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Voltage Stability Assessment for local Network Scheme using Evolutionary Programming Technique

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ABSTRACT

Voltage stability is a crucial aspect in the power system operation and planning. The stressed condition in power system caused by reactive power loading has made the system operating close to its stability limit while reducing the voltage on a particular load bus. Hence some measures should be taken in order to improve the voltage stability condition in the electric power systems. Reactive power planning(RPP) includes the reactive power dispatch, capacitor placement on the load bus to improve local voltage profile. This research paper presents the application of Evolutionary Programming (EP) was tested on IEEE-30 bus system and 27-bus LibyanNetworksystem, by using MATLAB software in optimistion of reactive power dispatch as one of RPP procedures to improve voltage stability condition in an electric power system.

Key word: Reactive power planning(RPP), Evolutionary Programming (EP), voltage stability.

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تقييم ثبات الجهد لنظام الشبكات المحلية باستخدام تقنية البرمجة التطورية

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الملخص

يعد استقرار الجهد جانبًا حاسمًا في تشغيل نظام الطاقة وتخطيطه. وقد أدت حالة الإجهاد في نظام الطاقة الكهربائية الناجمة عن تحميل الطاقة التفاعلية إلى جعل النظام يعمل بالقرب من حد استقراره مع تقليل الجهد على ناقل حمل معين. ومن ثم ينبغي اتخاذ بعض التدابير من أجل تحسين حالة استقرار الجهد في أنظمة الطاقة الكهربائية. يتضمن تخطيط الطاقة التفاعلية (RPP) توزيع الطاقة التفاعلية ووضع المكثفات على ناقل الحمل لتحسين حالة الجهد المحلي. تعرض هذه الورقة البحثية تطبيق البرمجة التطورية (EP) على نظام IEEE-30 bus ونظام الشبكات الليبية 27 قضيب باستخدام برنامج MATLAB في تحسين توزيع الطاقة التفاعلية كأحد إجراءات تخطيط الطاقة التفاعلية لتحسين حالة استقرار الجهد في نظام الطاقة الكهربائية.

الكلمات المفتاحية: تخطيط الطاقة التفاعلية (RPP)، البرمجة التطورية (EP)، استقرار الفولتية.

Introduction

Power Voltage stability is a problem in power systems, which are heavily loaded, faulted or have a shortage of reactive power. The nature of voltage stability can be analyzed by examining the production, transmission and consumption of reactive power. The problem of voltage stability concerns the whole power system, although it usually has a large involvement in one critical area of the power system.

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Voltage stability is the ability of a power system to maintain steady acceptable voltage at all buses in the system under normal operating conditions and after being subjected to a disturbance. A system enters a state of voltage instability when a disturbance, increase in load demand, or change in system condition causes a progressive and uncontrollable drop in voltage. The main factor causing instability is the inability of the power system to meet the demand for reactive power. The heart of the problem is usually the voltage drop that occurs when active power and reactive power flow through inductive reactance associated with the transmission network [1].

The first part of the problem formulation was started by defining the objective functions required for the optimization in the Reactive power planning (RPP). In this study RPD is chosen as a technique for the RPP. Voltage stability improvement has been identified as the objective for the optimization process with *FVSI* values being the fitness of the objective function. With this objective function total losses in the system are expected to reduce once the RPD has been performed [2]. The results obtained from the optimization process would be taken as the amount of reactive powers required to be dispatched in order to improve the voltage stability condition in the system caused by heavily loaded system.

The second part of the problem was the relation between FVSI and reactive power at receiving end [4]. The characteristics of the values of FVSI by increasing reactive power of the load to estimate the maximum loadability.

The developing of voltage stability by using reactive power dispatch use evolutionary programming to obtain reactive power dispatch when FVSI is used as the objective function. Then this reactive power dispatch implements on the system to determine reactive power at loads then it used to calculate the fast voltage stability index (FVSI), it used also to estimate maximum loadability by increasing reactive load gradually and indicate the value of FVSI that is closed to unity. This method is implemented on two systems (IEEE -30 bus and 27-bus for Libyan Network). In this research paper the software that had used is MATLAB.

Optimization techniques

This technique is based on the application of evolutionary programming to optimal reactive power dispatch and voltage control of power systems. The objective function has been developed to make the EP suitable to the practical optimal problems of large scale systems method to power system economical and secure operations.

