International Journal of Engineering Trends and Technology
ISSN: 2231–5381 / https://doi.org/10.14445/22315381/IJETT-V71I9P225

Volume 71 Issue 9, 282-293, September 2023
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Original Article

Operation of Transmission Congestion Management Through Optimal Size of PV using a Hybrid: Whale Optimization and Firefly Algorithms

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Received: 29 December 2022 Revised: 18 June 2023 Accepted: 18 August 2023 Published: 03 September 2023

Abstract - *Congestion control in relaxed power system networks is addressed in this study with a hybrid approach that factors in the optimal placement of distributed generators. This method is unique because it assesses the 118-bus system to determine the best location for a photovoltaic (PV) facility within a deregulated electrical grid. The MATPOWER-supported 118-bus test system facilitates PV recitation research for improving power system safety. Unexpected loads can compromise the strength and safety of a power grid. Safety measures against disturbances that include compensation are a must. The structure is checked out to unclog the line while electricity is still being transmitted. Several scenarios, including those with and without a PV system modified by whale-firefly, have been tested to determine the optimal operating parameters for the suggested setup. According to the results, a hybrid algorithm-tuned PV system is more effective than one without PV components. The system is evaluated on the 180 buses for its effectiveness and usefulness.*

Keywords - *Photo voltaic, Whale algorithm, Firefly algorithm, Continuation power flow, Congestion management.*

1. Introduction

Recent years have seen significant shifts in the energy market as a result of privatization and deregulation initiatives around the world. Transmission grids are seeing increased utilization due to the upgraded electricity system. Power plants in a deregulated electricity market frequently operate at or near their maximum capacity since everyone involved is looking to maximize profits. One technological difficulty that arises in a free-market economy is the possibility of transmission bottlenecks. One of the biggest obstacles to the calm operation of the electrical system is congestion control. A multitude of factors, such as a rise in consignment demand, a lack of maintenance, or a broken piece of equipment, can contribute to congestion in a deregulated system. The photovoltaic effect is typically used by photovoltaic cells to convert solar energy into electricity. Most PV systems nowadays are employed as part of grid-connected energy generation schemes. However, their original real-world application was to provide electricity to satellites and other spacecraft in orbit. An inverter would be needed to convert the DC power source into an AC one. Production of solar cells and photovoltaic systems has skyrocketed in recent years in response to surging demand. The stability, availability, and dependability of the energy grid are all at risk due to a lack of knowledge in the field of congestion management in the distribution network. When one or more transmission lines are overloaded, it can cause instability in the electrical grid. In order to keep the voltage stable and cut down on energy waste, a revolutionary hybrid algorithm is applied for system evaluation.

There has been a lot of research done on the bus system. The 118-bus specification is utilized here. A lot of study has gone into bus architecture. This study is the first to employ the 118-bus standard in an academic investigation. This study stands out from the rest because it uses an innovative hybrid technique to control the optimal location of DG with respect to reducing overall system wounded. This paper's use of a combined method to ascertain where DG is most beneficial in terms of lowering system losses is particularly intriguing. As a result of (1) effectively eliminating the surplus in the positions produced by various measured possibilities with the minimum shift in the generation agenda, (2) effectively improving the hybrid algorithms as an optimizing implement to minimize losses under the 118-bus system, and (3) providing evidence that the projected hybrid method is greater to a single algorithm in the given application, this study contributes significantly to the field.

2. Outline of Literature Survey

Deals with the issue of managing congestion while avoiding stability-related offline transmission capacity constraints [1]. To maintain an adequate level of protection, the limitations on line power flows are changed by optimum power flows limitations that usually target voltage uncertainties, which are the most frequent cause of constancy issues. An efficient way of controlling congestion in power systems is presented in [2]. By rescheduling generating or reducing demand on participating producers and loads, transmission system congestion or overloads are minimized. The two competing goals of (a) reducing overload and (b) minimizing operational costs are optimized to produce Pareto-optimal results. [3] The enlargement of social welfare and the expansion of profit are two separate goals for which the tricky of optimum location, size included, is stated. Built on location and sizing price, potential places for DG placement are found.

Another ranking to use to choose potential nodes for DG location is customer expense, which is calculated as an effect of LMP and load at each load bus. One of the most popular and apparent methods for reducing congestion is rearranging the power outputs of the system's generators, according to [4]. However, not all system generators are obligated to take part in congestion management. The goal of this effort is to create an appropriate formulation and solution approach for this problem. The current paper offers two new insights. First, a method for choosing contributing generators founded on their sensitivity to the flow of electricity on choked lines has been shaped. The second reference in this work is a PSO-based method to reduce the discrepancy between the rescheduled generator power output levels and those that were primarily proposed. To decrease power loss, [5] introduces a GA-based technique to choose the best size and place of distributed generation components to be located in radial and networked systems. A cost investigation method for choosing the best place and extent of distributed resources to reduce bottlenecks and boost system security is presented in [6].

A list of prospective buses with the highest priority is shaped in instruction to find the solution space. The perfect placement and size problem is then examined. Different load levels are added to this training based on the load period curve, increasing the outcomes' exactness. The suggested strategy takes into explanation economic issues such as congestion charges, postponed upgrade investment, and DR expenses. [7] suggested an assessment of the cluster/zone method and comparative electrical distance method for the switch of bottleneck constructed on the criteria considered. The cluster or zone technique bases the generation rescheduling on users' impact on congestion by using transmission congestion distribution parameters. The appropriate ratios of generations for the planned overload relief are obtained using the comparative electrical distance technique. [8] The suggested congestion organization delinquent is designed to reduce the cost of switching between renewable and conservative generators to reduce congestion, subject to operative, line overcapacity, periodic, and time limitations. With the concept of voltage constancy as a Loadability constraint, [9] addresses the significant subject of management transmission arrangement bottleneck in a pool energy market situation. To maximize social benefit, [10] offers a comprehensive optimal perfect of bottleneck organization for the de-restricted electricity division that communications the pool in conjunction with bilateral and multidimensional arrangements that have been confidentially exchanged. This model establishes Locational Marginal Pricing (LMP) based on the marginal cost theory. It also establishes pool demand, generations, and non-firm transaction sizes.

