Hindawi
Complexity
Volume 2022, Article ID 5742846, 8 pages
https://doi.org/10.1155/2022/5742846

Research Article

A Unified Power Quality Conditioner for Feeder Reconfiguration and Setting to Minimize the Power Loss and Improve Voltage Profile

Zhigao Huang,[1] **Farid Shahbaazy**,[2] **and Afshin Davarpanah**[3]

[1]*Wuhan Railway Vocational College Technology, Wuhan, Hubei 430205, China*
[2]*Department of Electrical Engineering, Islamic Azad University, Borujerd Branch, Borujerd, Iran*
[3]*Young Elite Researchers, Science and Research Branch, Islamic Azad University, Tehran, Iran*

Correspondence should be addressed to Zhigao Huang; zhigao-huang2021@163.com and Afshin Davarpanah; afshindpe@gmail.com

Received 16 November 2021; Revised 8 January 2022; Accepted 27 January 2022; Published 15 February 2022

Academic Editor: Viet-Thanh Pham

Using devices such as unified power quality conditioners (UPQCs) in distribution networks seems essential for higher electricity quality. Moreover, distribution network reconfiguration is a suitable model for improving network characteristics, including loss reduction and voltage increase for distribution networks, and is widely used in this era. Here, the study discusses the rechanging of distribution networks for UPQC via proposing an appropriate model for it. In addition to the optimum structure of distribution networks, the most appropriate branch where UPQC must be located and the most appropriate reactive power size with which series and shunt filters must be injected into the grid are determined. The simulations have been applied on two 69- and 84-standard-bus networks. The results of the simulations indicate much power loss reduction and much voltage increase in the presence of UPQC compensators.

1. Introduction

The important goal of companies for electric effectiveness is providing the sinusoidal voltage continuously and stable voltage to all customers. In previous studies, parameters of PQ including the harmonics power, voltage cell, frequency, power factor, and reactive power are examined by using the infusion generators. The problem of power eminence is yielded in separation of customer equipment by using some problems in current, deviation of frequency, and voltage. The subjects of PQ have engrossed high consideration from companies and clients because of utilization of various types of susceptible electronic devices. The differences of PQ regarding load switching are obtained through short circuits, voltage decrease, gleam and relief, and distortions of harmonics. The electrical misses have happened via burst in electrical cycles, sudden loads, firelight, and radiated frequency. The various types of disturbances of PQ are occurring in the outline of electrical power. The evaluation of proficiency from PQ indicated that 50 percent of troubles of PQ are related to bonds of the ground, voltage neutral to the ground, and more ground-related problems. Distribution network reconfiguration is an effective way of reducing losses among the existing loss reduction methods in distribution networks. As distribution networks are designed in ring or mesh but are exploited in radial distribution, two customarily opened and normally closed switches exist. Reconfiguration represents selecting the open or closed state of these switches. However, the aim of reconfiguration may not be only to reduce losses. Previously, there have been several successful methods developed and employed. Improving voltage profile, balancing the load, and service restoration are some of the objectives mentioned in reconfiguration studies. In previous works, the heuristic model is proposed to obtain minimum loss configuration [1]. In [2], an innovative approach is provided for reducing losses and improving voltage profiles. In [3], a method is suggested to balance feeder load and reduce losses for unbalanced distribution networks. In [4], models to provide network reconfiguration are proposed. Regardless of the aim of reconfiguration, reconfiguration studies can be categorized as far as the presence of different compensator devices is concerned.

1.1. In the Presence of a Capacitor. Capacitors have various advantages in distribution networks, such as voltage regulation, power factor improvement, and losses reduction. Multiple studies have investigated reconfiguration and capacitors simultaneously. For instance, reconfiguration and capacitor control are investigated simultaneously using the simulated annealing method [5]. An algorithm is presented in a study [6] by considering different load levels based on MINLP for performing reconfiguration and capacitor allocation.

1.2. In the Presence of Distributed Generations (DGs). DGs have many economic and operational advantages [7]. Various articles have investigated the distribution reconfiguration. For instance, distribution reconfiguration is used for DG via the genetic algorithm [8]. A study [9] has considered DG's active power generation cost in reconfiguration. Other objective functions that PSO optimize in this article include the operational power generation cost of distribution networks, the number of switches functions, and bus voltage deviation. A model is presented in a study [10] based on MINLP for distribution reconfiguration for DGs.

1.3. In the Presence of DSTATCOM. Some advantages of DSTATCOM include voltage flicker reduction, harmonic reduction in-network, improving bus voltage, reducing losses, and continuous control of reactive power [11]. Distribution network reconfiguration and DSTATCOM placement are investigated simultaneously in a study [12]. The present study aims to reduce losses and improve voltage levels via DEA.