Figure 1 shows the procedure of main steps for evolutionary programming with the assistance of load flow program which used as subroutine. It consists of five steps.

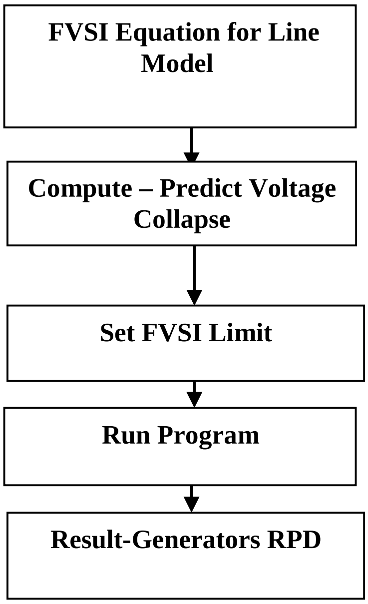

Figure 1. Flow chart of EP

Line- Based Voltage Stability Index

As described in the earlier section, the voltage stability improvement has identified as the objective function for the optimisation process. The fitness will be the line-based voltage

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stability index, termed as fast voltage stability index (FVSI). The mathematical equation for (FVSI) was formulated from a line model as shown in figure 2.

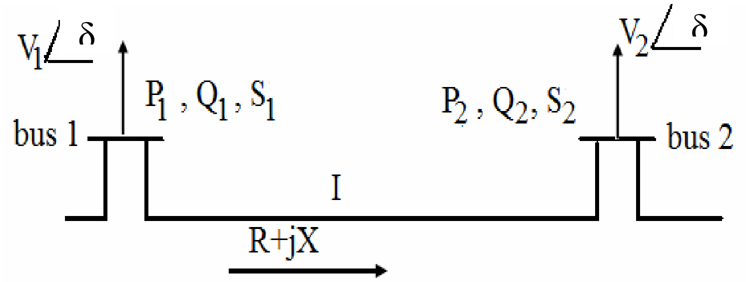

Figure 2. Line model

The receiving end voltage can be presented in quadratic form as [5].

$$V_2^2 - \left(\frac{R}{X}\sin\delta + \cos\delta\right)V_1V_2 + \left(X + \frac{R^2}{X}\right)Q_2 = 0 \qquad (1)$$

Where:

$\delta = \delta1 - \delta2$ (2)

The general quadratic equation is normally written as:

$$aV_2^2 + bV_2 + c = 0 \qquad (3)$$

Comparing (1) with the general quadratic in (3) and in order to obtain real roots for the receiving end voltage, the discriminant ($_b{}^2$ - 4ac=0) of the voltage roots must be greater than zero, thus making the discriminant as simplified to:

$$\left[\left(\frac{R}{X}\sin\delta + \cos\delta\right)V_1\right]^2 - 4\left(X + \frac{R^2}{X}\right)Q_2 \geq 0 \qquad (4)$$

Rearranging the equation (4)

$$\frac{4Z^2 Q_2 X}{(V_1)^2 (R\sin\delta + X\cos\delta)^2} \leq 1 \qquad (5)$$

Since the difference in the angle between the sending bus and the receiving bus, δ, is normally very small, therefore.

$$\delta \approx 0,\ R\sin\delta \approx 0 \quad \text{and} \quad X\cos\delta \approx X \qquad (6)$$

Taking ‘j’ as the receiving bus and ‘i’ as the sending bus, hence, the FVSI formulation can be expressed as

$$FVSI_{ij} = \frac{4{Z_{ij}}^2 Q_j}{V_i^2 X_{ij}} \qquad (7)$$

Where;

Z_{ij} is the line impedance.
Q_j is reactive power at receiving end.
V_i is the sending end voltage.
X_{ij} is the line reactance.

Compute Predict Voltage Collapse

FVSI value for each line in the system is computed to indicate the voltage stability condition of the respective line in the system. Based on the FVSI values computed in the system, voltage collapse can be predicted .FVSI value has to be remained less than unity in order to maintain the system to be in stable condition. If the value computed on any line exceeds unity, the system loses its stability condition leading to sudden voltage drop and hence voltage collapse [3].

Set FVSI Limit

The constraints impose during the initialization are the FVSI value must be less than 0.9 p.u to ensure the stability.

