan, and Banu Y. Ekren. "Size optimization of a PV/wind hybrid energy conversion system with battery storage using simulated annealing." *Applied energy* 87, no. 2 (2010): 592-598. https://doi.org/10.1016/j.apenergy.2009.05.022
[11] Khalid, Muhammad, Abdollah Ahmadi, Andrey V. Savkin, and Vassilios G. Agelidis. "Minimizing the energy cost for microgrids integrated with renewable energy resources and conventional generation using controlled battery energy storage." *Renewable Energy* 97 (2016): 646-655. https://doi.org/10.1016/j.renene.2016.05.042
[12] Thongchart Kerdphol, Kiyotaka Fiji, Yasunori Mitani, Masayuki Watanabe and Yaser Qudaih, "Optimization of Battery Energy Storage using particle swarm optimization for standalone micro-grids," *Electrical power and energy systems* 81 (2016): 32-39. https://doi.org/10.1016/j.ijepes.2016.02.006
[13] Chen, W. Z., Q. B. Li, L. Shi, Y. Luo, D. D. Zhan, N. Shi, and K. Liu. "Energy storage sizing for dispatchability of wind farm." In *2012 11th International Conference on Environment and Electrical Engineering*, pp. 382-387. IEEE, 2012. https://doi.org/10.1109/EEEIC.2012.6221407
[14] Chaiyatham, Theerawut, and Issarachai Ngamroo. "Bee colony optimization of battery capacity and placement for mitigation of voltage rise by PV in radial distribution network." In *2012 10th International Power & Energy Conference (IPEC)*, pp. 13-18. IEEE, 2012. https://doi.org/10.1109/ASSCC.2012.6523231
[15] Montoya-Bueno, Sergio, Jos Ignacio Muoz, and Javier Contreras. "A stochastic investment model for renewable generation in distribution systems." *IEEE Transactions on Sustainable Energy* 6, no. 4 (2015): 1466-1474. https://doi.org/10.1109/TSTE.2015.2444438
[16] Tanwar, Surender Singh, and Dheeraj Kumar Khatod. "Techno-economic and environmental approach for optimal placement and sizing of renewable DGs in distribution system." *Energy* 127 (2017): 52-67. https://doi.org/10.1016/j.energy.2017.02.172
[17] Awad, Ahmed SA, Tarek HM El-Fouly, and Magdy MA Salama. "Optimal ESS allocation for load management application." *IEEE Transactions on Power systems* 30, no. 1 (2014): 327-336. https://doi.org/10.1109/TPWRS.2014.2326044
[18] Bahramirad, Shaghayegh, Wanda Reder, and Amin Khodaei. "Reliability-constrained optimal sizing of energy storage system in a microgrid." *IEEE Transactions on Smart Grid* 3, no. 4 (2012): 2056-2062. https://doi.org/10.1109/TSG.2012.2217991
[19] Nick, Mostafa, Marc Hohmann, Rachid Cherkaoui, and Mario Paolone. "Optimal location and sizing of distributed storage systems in active distribution networks." In *2013 IEEE grenoble conference*, pp. 1-6. IEEE, 2013. https://doi.org/10.1109/PTC.2013.6652514
[20] Amanifar, O. "Optimal distributed generation placement and sizing for loss and THD reduction and voltage profile improvement in distribution systems using particle swarm optimization and sensitivity analysis." In *16th Electrical Power Distribution Conference*, pp. 1-7. IEEE, 2011.
[21] Miranda, Vladimiro. "Wind power, distributed generation: new challenges, new solutions." *Turkish Journal of Electrical Engineering and Computer Sciences* 14, no. 3 (2006): 455-473.
[22] Kim, Kyu-Ho, Yu-Jeong Lee, Sang-Bong Rhee, Sang-Kuen Lee, and Seok-Ku You. "Dispersed generator placement using fuzzy-GA in distribution systems." In *IEEE Power Engineering Society Summer Meeting,*, vol. 3, pp. 1148-1153. IEEE, 2002.
[23] Silvestri, Andrea, Alberto Berizzi, and Sergio Buonanno. "Distributed generation planning using genetic algorithms." In *PowerTech Budapest 99. Abstract Records.(Cat. No. 99EX376)*, p. 257. IEEE, 1999.
[24] Chen, Shuai X., Hoay Beng Gooi, and MingQiang Wang. "Sizing of energy storage for microgrids." *IEEE transactions on smart grid* 3, no. 1 (2011): 142-151. https://doi.org/10.1109/TSG.2011.2160745
[25] Injeti, Satish Kumar, and N. Prema Kumar. "A novel approach to identify optimal access point and capacity of multiple DGs in a small, medium and large scale radial distribution systems." *International Journal of Electrical Power & Energy Systems* 45, no. 1 (2013): 142-151. https://doi.org/10.1016/j.ijepes.2012.08.043
[26] Sulaiman, Mohd Herwan, M. W. Mustafa, A. Azmi, O. Aliman, and SR Abdul Rahim. "Optimal allocation and sizing of distributed generation in distribution system via firefly algorithm." In *2012 IEEE international power engineering*

and optimization conference Melaka, Malaysia, pp. 84-89. IEEE, 2012. https://doi.org/10.1109/PEOCO.2012.6230840

[27] Alinejad-Beromi, Y., M. Sedighizadeh, M. R. Bayat, and M. E. Khodayar. "Using genetic alghoritm for distributed generation allocation to reduce losses and improve voltage profile." In *2007 42nd International Universities Power Engineering Conference*, pp. 954-959. IEEE, 2007. https://doi.org/10.1109/UPEC.2007.4469077

[28] Yang, Xin-She. "Firefly algorithms for multimodal optimization." In *International symposium on stochastic algorithms*, pp. 169-178. Berlin, Heidelberg: Springer Berlin Heidelberg, 2009. https://doi.org/10.1007/978-3-642-04944-6_14

[29] Faessler, Bernhard, Michael Schuler, Markus Preißinger, and Peter Kepplinger. "Battery storage systems as grid-balancing measure in low-voltage distribution grids with distributed generation." *Energies* 10, no. 12 (2017): 2161. https://doi.org/10.3390/en10122161

[30] Ramadan, H. S., A. F. Bendary, and S. Nagy. "Particle swarm optimization algorithm for capacitor allocation problem in distribution systems with wind turbine generators." *International Journal of Electrical Power & Energy Systems* 84 (2017): 143-152. https://doi.org/10.1016/j.ijepes.2016.04.041

[31] Dorigo, Marco, Gianni Di Caro, and Luca M. Gambardella. "Ant algorithms for discrete optimization." *Artificial life* 5, no. 2 (1999): 137-172. https://doi.org/10.1162/106454699568728