Today, the need for high power quality is felt more than ever. In general, it can be stated that low power quality causes additional costs for producers and consumers. For instance, an equipment malfunction, more network losses, consumer dissatisfaction, and life loss of equipment are examples of some extra charges imposed on producers and consumers due to low power quality. However, electricity distribution networks may not have high quality due to nonlinear loads, single-phase consumers, power electronics loads, etc. As a result, the use of devices that guarantee the power quality of distribution networks is essential. UPQC is one of the best devices which can improve power quality effectively [13]. UPQC has a series and a shunt filter that are connected back to back. The active series filter is responsible for damping feeding disturbance, and the active shunt filter damps the current quality generated by consumers [14].

In [15, 16], a model to assess the technical efficiency of PQ change strategy via FACTS devices is reported. In [17], the control strategy is reported using UPQC. In [18], the flow pattern is recommended for feeder reconfiguration to obtain the best start in search models. In [19], a model is reported to optimize the NR problems in PDS to decrease VP in advance. In previous studies, NR was used to increase the VP and decrease power loss. In [20], a UPQC with two CAMCs in back-to-back connection is proposed. The hybrid modulation technique used in the CAMC made the implementation of the control objectives easier. Due to the applicability of power electronic devices in improving the FACTS performances, the expectancy of using various kinds of controllers for efficient shunt are increased. The devices of FACTS are answered to alter in-network positions. The implication of FACTS devices in transmission and analogous systems is implemented properly in distribution systems. The devices of distribution-FACTS are utilized to recover the problems of power in systems of distribution [1, 2] that happen at a measure of milliseconds. In the mentioned time, D-FACTS has injected the active power and reactive power in the system to recover sensitive loads [9]. The DSTATCOM as a converter of the voltage source is used to recover the problems of power quality [13–19]. The DVR as an important converter is utilized to recover the problems of power quality. In [7], ANFIS, which is related to a controller of hysteresis, is suggested to obtain the efficiency of power quality. The novel works were produced by the incorporation of fuzzy and neural networks. The suggested models of D-FACTS are used in systems of two bus distributions including the sensitive load and source. The D-FACTS effects on recovery of the problem of power quality are examined. But, the D-FACTS effects on the system of large distribution are not examined. Also, the D-FACTS impacts are investigated for a short duration but not examined for a long term.

Considering the importance of reconfiguration and the increasing importance of UPQC, this work investigates distribution reconfiguration for UPQC. In this paper, first, a model will be extracted for UPQC load flow. Then, based on this model and with the aid of a genetic algorithm, reconfiguration of distribution networks will be carried out in the presence of UPQC. Reducing losses and improving voltage profile are the objective functions based on the network form, by which the best UPQC location and the most appropriate injected power will be determined. To combine loss reduction and voltage improvement as one objective function, these objective functions should be normalized. In this study, Utopia Point and Nadir Point methods are used for normalizing objective functions.

2. The Problem's Objective Functions

As mentioned above, the present study aims to decrease the losses and increase voltage for networks. Objective functions considered for optimization purposes are total active losses, voltage deviation average, and the sum of the normalized values of these two objective functions. These objective functions can be formalized as follows [1–3]:

$$f_1 = \sum_{i=1}^{N_L} \frac{P_i^2 + Q_i^2}{V_i^2} = P_{\text{total,loss}}, \quad (1)$$

$$f_2 = \sum_{i=1}^{n} \frac{\left|1 - V_i\right|}{n}, \quad (2)$$

$$f_3 = \overline{f}_1 + \overline{f}_2, \quad (3)$$

where $P_{\text{total,loss}}$ is total power losses (W) and V_i is the voltage magnitude of bus i. Also, $\overline{f_1}$ and $\overline{f_2}$ are the normalized values of the first and second objective functions, respectively. n indicates the number of buses. N_L shows the number of lines. P (MW) and Q (Var) are active and reactive power, respectively. The constraints which should be considered in this optimization are as follows (constraints 1 and 2 must be regarded for common reconfiguration and constraints 3 and 4 for reconfiguration in the presence of UPQC):

(1) Bus voltage must not exceed the permitted limits:

$$V_{\min} < V_i < V_{\max}. \quad (4)$$

(2) The branch's current must not exceed the permitted limits:

$$\left|I_i\right| < I_{i,\max}. \quad (5)$$

(3) The sum of UPQC injected series and shunt reactive power size is lower than reactive load power:

$$\sum_{I=1}^{N_{\text{UPQC}}} \left(Q_i^{\text{series}} + Q_i^{\text{shunt}} \leq Q_{\text{Total,Load}}\right). \quad (6)$$

(4) The branch that the optimization algorithm proposes for opening must not be the same as UPQC's location.