Run the Program

After implement the previous steps the input of main program is random numbers of reactive power will be dispatched by the

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generators and the output of the program is optimal reactive power, thus the EP flow chart as shown in figure 3.

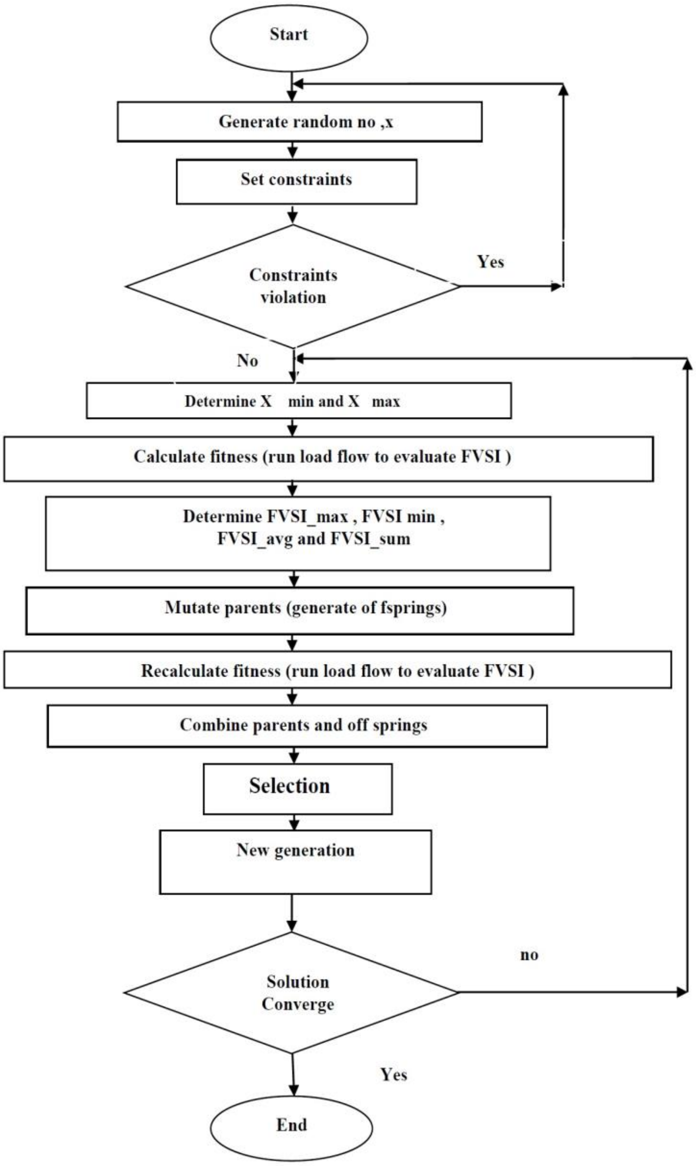

Figure 3. Flow chart of all steps of EP.

Results and discussion

The results of maximum loadability are for different buses and the results of voltage stability for two systems.

IEEE-30 Bus

The simulation work was carried out on the IEEE bus test system, which is the IEEE 30 bus test system. The single line diagram for this system is illustrated in figure4.