This model takes into explanation communications involving both firms and non-firms. The proposed model has been used to analyze the proposed model and has been practical to the 30-bus test arrangement. By regulating power flows in the system, [11] proposed FACTS devices benefit from minimizing the movements in extremely loaded lines, cumulative the load ability of the system and dropping manufacturing costs. There are two steps involved in managing congestion with FACTS devices. Before setting these devices' control parameter settings, the best place for them in the system must be determined. In turn, transmission cables get congested [12]. Managing power system congestion is of extreme importance. This paper consolidates all the publications on congestion management by examining several strategies. By designating a STATCOM device, [13] address system voltage variation has been reduced. By installing a UPFC controller, the fitness value, which includes actual power loss and overall voltage deviation, has been decreased. That positioning has reduced the system's overall line loading. For proper FACTS device sizing and settlement, Differential Evolution has been selected. The 30-bus scheme has been used as a testing system. [14] The best times and places to apply demand response programs have been recognized using a novel method planned in this paper. [15, 16] Congestion regulation involves both technological and economic concerns.

The objective function requires a quadratic method since linear methods cannot minimize grid losses. By combining branch loading, voltage constancy, and loss minimization as purposes, [17, 18] shows the best location for FACTS controllers. It has been noted that the ideal locations for one purpose are unsuitable for the other two objectives. The difference line operation factor and gravitational search algorithm based on optimal tuning of IPFC are proposed in the [19]. The first issue raised by [20] is locating the congested line's precise position to deploy the best-sized DG there and reduce costs. In this study, a hybridizing of the firefly method and differential evolution optimization search has been recommended. For locating and sizing the static VAR compensator in a hybrid power structure, [22] proposes an effective optimization approach. The voltage deviation minimization and the voltage constancy enhancement index are explained in this paper to establish the best place and size for SVC. An effective approach to the power system congestion regulator is presented in the [23, 24] study. The two competing goals of (a) reducing overload and (b) minimizing effective costs are optimized to produce Pareto-optimal results. In [25], it presents a novel CM method to reduce congestion and advance the voltage outline in a structure using controllers in the efficient power system. [26] was discussed the key problems and tasks in restructured power systems.

The authors emphasized that the competitive market CM plays a significant role in the process of economical, steady procedure of the power flow in the structure. This research paper's research gap addresses the issue of congestion management in the past. The creation of a cutting-edge method to address the congestion management issue is a key driving reason behind the current endeavor. The current trend is to use metaheuristic algorithms inspired by nature to solve such problems, and it has been shown that metaheuristics are incredibly effective. In contrast to previous algorithms, a hybrid operates independently and seeks the optimal location for itself while taking into account both its current location and the locations of other fireflies. As a result, it requires fewer iterations to transition from the local minima to the global minima. The hybrid also incorporates the advancement within its space from earlier stages and the self-improvement procedure within the current environment. This approach is the best ideal to utilize for these kinds of optimization problems due to its robustness and high convergence rate. The flow chart is described in Fig 1.

3. Selection of Objective and Constraint Function

The unbiassed function is maximizing through loading parameters. It is used to advance the maximum load ability. First, the fitness function should be analyzed; it is that.

$$\text{Fitness} = \max(\lambda) \quad (1)$$

It is subjected to

$$P_{gmin-18} < P_{g-18} < P_{gmax-18} \quad (2)$$

$$P_{gmin-35} < P_{g-35} < P_{gmax-35} \quad (3)$$

$$P_{gmin-41} < P_{g-41} < P_{gmax-41} \quad (4)$$

$$P_{gmin-55} < P_{g-55} < P_{gmax-55} \quad (5)$$

$$P_{gmin-73} < P_{g-73} < P_{gmax-73} \quad (6)$$

Equality constraints

$$P_{G1} - P_{D1} - V_{s1} = 0 \quad (7)$$

$$Q_{G1} - Q_{D1} - V_{s} = 0 \quad (8)$$

V_{s1}, V_{r1}= Transfer conductance between bus “s1” and “r1”.
G_{s1r1}, B_{s1r1} = Transfer conductance &susceptance between bus “s1” and “r1”.
P_{Gs1}, P_{Ds1} = Active power inject & demand at bus “s1”.
Q_{Gs1}, Q_{Ds1} = Reactive power inject & demand at bus “s1”.
δ_{sr} = Voltage angle difference between bus “s1” and “r1”.

Inequality Constraints

$$V_{min} < V < V_{max} \quad (9)$$

$$T_{min} < T < T_{max} \quad (10)$$

V- voltage and T – transformer tap settings. Here, the power generation of the PV arrangement is chosen to tune as per the algorithmic method.

In Table 1, the boundaries of parameters have been given. The lower bound is 1, and the upper bound is 50 for the PV generator. In Table 2, the optimal sizing of PV systems has been found by using a hybrid algorithm.

Table 1. Parameter boundaries

	PV(18)	**PV(35)**	**PV(41)**	**PV(55)**	**PV(73)**
LB	01	01	01	01	01
UB	50	50	50	50	50

Table 2. The optimal size of the PV system using whale optimization and firefly algorithm

Bus 18	**Bus 35**	**Bus 41**	**Bus 55**	**Bus 73**
10	12.64	44.54	50	50

4. Proposed and Analysis of 118 Buses System

Figure 1 depicts the 118-bus test setup used to identify the system bottleneck; it includes 19 generators, 99 loads, and 5 PV procedures. PV systems' effectiveness is evaluated when they are not producing any electricity and when they are. The system becomes overwhelmed as the load increases over time. The PV system has been expanded to increase the system's load capacity to counteract this. The appropriate size of the PV system has been calculated with the help of WOA-Firefly, considering the system's presentation. Figures 2 and 3 represent the voltage profile and PV power generation, and figures 4 and 5 explain the profile with PV power generation disabled.