In these equations, Q_i^{series} and Q_i^{shant} are injected reactive power by compensator i and N_{UPQC} is the total number of existing UPQCs in the network. $V_{\min}$ and $V_{\max}$ (V) are network voltage constraints, and I_i and $I_{\max}$ (A) are the branch current i and the maximum branch current i, respectively. $V_{\min}$ and $V_{\max}$ are lower and upper bounds of voltage, respectively. $Q_{\text{Total,Load}}$ is the total reactive power for the consumer. N_{UPQC} is the number of UPQC devices [20].

The sum of two different objective functions is considered one objective function for simultaneous optimization; it is necessary to normalize them because each function is in different units. In this study, Utopia Point and Nadir Point methods are used for normalizing objective functions [21]. If x_i^* is the best response for optimizing the single objective function i, then the normalized objective function i $\overline{f}_1$ will be defined as follows [21]:

$$\overline{f}_i = \frac{f_i - f_i^U}{f_i^N - f_i^U}, \quad (7)$$

where f_i^U is the Utopia Point and is defined as follows:

$$f^U = [f_1(x_1^*) f_2(x_2^*) \ldots f_n(x_n^*)],$$
$$f_i^U = f_i(x_i^*). \quad (8)$$

Utopia Point f^U is obtained from the best data of Pareto solution, and a Utopia Point is computed as a result of optimization of n single criteria in time serving.

And, f_i^N is the Nadir Point that is defined as follows:

$$f_i^N = \max[f_i(x_1^*) f_i(x_2^*) \ldots f_i(x_n^*)]. \quad (9)$$

Nadir Point f^N is obtained from the worst data of the Pareto solution, and finding a Nadir Point is difficult when the problems have three and more criteria. The given points via the user, Utopia Point $f^{U,}$ and Nadir Point f^N, define the piecewise function u.

3. UPQC Modeling

UPQC can inject active and reactive power and is used to increase sag and unbalance voltages [20, 22]. A very complicated PV model is presented in a study for modeling UPQC in a distribution network within which only the series part is controllable. In the present paper, a simpler and more appropriate model is presented for the placement of UPQC in the network by evolution algorithms. UPQC compensators can inject power. Figure 1 shows a general view of a UPQC installed between buses i and j, with its series and shunt parts specified.

The series for UPQCs operates entirely between each other for injecting power, and it has enough the power for reactive load of bus j for modeling shunt injected reactive power. The shunt injected reactive power is intended as a negative load for bus j as in Figure 2 [20]. The reactive load of bus j after modeling the shunt part of UPQC is changed, and in this equation, Q_{shunt} is the injected power for UPQC.

The series injected power to the line will be simulated after modeling the shunt part separately and as a reactive negative load. The single line diagram of Figure 2 is changed by voltage (Figure 3).

If the network's Norton equivalent circuit is achieved from the points of i and j, the Thevenin's circuit will be converted to Norton circuit as in Figure 4. In this situation, we can model the injected series power as loads of i and j buses:

$$I_s = \frac{V_s}{Z_s}. \quad (10)$$

The V_s, I_s, and Z_s are voltage, current, and impedance for buses, and these parameters are formulated as follows:

$$V_s = V_{sm} \angle \delta_{Vs},$$
$$I_s = I_{sm} \angle \delta_{Is}, \quad (11)$$

where δ_{Vs} and δ_{Is} are the angle of voltage and current, respectively. V_{sm} and I_{sm} are the maximum values of voltage and current, respectively. Equal power is needed in the load flow. Therefore, the current source will be replaced with it by using equivalent power equations, and Figure 4 will be converted to Figure 5 subsequently.

The active power is obtained via [21]

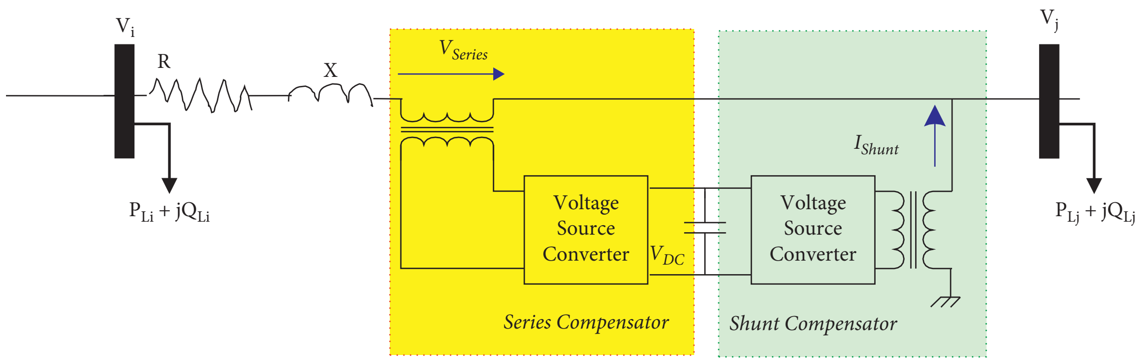

FIGURE 1: Single line diagram of the UPQC structure.