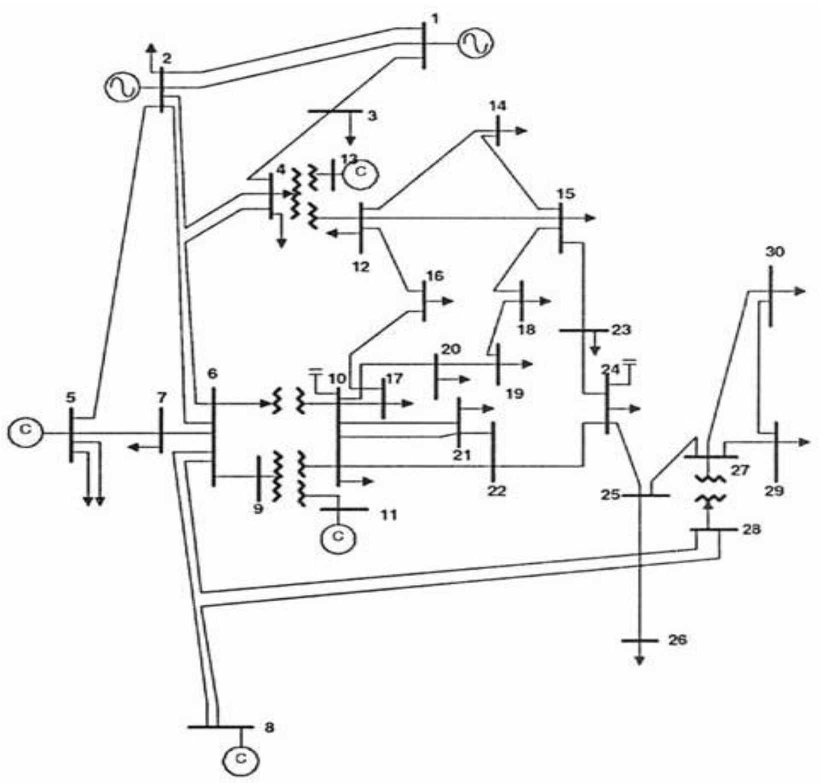

Figure 4: IEEE 30 bus network

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This system is part of American Electric Service Corporation network, which is being made available to electric utility industry as standard test case for evaluating various analytical methods and computer programs for the solution of power system problems. This system contains of 30 bus, 6 generators and 41 lines. Bus 1 is taken as slack bus. The data for the limitation of the voltage-controlled buses in table 1.

Table 1. Limitation of the voltage control buses

Bus-No.	Voltage (pu)	Capacity (Min-Mvar)	Capacity (Max-Mvar)
2	1.043	-40	50
5	1.010	-40	40
8	1.010	-10	40
11	1.082	-6	24
13	1.071	-6	24

The data for the injected Q due to shunt capacitor isin table 2.

Table 2. Data of shunt capacitorin IEEE 30 bus system

Bus No.	Mvar
10	19
24	4.3

Libyan Network-27 Bus

This system is part of Libya Electric Service Corporation network, which is being made available to electric utility industry as standard test case for evaluating various analytical methods and computer programs for the solution of power system problems. This system contains of 27 bus, 6 generators and 35lines. Bus 1 is taken as slack bus .The data for the limitation of the voltage-controlled buses in table3.

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Table 3. Limitation of the voltage control buses

Bus-No.	Voltage (pu)	Capacity (Min-Mvar)	Capacity (Max-Mvar)
2	1.020	-30	40
3	1.001	-20	90
4	1.020	-20	30
11	1.001	-40	60
27	1.012	-12	34

The data for the injected Q due to shunt capacitor is in Table 4.

Table 4. data of shunt capacitor in Libyan Network-27 Bus

Bus No.	Mvar
1	7
7	5
20	7
24	5

The system of 27-bus for Libyan Network is illustrated in figure5.