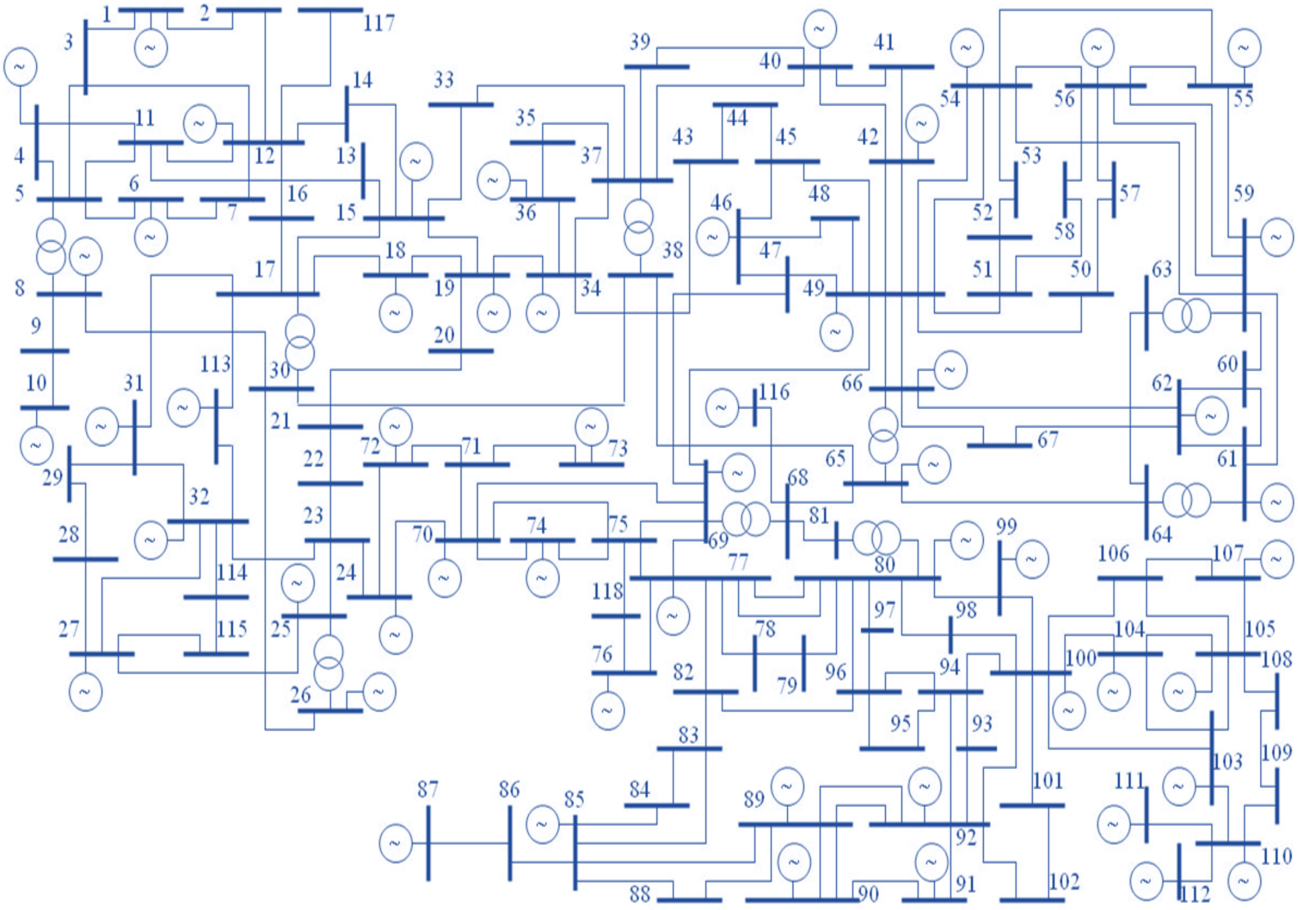

Fig. 1 Complete analysis of 118 bus system structure

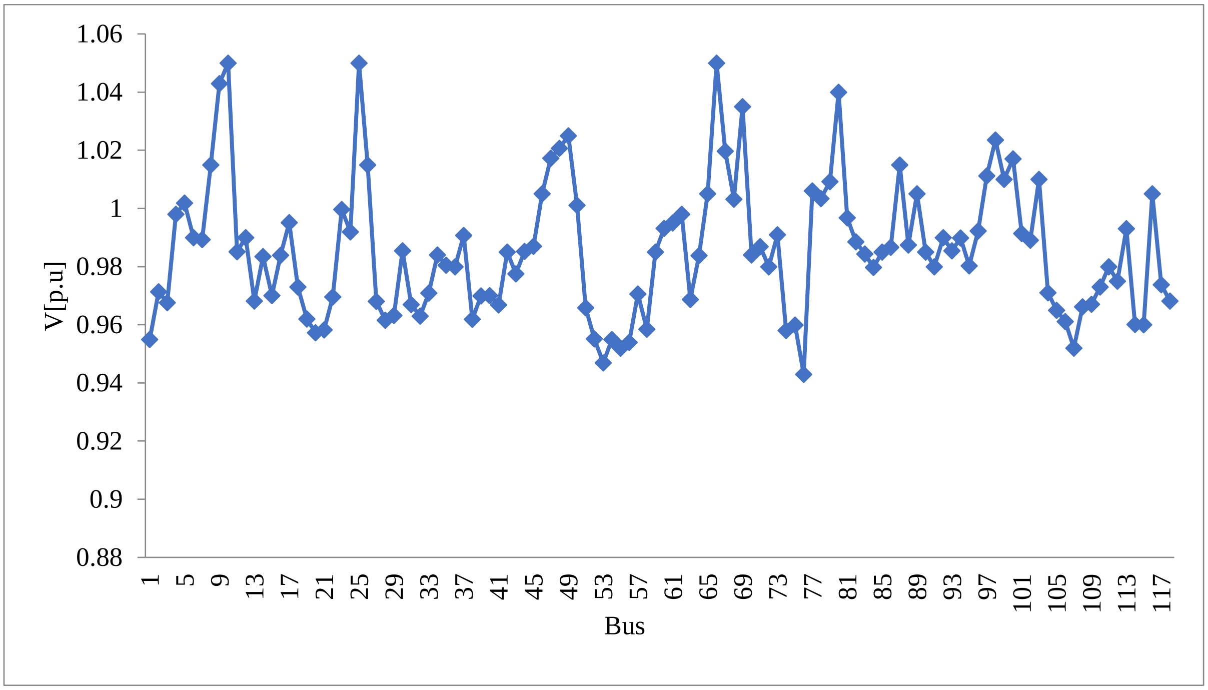

Fig. 2 Voltage magnitude without a PV arrangement

Figure 2 depicts the system's voltage profile in the absence of a PV installation. Buses 10, 25, and 66 have the highest voltage at 1.05 p.u. Figures 3 and 4 show the system's real and reactive power profiles without a PV system. At bus 89, the real power peak is 607 MW. At bus number 87, a real power peak of 4 MW is required. Bus number 49 defines a maximum reactive power outline of 113.29 MVAR. For route 69's bus, a minimum reactive profile of -73.99 MVAR is specified—total power output and losses in the absence of PV, as shown in Table 3.