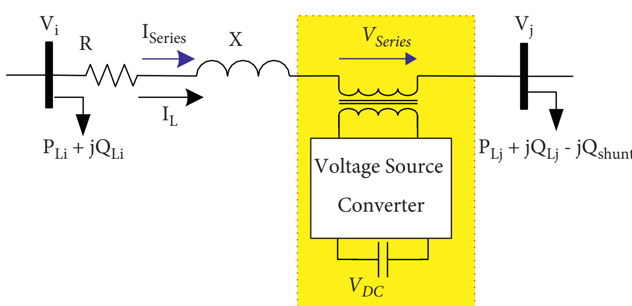

FIGURE 2: UPQC structure with modeling of the shunt part as the negative load for bus j.

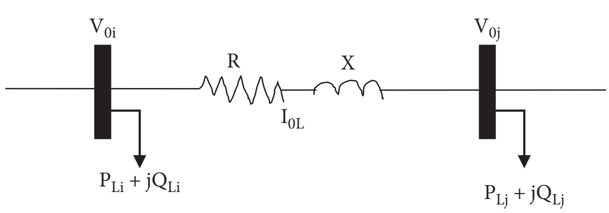

FIGURE 3: Thevenin's equivalent circuit for UPQC.

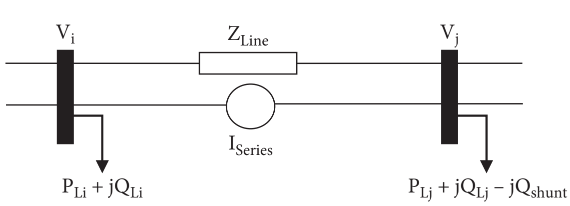

FIGURE 4: Norton equivalent circuit of the series part of UPQC.

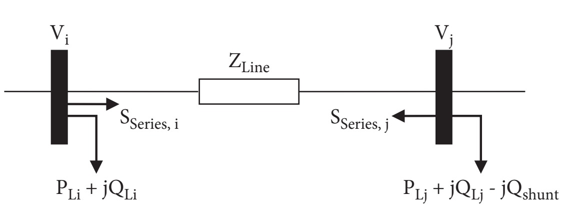

FIGURE 5: The load model for the series part of UPQC.

$$S_{\text{series},i} = V_i * (-I_s^*), \quad (12)$$

$$P_{\text{series},i} = \text{real}\left\{S_{\text{series},i}\right\}, \quad (13)$$

$$Q_{\text{series},i} = \text{Im}\left\{S_{\text{series},i}\right\}, \quad (14)$$

where $S_{\text{series},i}$ (VA), $P_{\text{series},i}$ (W), and $Q_{\text{series},i}$ (Var) are complex, active, and reactive power in series lines, respectively. The exact process will be conducted in bus j. These operations will be performed in each of the load flow iterations. Operational management cannot be used to inject and it is [21–23] as follows:

$$P_{\text{series},i} = \text{real}\left\{S_{\text{series},i}\right\} = 0. \quad (15)$$

The current angle of I_s will be calculated in the following way:

$$\delta_{I_s} = \frac{\angle V_i + \pi}{2}. \quad (16)$$

Before calculating equations (12)–(14), first, the source current in each iteration is calculated with the aid of the following equation:

$$I_s = \frac{V_{sm}}{|Z_m|}\angle\frac{V_i + \pi}{2}. \quad (17)$$

Since I_s a constant amount, only its angle will be changed in each iteration to adjust to the injected reactive power. After completing the load flow iterations, the injected series voltage angle will be calculated using the following equation:

$$\delta_{V_s} = \angle\left(\frac{I_s}{Z_s}\right). \quad (18)$$

4. Performing Reconfiguration and UPQC Placement in a Distribution Network

The switch types are available in distribution networks, and each ring includes one typically opened switch. Performing rechanging by using intelligent algorithms can be simulated in two ways: (a) all the switches should be considered open in the initial state and then by closing some of the switches, a network structure will be obtained that, in addition to being radial, must reduce the objective function to its minimize amount; (b) in the initial state of the problem, all switches should be considered closed and then by opening a specific number of switches, the radial limitation and minimization of the objective function will be met. The number of normally closed switches in distribution networks is much more than the number of customarily opened ones. Hence, if we perform the reconfiguration according to the second method, the problem will be less complicated.

The following states can be considered for performing reconfiguration concerning UPQC placement:

(1) First, reconfiguration and then UPQC placement
(2) First, UPQC placement and then reconfiguration
(3) Distribution network reconfiguration and UPQC placement simultaneously

The third method can have the characteristics of the other two ways at the same time. Here, the algorithm is used for optimization. In the first step of the genetic algorithm, the initial populations (chromosomes) are generated. For distribution network reconfiguration, concerning UPQC placement, each chromosome can be considered a structure as shown in Figure 6.