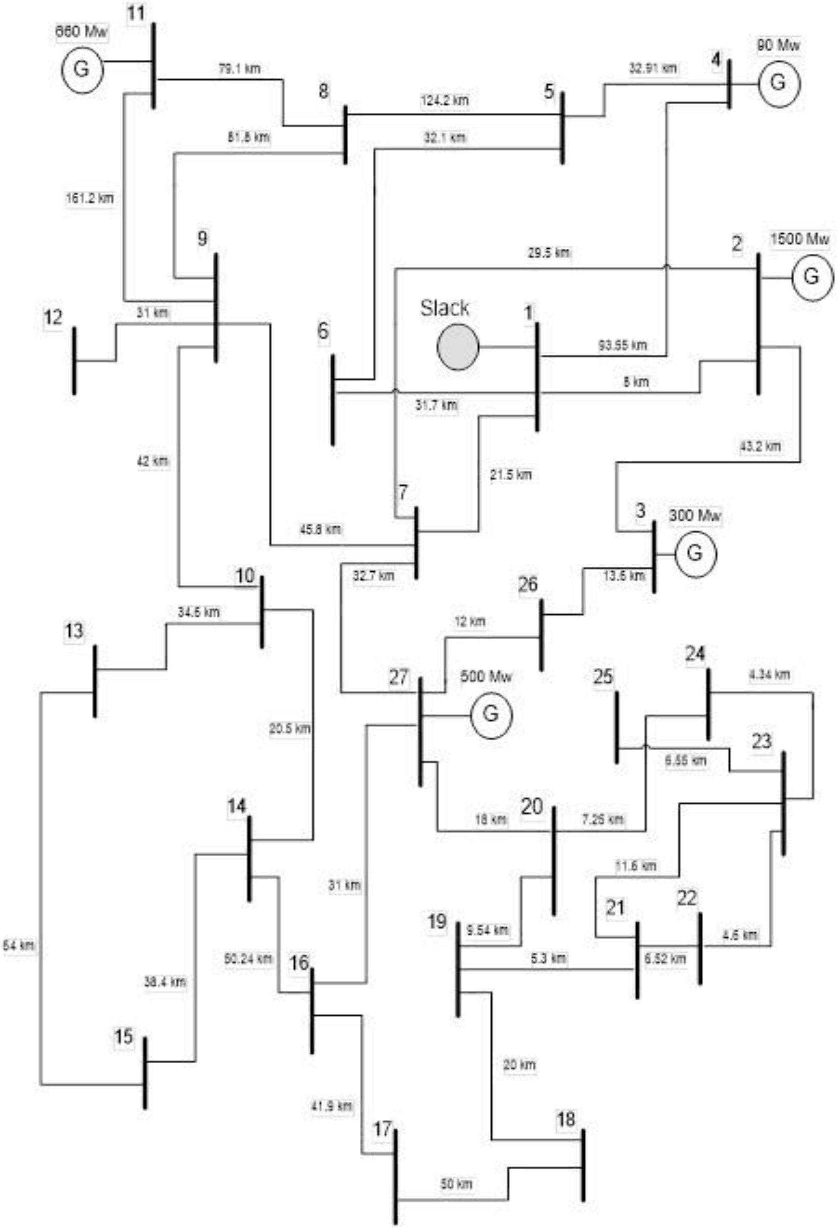


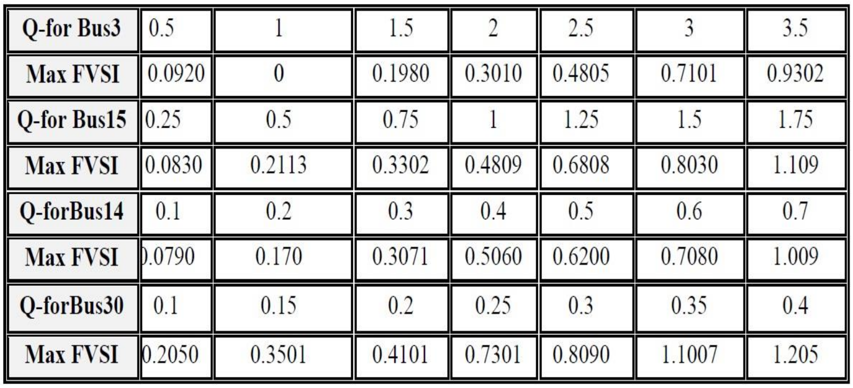
Figure 5. 27-bus for Libyan network

Results of Maximum Loadability

To determine maximum loadability at the main steps method.the maximum reactive power loading is referred to as the maximum loadability of a particular bus.

After implement previous steps on IEEE 30 bus to determine the maximum loadability,Since the total load for IEEE 30 bus is 126 MVAr. The results obtained in tables 5.

Table 5. The values of FVSI by increase Q (30-bus)



Q-for Bus3	0.5	1	1.5	2	2.5	3	3.5
Max FVSI	0.0920	0	0.1980	0.3010	0.4805	0.7101	0.9302
Q-for Bus15	0.25	0.5	0.75	1	1.25	1.5	1.75
Max FVSI	0.0830	0.2113	0.3302	0.4809	0.6808	0.8030	1.109
Q-forBus14	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Max FVSI	.0790	0.170	0.3071	0.5060	0.6200	0.7080	1.009
Q-forBus30	0.1	0.15	0.2	0.25	0.3	0.35	0.4
Max FVSI	0.2050	0.3501	0.4101	0.7301	0.8090	1.1007	1.205

Discussion of the Result of MaximumLoadabilityfor 30 bus System

Table 5 contains the values of FVSI by increasing the reactive power loading at the buses 3, 15, 14 and 30.

The response for FVSI versus reactive power dispatch is shown in figures 6 and 7.