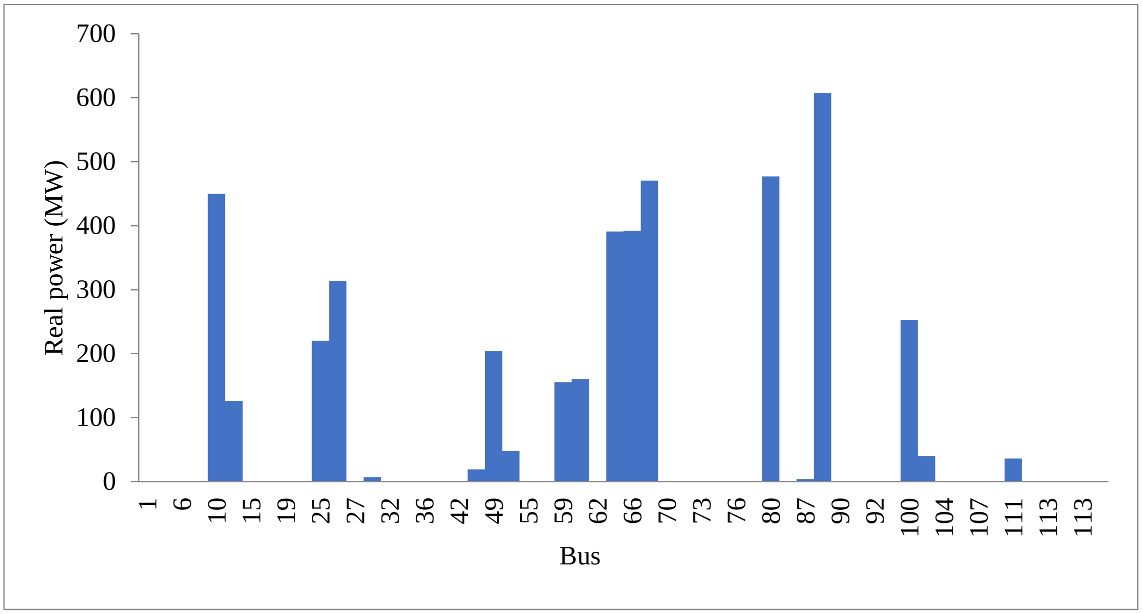

Fig. 3 Real power without a PV arrangement

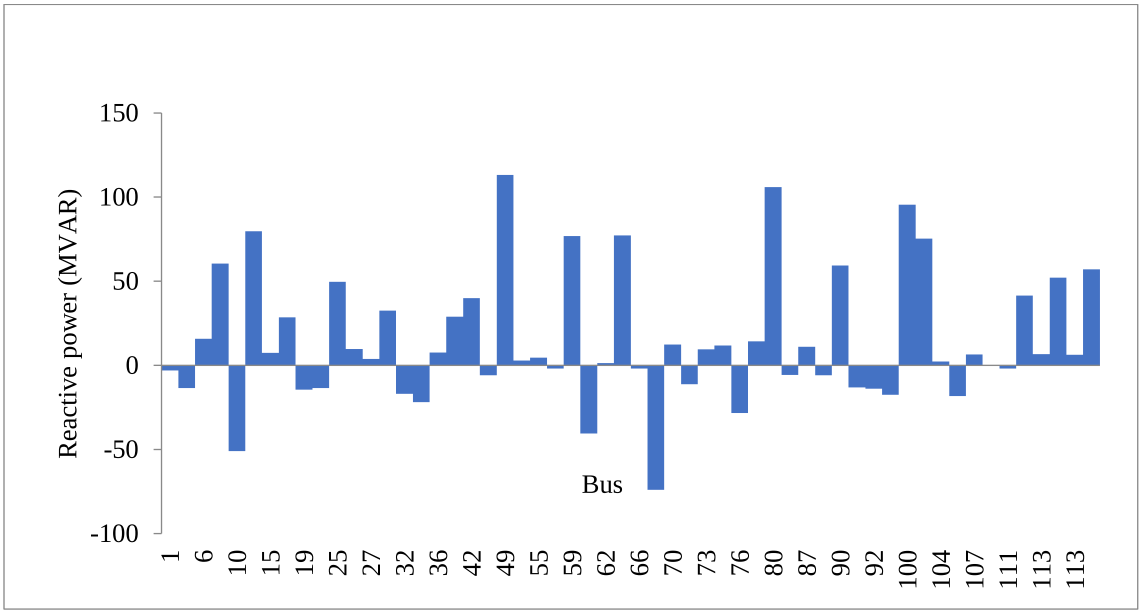

Fig. 4 Reactive power without a PV arrangement

Table 3. Overall generation and losses without PV system

	Generation	**Load**	**Losses**
Real power	4372.59	4242.00	130.59
Reactive power	771.28	1438.00	-666.72

When the load is cumulative up to 10% without PV, the maximum voltage outline is 1.05 p.u at bus No 10, No 25, and No 66. The maximum real power outline is 698.513 MW at bus No 69. The minimum real power outline is 4 MVAR at bus No 87. The maximum reactive power outline is 151.66 MVAR at bus No 49. The minimum reactive power outline is -93.32 MVAR at bus No 69. It is shown in Fig. 5, 6, and 7.