Step 1: the genes of this part represent the typically opened switch number. According to Graph's theory, the number of these genes or usually opened switches will be calculated by the following equation:

$$N = L - n + 1. \tag{19}$$

Here, N is the number of customarily opened switches, L is the branch number, and n is the network bus number.

Step 2: the genes in this part of the chromosome indicate the branches in which UPQC will be located.

Step 3: the genes in this part of the chromosome indicate the shunt injected reactive power of all UPQCs.

Step 4: the genes in this part of the chromosome indicate the series injected reactive power of all UPQCs.

For instance, for a 69-bus network with 73 branches with five typically opened switches and one UPQC, each chromosome has eight genes. Five of these genes are network switches that must be opened. The sixth gene indicates the branch in which UPQC will be located. The seventh gene indicates the shunt injected reactive power, and the eighth gene indicates the series injected reactive power of UPQC.

Once the initial population is generated randomly, the objective functions will be evaluated. After evaluating the objective function, genetic operators (usually three operators of selection, crossover, and mutation) will be applied in the initial population. The generated chromosomes will be reevaluated, and this process continues until the stopping conditions are met.

5. Simulation Results

In this paper, two 69- and 84-bus networks are considered for simulation. Data are compared by the following:

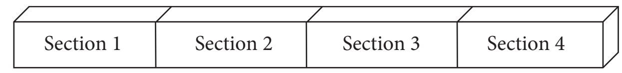

Figure 6: Chromosome structure for reconfiguration and UPQC setting optimization.

(1) The primary state of the network
(2) Network reconfiguration without the presence of UPQC
(3) Reconfiguration and UPQC to optimum the losses
(4) Reconfiguration and UPQC to improve the voltage level
(5) Reconfiguration and UPQC to decrease losses and to increase voltage levels simultaneously

5.1. 69-Bus Network. In this study, a system with 12.66 kV, 69-bus, 8-lateral radial distribution according to modern node counting with some corrections in demands of active power and reactive power is remarked as another test system. The whole load of the studied system is obtained as (4.0951 +j2.8630) MVA. The obtained results of the studied system are calculated from [22]. This distribution network has 69 buses and 73 branches. The total load over its feeders is 3.801 MW and 2.6944 MVAR. Data of this network are taken from [23]. The population size is assumed to be 50, and the iteration number is 200 for simulation. Based on equation (6), the amount of UPQC series and shunt injected power must not exceed 2.6944 MVAR (total reactive power of this network). Data of simultaneous network reconfiguration and UPQC placement are demonstrated in Table 1. The suitable effect of reconfiguration and UPQC placement can be observed clearly in this table. As can be observed, in optimizing the first objective function (f_1), the network losses have been reduced significantly and have decreased from 224.92 to 73.10 kW. Therefore, the objective function is improved by about 66% which is very considerable. In this state, switches 14, 58, 63, 69, and 70 are suggested to be open, and UPQC is located in line 60, and the shunt and series injected power are 1.1 and 0.91 MVAR, respectively. In optimizing the second objective function (f_2), a significant improvement is observed in the voltage level enhancement. As Table 1 shows, this function has decreased from 0.0265 PU to 0.0045 PU. The voltage means reached the ideal amount of 0.9955 PU that is rather suitable and noticeable. In this state, the opened switches are 10, 12, 18, 58, and 61, and the UPQC location is line 73, and its series and shunt injected power are 1.03 and 1.49 MVAR, respectively. For optimizing the fifth case or optimizing the third objective function, the amounts of f^U and f^N should be determined concerning the third and fourth cases:

$$\begin{aligned} f^N &= [150.72KW0.0112PU], \\ f^U &= [73.1KW0.0044PU]. \end{aligned} \tag{20}$$

Thus, considering these obtained amounts and equations (3) and (7), the third objective function is as follows:

Table 1: The results of UPQC placement and reconfiguration simultaneously in 69-bus network.

	Tie switches	UPQC characteristics Line	Shunt power (MVAR)	Series power (MVAR)	Total losses (KW)	Voltage deviation	V_{min} (PU)	V_{ave} (PU)
Case 1	69, 70, 71, 72, 73	-	-	-	224.92	0.0265	0.9091	0.9734
Case 2	12, 13, 58, 61, 69	-	-	-	99.88	0.0135	0.9427	0.9865
Case 3	14, 58, 63, 69, 70	60	1.1	0.91	73.10	0.0112	0.9654	0.9887
Case 4	10, 12, 18, 58, 61	73	1.49	1.031	150.72	0.0044	0.9688	0.9956
Case 5	14, 58, 64, 69, 70	61	1.78	0.384	84.85	0.0082	0.9719	0.9917

$$f_3 = \frac{f_1 - f_1^U}{f_1^N - f_1^U} + \frac{f_2 - f_2^U}{f_2^N - f_2^U} = \frac{f_1 - 73.1}{77.62} + \frac{f_2 - 0.0044}{0.00068}. \quad (21)$$

This function is optimized as an objective function by a genetic algorithm; the first and second objective functions have the same importance from the optimizing algorithm perspective. According to Table 1, the optimizing algorithm suggested a response between the third and fourth cases in the fifth case, and a relative balance is established between these two functions. In this state, the loss is 84.85 kW and the average voltage of the network is 0.9917 PU. It should be noted that in (20), the f_1 (losses) must be in kW and the f_2 (voltage deviation) must be in the PU unit.