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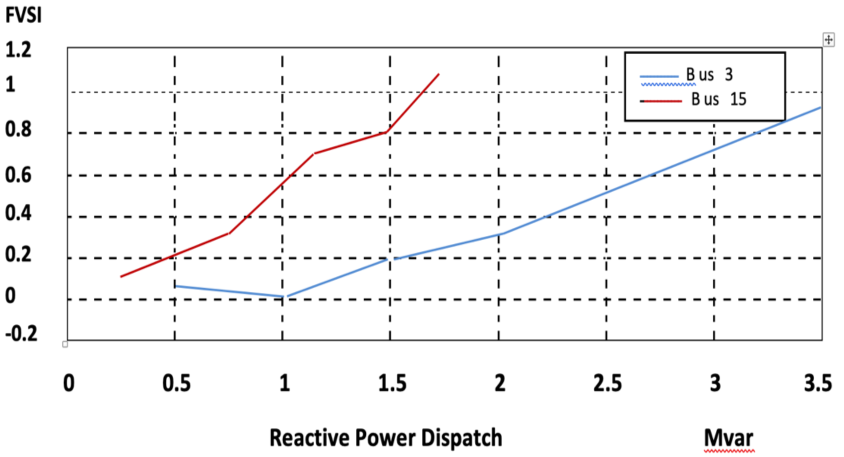

Figure 6. FVSI vs. Reactive load in IEEE 30 bus system (bus 3 and 15)

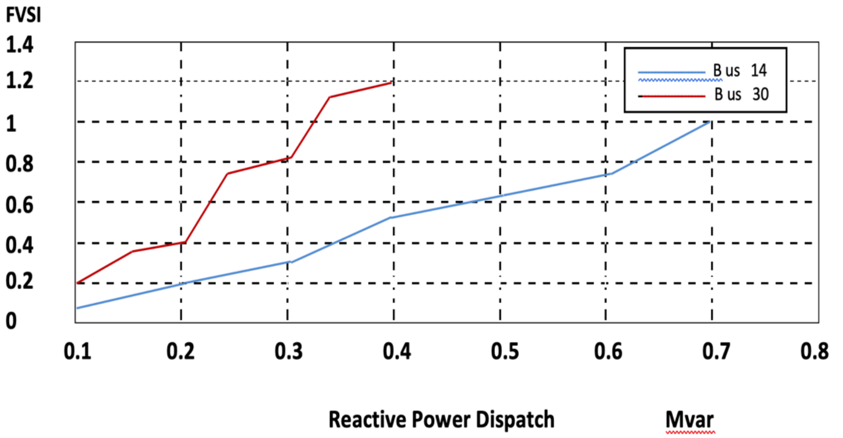

Figure 7. FVSI vs. Reactive load in IEEE 30 bus system (bus 14 and 30)

The individual FVSI curve is the most critical line referred to a bus. For instance, L4 (bus 3) means that line 4 is the most critical line with respect to bus 3, L18 is the most critical line with respect to bus 15, L20 is the critical line for bus 14 and L38 is the critical for bus 30.The value of FVSI for each line is maximum at the maximum loadability of each individual load bus.

The FVSI values at these points are close to unity indicating that the system has reached its stability limit. According to the figures and the table of IEEE-30 bus the maximum loads at 3 , 14 , 15 and 30 are 3, 55 1.5, 0.5 and 0.25 .All the results were obtained when the reactive power dispatched by the generators 1, 2, 4 are 1, 1, 1.24 respectively.

Results of Reactive Power Dispatch and Voltage Stability

The Evolutionary Programming (EP)has been tested on the two test systems (IEEE 30 bus technique and 27-bus for Network Libyan) for improving voltage stability by minimize the objective (FVSI) and the loads for the systems as described early. The results obtained from the EP are compared with the results from normal load flow. The results are as shown in tables 6, 7,8 and 9 , and figure 8 and 9.

Table 6. The reactive power dispatched by the generators and the voltage using EP for the buses for IEEE- 30 bus system.

Bus No	**1**	**2**	**5**	**8**	**11**	**13**
Voltage (pu)	1.06	1.061	1.078	1.034	1.086	1.083
Total Loss (MW)	08.704					

Table 7. The reactive power dispatched by the generators and the voltages using normal load flow for IEEE-30 bus system.