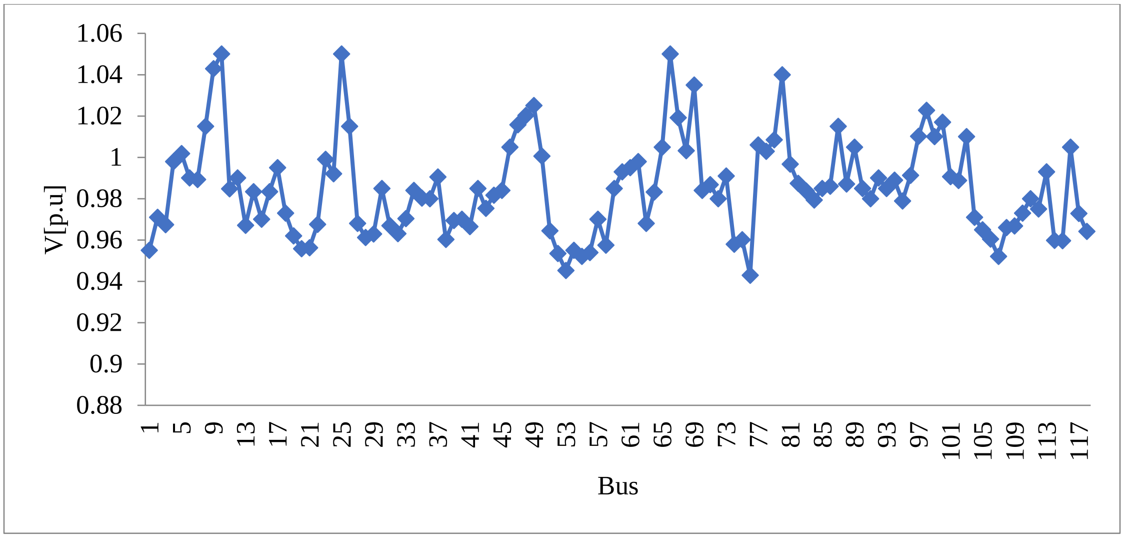

Fig. 5 Voltage magnitude with load 10% *increased* without a PV system

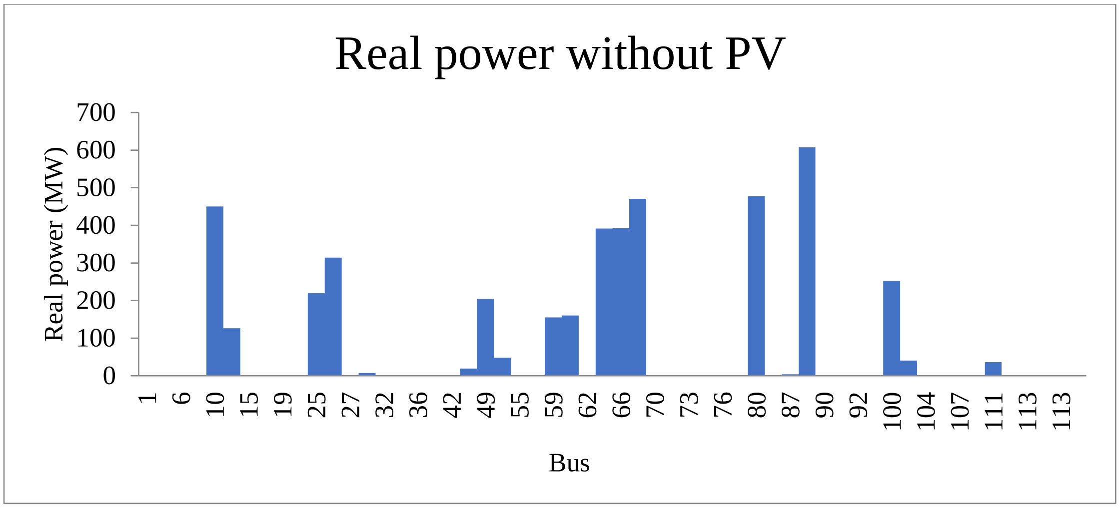

Fig. 6 Real power with a load of 10% increased without a PV system

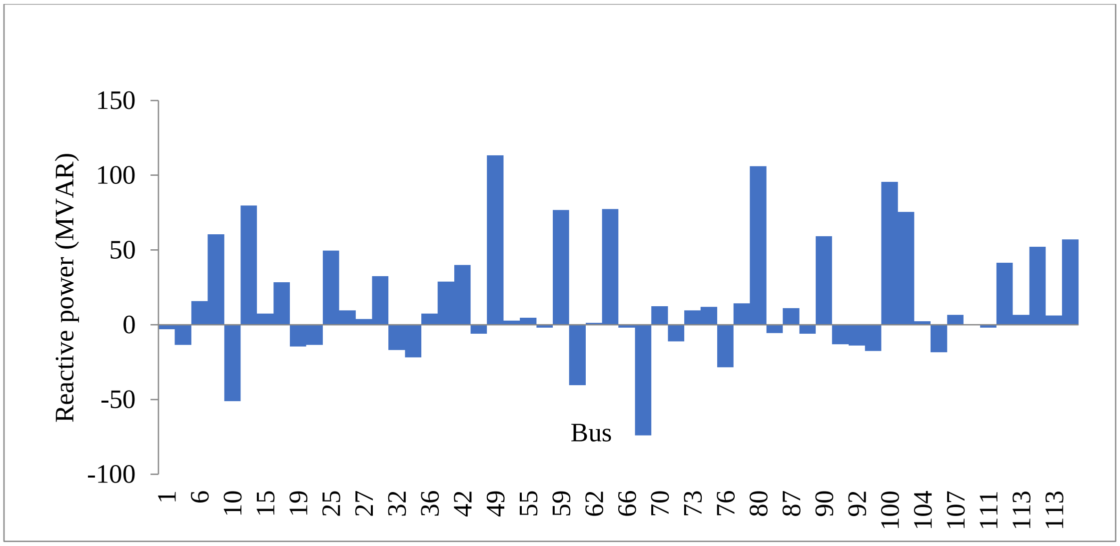

Fig. 7 Reactive power *with a* load of 10% increased without a PV *system*

5. Flow Chart

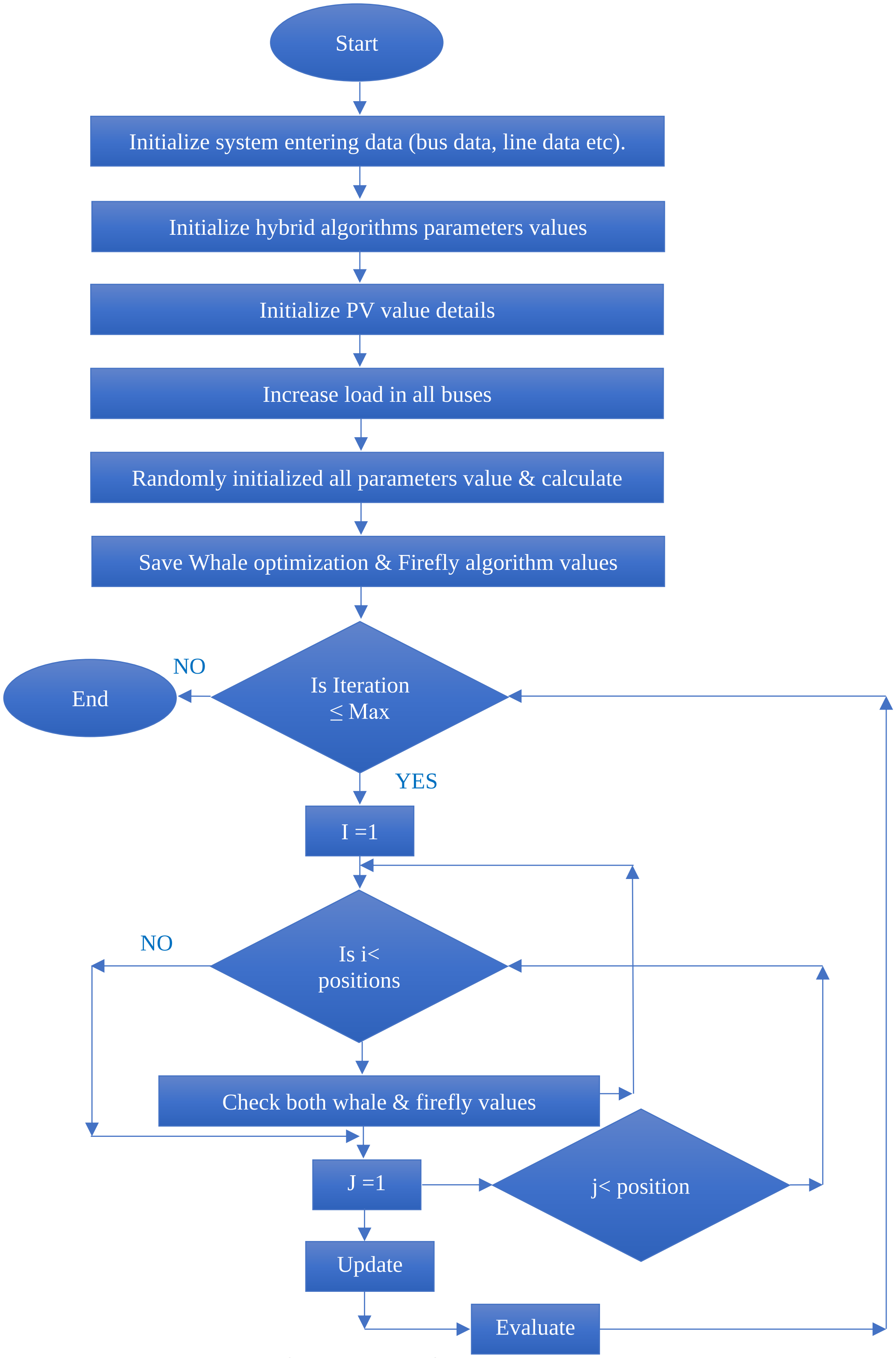

Fig. 8 Flow chart of the optimal size of PV by a hybrid algorithm

Table 4. Overall power generation and losses increase the load by 10% without a PV

Name	Generation	Load	Losses
Real power	4834.31	4666.20	168.11
Reactive power	1123.27	1581.80	-458.53

The flow chart is developed with the help of both algorithms, and PV is placed at optimal points to improve voltage magnitude. And also analysis of other parameters. It is described in Figure 8.

6. Results and Discussion

The system makes use of a combination of the firefly algorithm and the hybrid whale optimization technique. Figure 9 depicts the magnitude of the PV system's voltage. At bus nos. 10, 25, and 66, the voltage peaks at 1.05 p.u.

The system's real and reactive power outlines without a PV structure are described in Figure 10 and Figure 11. The maximum real power outline is 607 MW at bus 89. The minimum real power outline is 4 MW at bus 87. The maximum reactive power outline is 103.66 MVAR at bus 80. The minimum reactive power outline is -55.96 MVAR at bus 69.