The voltage profile for all buses in different cases is presented in Figure 7. Following the figure, the voltage in the primary structure is not in an appropriate state. Still, after reconfiguration and UPQC placement for improving voltage levels (fourth case), it reaches the best state compared to other mentioned cases. Especially in the range of buses 1 to 50, the voltage levels are improved more than in other cases and it can be stated that the voltage is around one PU. But, in this state, the net loss is 150 kW. According to the figure, in the fifth case, where the voltage levels and network losses are optimized simultaneously, failures are more satisfying than in the fourth case. In bus 61, a considerable load is available which is the cause of voltage sag in this area. In the fifth case, voltage sag is compensated appropriately due to the placement of a compensator on this bus. When the effects of installation of D-FACTS devices in two states are investigated, it can be concluded that in the studied systems, the performances and effectiveness of D-FACTS devices are similar.

5.2. 84-Bus Network with 96 Branches. The loads on this network are 28.35 MW and 20.70 MVAR, and lines 96–84 are open in the initial state. The operational losses and average voltage deviation in this network are 532.61 KW and 0.03078 PU, respectively. For more information, please refer to [23]. For this large network, two UPQCs are considered with 13 typically opened switches (tie switch) and considering two UPQCs, each chromosome has 19 genes. Due to the extent of each chromosome, more population and iteration numbers are considered compared to a 69-bus network. The population and iteration numbers are 50 and

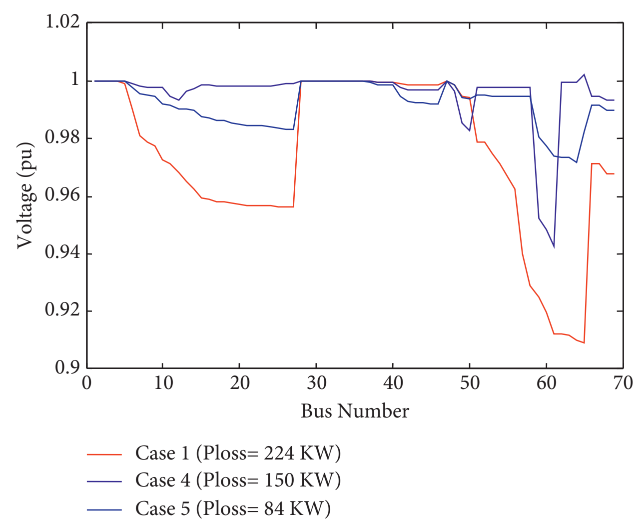

Figure 7: Voltage for cases of the 69-bus network.

250, respectively. The UPQC characteristics and simulation results in different cases are shown in Tables 2 and 3. In addition to the proposed structure, the optimization of objective function *f*1 proposes the locations of two UPQCs at lines 79 and 7; this condition could reduce the network losses to 407.43 KW and increase over 20%. In *f*2 and the new proposed structure, lines 7 and 78 are designated for the placement of UPQCs. The voltage reached 0.0129 PU. The intermediate voltages reached 0.9888 PU, which is a satisfactory result. The line losses are too high and cannot be accepted (624.58 KW). As the previous network, for optimizing the third objective function, firstly, the f^U and f^N will be defined concerning the third and fourth cases in Table 3:

$$f^U = [407.43KW 0.0129PU], \quad f^N = [624.58KW 0.0199PU]. \quad (22)$$

Then, considering these obtained amounts and equations (3) and (7), we will receive

$$f_3 = \frac{f_1 - f_1^U}{f_1^N - f_1^U} + \frac{f_2 - f_2^U}{f_2^N - f_2^U} = \frac{f_1 - 407.43}{217.15} + \frac{f_2 - 0.0129}{0.007}. \quad (23)$$

As the 69-bus network, in this case, the structure and location of UPQC are suggested precisely. These indicate the appropriate performance of normalization by Utopia Point

Table 2: UPQC characteristics for the 84-bus network.

	First UPQC characteristics			Second UPQC characteristics		
	Line	Shunt power (MVAR)	Series power (MVAR)	Line	Shunt power (MVAR)	Series power (MVAR)
Case 3	79	2.75	2.28	7	3.18	1.8
Case 4	7	5.63	1.355	78	8.14	5.506
Case 5	21	4.086	0.732	7	4.16	3.992

Table 3: Data of UPQC placement and reconfiguration for the 84-bus network.

	Tie switches	Total losses (KW)	Voltage deviation	V_{min} (PU)	V_{ave} (PU)
Case 1	84–96	532.61	0.03078	0.9285	0.9692
Case 2	7, 13, 34, 39, 42, 55, 62, 72, 83, 86, 89, 90, 92	470.26	0.0248	0.9532	0.9752
Case 3	7, 13, 34, 39, 42, 55, 64, 72, 86, 89, 90, 91,92	407.43	0.0199	0.9531	0.9801
Case 4	14, 20, 34, 39, 42, 54, 59, 71, 86, 88, 90, 92, 96	624.58	0.0129	0.948	0.9888
Case 5	6, 34, 39, 42, 54, 64, 72, 81, 86, 88, 89, 90, 92	459.32	0.0147	0.9531	0.9854

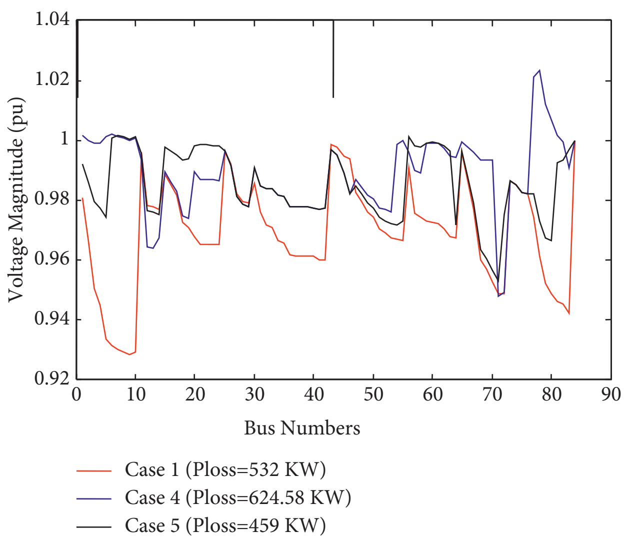

Figure 8: Voltage magnitude in different cases of the 84-bus network.

and Nadir Point methods. Although in this case, the voltage levels are less than those of the fourth case, the losses are not considered and the amount of network losses is acceptable (459.32 KW) compared to the initial state.

The voltage profile of all buses in different cases is presented in Figure 8. The voltage profile in the primary structure does not have an appropriate state. Still, after reconfiguration and placement, it is in the best state compared to the other mentioned cases.

To make a comparison with other methods, we have selected an 84-bus network in mode 1. The evolutionary algorithm optimization methods, linearized mathematical method, and simulated annealing algorithm have been considered. Accordingly, the obtained results from losses are 538.32 kW for the evolutionary algorithm, 541.43 kW for the mathematical linearization method, and 536.76 kW for the simulated refrigeration algorithm. From the obtained results, our method has received the best answer in comparison to other mentioned methods, that is, 1.2%, 1.7%, and 0.8%, respectively.

6. Conclusion

In this paper, the reconfiguration of the distribution network and the placement of UPQC were studied. A simple load flow model was proposed for the placement of UPQCs. In general, the location and size of UPQC and typically opened switch numbers were investigated for different purposes. Therefore, three objective functions were studied: losses, voltage deviation, and the combination of these two. It was found that the simultaneous combination of reconfiguration and UPQC placement reduces the active power losses to more than 50% of the primary structure and significantly improves the voltage characteristics. The sum of loss objective function and the voltage deviation objective function were considered as objective functions so that the optimization algorithm could optimize these two objective functions simultaneously. The normalization method was used to scale these objective functions, and the results obtained were quite desirable and logical. With careful consideration of the simulations, the improvement in voltage level and reduction in losses are obvious in the presence of UPQC.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

References

[1] Y. Merzoug, B. Abdelkrim, and B. Larbi, "Distribution network reconfiguration for loss reduction using PSO method," *International Journal of Electrical and Computer Engineering*, vol. 10, no. 5, Article ID 5009, 2020.

[2] I. Benitez Cattani, E. Chaparro, and B. Baran, "Distribution system operation and expansion planning using network reconfiguration," *IEEE Latin America Transactions*, vol. 18, no. 05, pp. 845–852, 2020, þ.

[3] R. V. A. Monteiro, J. P. Bonaldo, R. F. da Silva, and A. S. Bretas, "Electric distribution network reconfiguration optimized for PV distributed generation and energy storage,"

Electric Power Systems Research, vol. 184, 2020 þ, Article ID 106319.

[4] S.-M. Park and Y.-G. Kim, "User profile system based on sentiment analysis for mobile edge computing," *Computers, Materials & Continua*, vol. 62, no. 2, pp. 569–590, 2020.