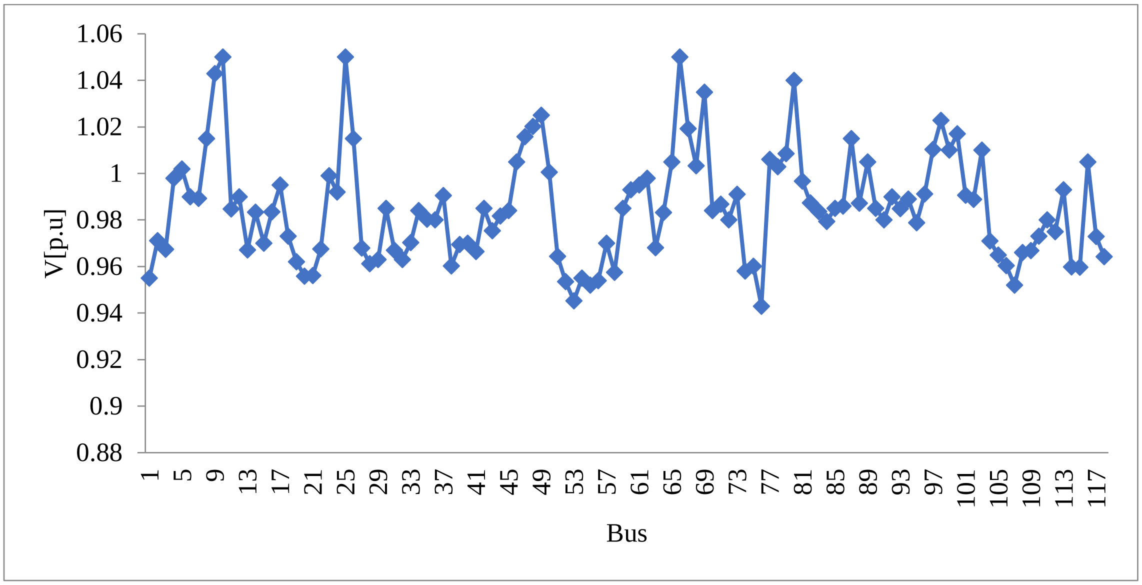

Fig. 9 Voltage magnitude with PV arrangement tuned in the hybrid algorithm

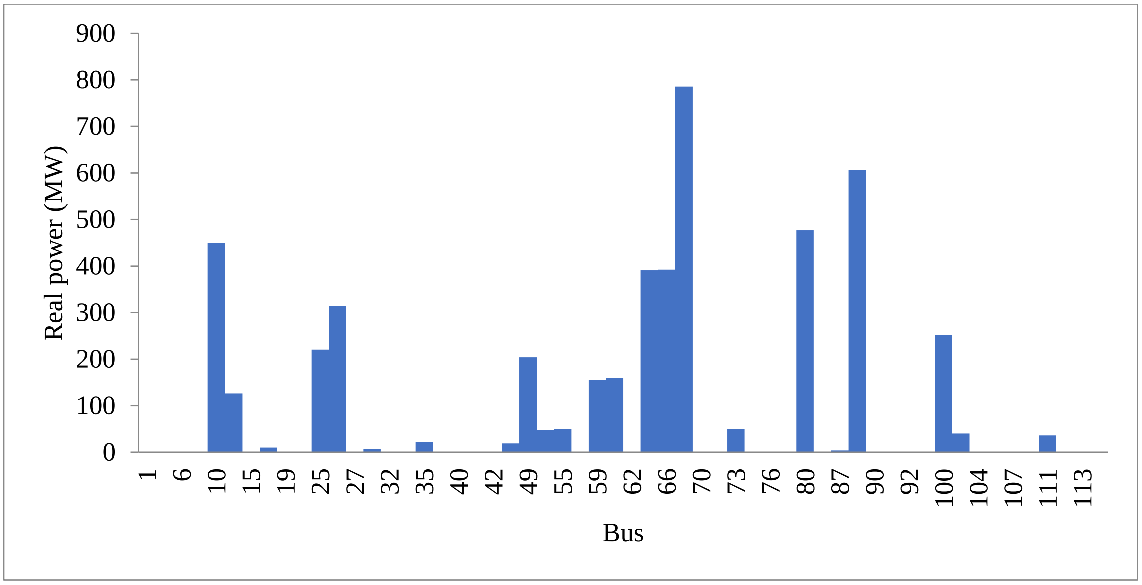

Fig. 10 Real power with PV system tuned in the hybrid algorithm

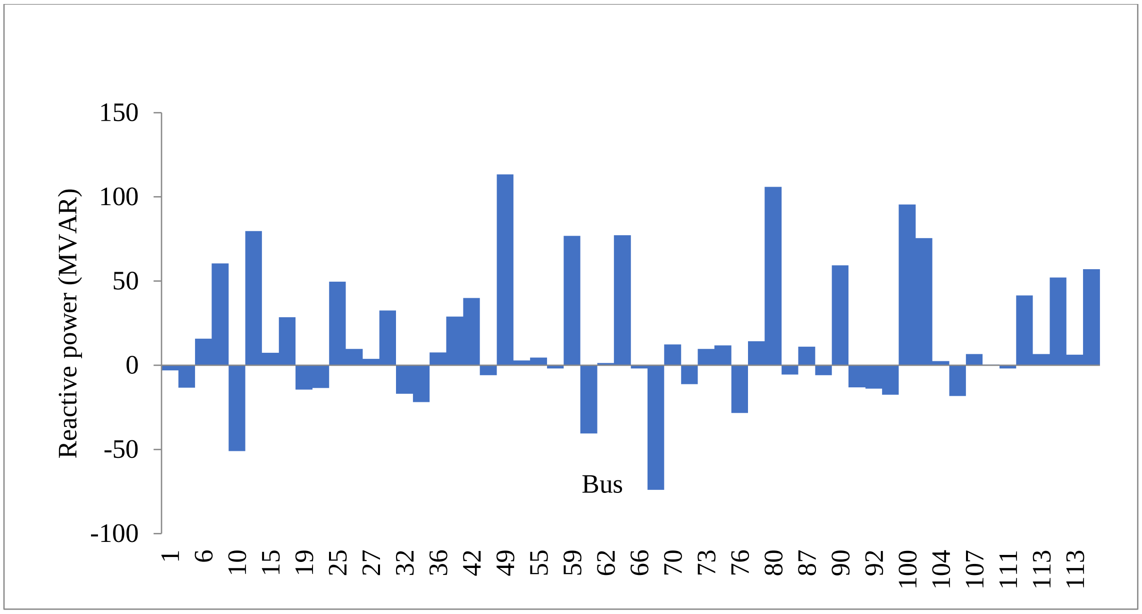

Fig. 11 Reactive power with PV arrangement tuned in the hybrid algorithm

The total generation and losses with the PV system tuned by the hybrid algorithm are shown in Table 5.

Table 5. Overall generation and losses with PV system tuned by a hybrid algorithm

	Generation	Load	Losses
Real power	4357.80	4242.00	115.80
Reactive power	694.66	1438.00	743.34

The load has been increased to 10% and tuned by a hybrid algorithm with a PV arrangement. The voltage magnitude is described in Figure 12. The maximum voltage profile is 1.05 p.u at bus 10,25,66.

The system's real power outline and reactive power profile with a PV system load of 10% are described in Figure 13 and Figure 14. The maximum real power outline is 785.29 MW at bus 89. The minimum real power outline is 4 MW at bus 87. The maximum reactive power outline is 140.86 MVAR at bus 49. The minimum reactive power profile is -91.55 MVAR at bus 69.

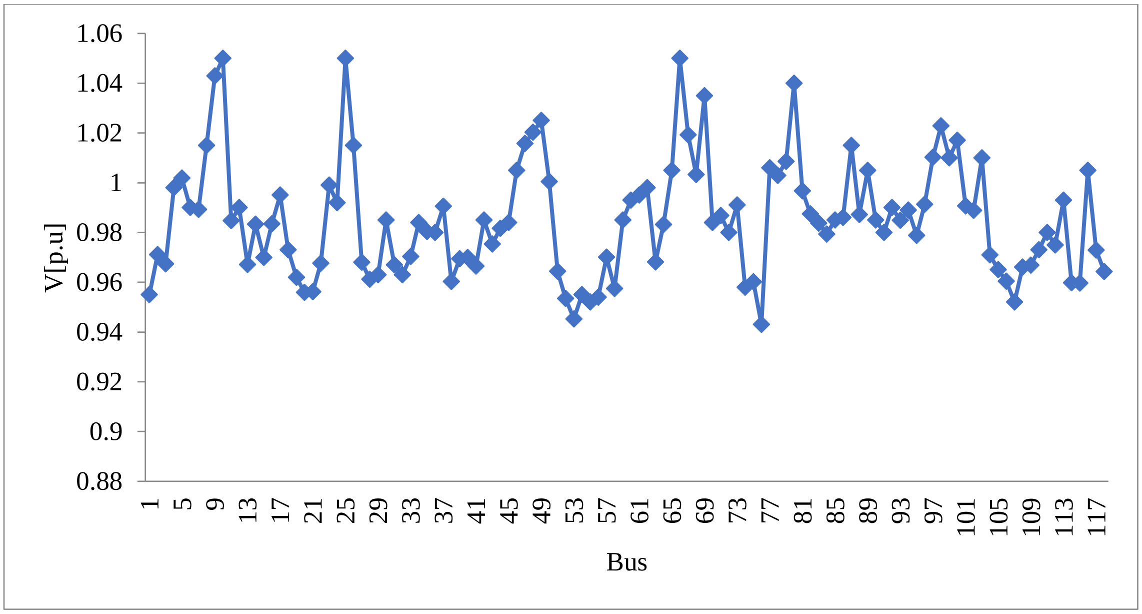

Fig. 12 Voltage magnitude and load 10% increased with the PV system tuned into the hybrid algorithm