[5] D. Dan Jiang and R. Baldick, "Optimal electric distribution system switch reconfiguration and capacitor control," *IEEE Transactions on Power Systems*, vol. 11, no. 2, pp. 890–897, 1996.

[6] L. W. de Oliveira, S. Carneiro, E. J. de Oliveira et al., "Optimal reconfiguration and capacitor allocation in radial distribution systems for energy losses minimization," *International Journal of Electrical Power & Energy Systems*, vol. 32, no. 8, pp. 840–848, 2010.

[7] W. El-Khattam and M. M. A. Salama, "Distributed generation technologies, definitions and benefits," *Electric Power Systems Research*, vol. 71, no. 2, pp. 119–128, 2004.

[8] J. H. Choi and J. C. Kim, "Network reconfiguration at the power distribution system with dispersed generations for loss reduction," *Power engineering society winter meeting*, vol. 4, pp. 2363–2367, 2000.

[9] J. Olamaei, T. Niknam, and G. Gharehpetian, "Application of particle swarm optimization for distribution feeder reconfiguration considering distributed generators," *Applied Mathematics and Computation*, vol. 201, no. 1-2, pp. 575–586, 2008.

[10] J. F. Franco, M. J. Rider, M. Lavorato, and R. Romero, "A mixed-integer LP model for the reconfiguration of radial electric distribution systems considering distributed generation," *Electric Power Systems Research*, vol. 97, pp. 51–60, 2013.

[11] I. Wasiak, R. Mienski, R. Pawelek, and P. Gburczyk, "Application of DSTATCOM compensators for mitigation of power quality disturbances in low voltage grid with distributed generation," in *Proceedings of the 9th International conference on electrical power quality and utilizations*, Barcelona, Spain, October 2007.

[12] S. Jazebi, S. H. Hosseinian, and B. Vahidi, "DSTATCOM allocation in distribution networks considering reconfiguration using differential evolution algorithm," *Energy Conversion and Management*, vol. 52, no. 7, pp. 2777–2783, 2011.

[13] E. Ali, A. Nasiri, and B. Stoyan, *Uninterruptible Power Supplies And Active Filters*, CRC Press, Boca Raton, FL, USA, 2004.

[14] S. K. Khadem, M. Basu, and M. F. Conlon, *Integration of UPQC for Power Quality Improvement in Distributed Generation Network – A Review*, ISGT Europe 2011, Manchester UK, Dec 2011.

[15] T. Yuvaraj, K. Ravi, and K. R. Devabalaji, "DSTATCOM allocation in distribution networks considering load variations using bat algorithm," *Ain Shams Engineering Journal*, vol. 8, no. 3, pp. 391–403, 2017.

[16] T. Jin, Y. Chen, J. Guo, M. Wang, and M. A. Mohamed, "An effective compensation control strategy for power quality enhancement of unified power quality conditioner," *Energy Reports*, vol. 6, pp. 2167–2179, 2020, þ.

[17] Y. Qu, "A global optimum flow pattern for feeder reconfiguration to minimize power losses of unbalanced distribution systems," *International Journal of Electrical Power & Energy Systems*, vol. 131, 2021 þ, Article ID 107071.

[18] A. O. Salau, Y. W. Gebru, and D. Bitew, "Optimal network reconfiguration for power loss minimization and voltage profile enhancement in distribution systems," *Heliyon*, vol. 6, no. 6, Article ID e04233, 2020.

[19] I. Y. Kim and O. L. de Weck, "Adaptive weighted-sum method for bi-objective optimization: Pareto front generation," in *Proceedings of the The 45th Structural Dynamics, and Materials Conference*, pp. 19–22, Palm Springs, Boca raton, FL, USA, April 2004.

[20] M. Hosseini, H. A. Shayanfar, and M. Fotuhi-Firuzabad, "Modeling of unified power quality conditioner (UPQC) in distribution systems load flow," *Energy Conversion and Management*, vol. 50, no. 6, pp. 1578–1585, 2009.

[21] S. P. Kapse, S. Krishnapillai, and S. Krishnapillai, "An improved multi-objective particle swarm optimization based on utopia point guided search," *International Journal of Applied Metaheuristic Computing*, vol. 9, no. 4, pp. 71–96, 2018, þ.

[22] N. C. Sahoo and K. Prasad, "A fuzzy genetic approach for network reconfiguration to enhance voltage stability in radial distribution systems," *Energy Conversion and Management*, vol. 47, no. 18-19, pp. 3288–3306, 2006.

[23] J.-P. Chiou, C.-F. Chang, and C.-T. Su, "Variable scaling hybrid differential evolution for solving network reconfiguration of distribution systems," *IEEE Transactions on Power Systems*, vol. 20, no. 2, pp. 668–674, 2005.