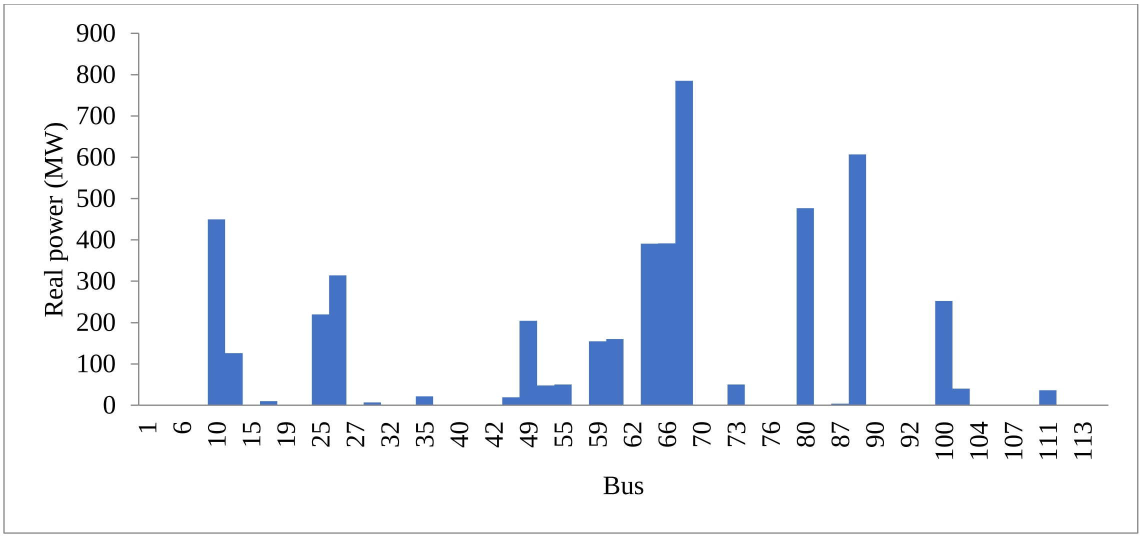

Fig. 13 Real power and load 10% increased with the PV system *tuned by* the hybrid algorithm

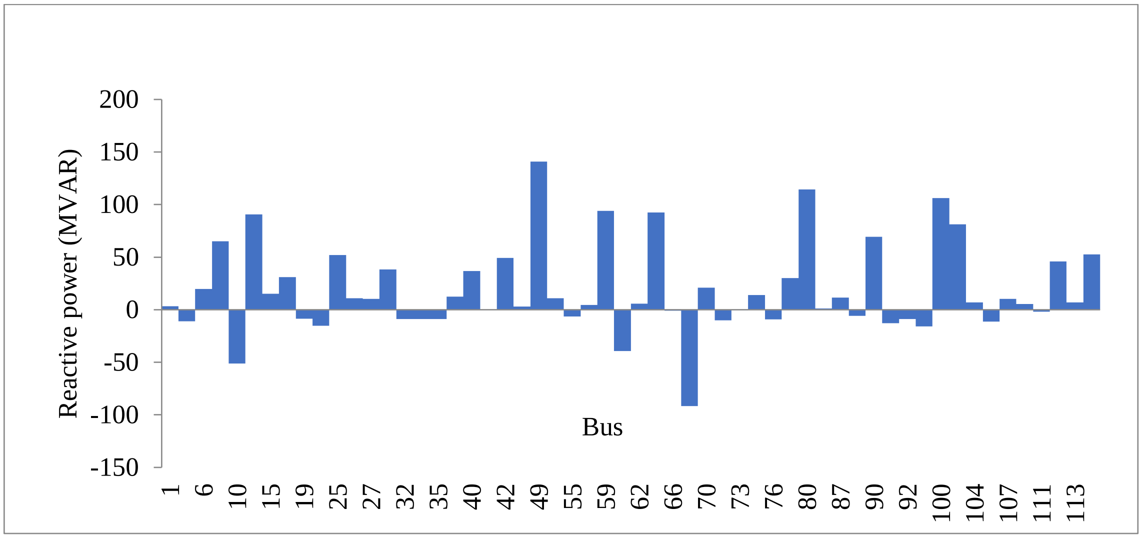

Fig. 14 Reactive power and load 10% increased with the PV arrangement tuned in the hybrid algorithm

Table 6. Overall power generation and losses increase the load by 10% with PV tuned by a hybrid algorithm

	Generation	**Load**	**Losses**
Real power	4810.90	4666.20	143.70
Reactive power	992.21	1581.80	-589.59

Table 7. Comparison of real power losses in the system

Cases	**Without a PV real power losses**	**With PV using WOA-Firefly, real power losses**
Normal	130.58 MW	115.80 MW
Load 10 % increased	168.10 MW	143.70 MW

The total generation and losses with PV–load 10% increased tuned by the hybrid algorithm as shown in table 6. The comparison of real power losses is shown in Table 7. The system with a PV system using WOA-Firefly has given better results than the system without a PV system.

7. Conclusion

Power flow simulations have continued to look into the system's congestion organization. The predicted algorithm was utilized to identify the most effective strategy for reducing actual power losses. To achieve minimum power losses in the range of 115.80 MW to 143.70 MW, the hybrid algorithm has fine-tuned the sizing of PV and located it on buses 18, 35, 41, 55, and 73. The voltage safety of the system has been improved by using the WOA-Firefly algorithm for appropriate scaling of the actual power generation. Therefore, the clogged state of the system has been prevented.

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