Bus-No	1	2	5	8	11	13
Voltage (pu)	1.06	1.043	1.010	1.010	1.082	1.071
Total Loss (MW)	17.598					

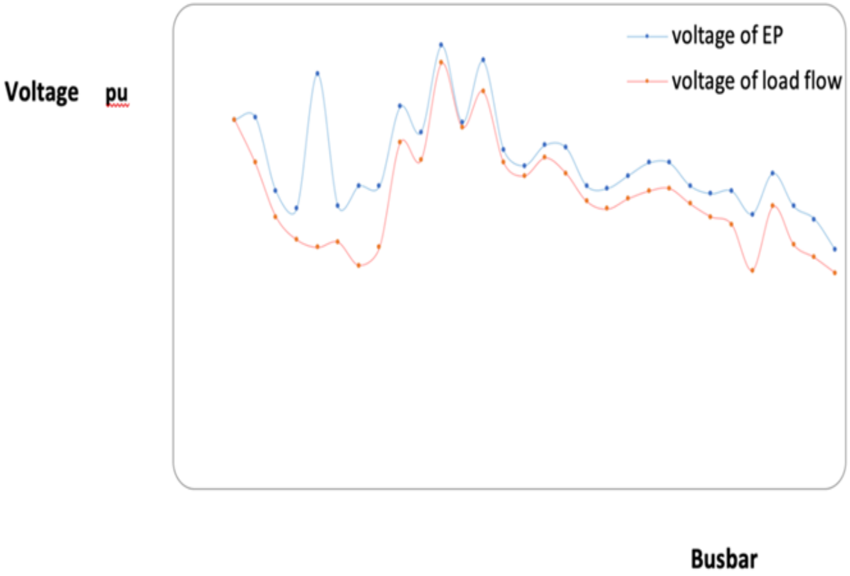

Figure 8. Voltage stability for IEEE-30 bus

Table 8. The reactive power dispatched by the generators and the voltages using EP for 27-bus for Libyan Network system.

Bus No	1	2	3	4	11	27
Voltage pu	1.022	1.0222	1.032	1.023	1.022	1.024
Total Loss MW	27.117					

Table 9. The reactive power dispatched by the generators and the voltages using normal load flow for 27-bus for Libyan Network system.

Bus No	1	2	3	4	11	27
Voltage pu	1.022	1.020	1.011	1.010	1.001	1.007
Total Loss MW	44.563					

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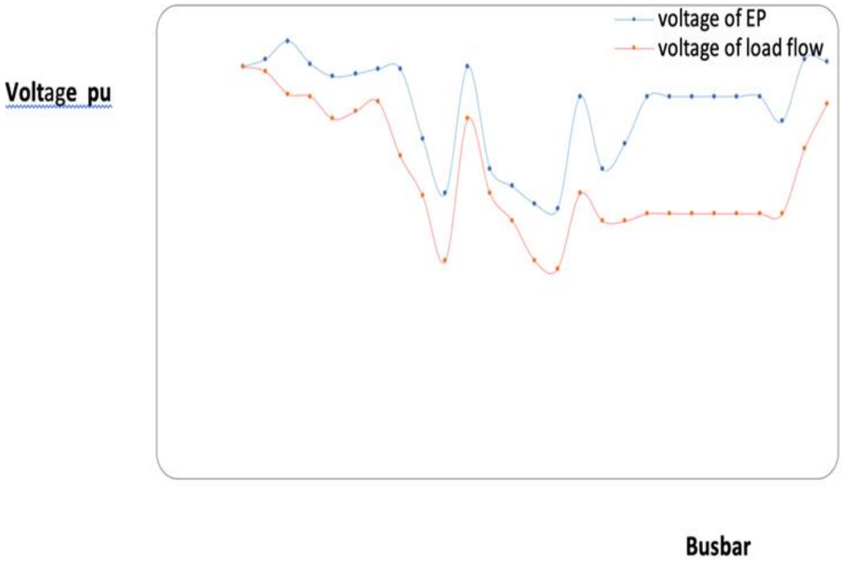

Figure 9: Voltage stability for 27-bus for network Libyan

Discussion of the Result for Voltage Stability

From the tables 6 and 7 by usingtheIEEE30- bus systemthe total loss of the system by using normal load flow is 17.595MW, whereas the total loss by using evolutionary programming (EP) is 08.704MWandthe results from the graphin figure 8, it is clearly that the result obtained from (EP) is much better than normal load flow. From the tables 8 and 9by using the Libyan network27- bus system the total loss of the system by using normal load flow is 44.563MW, whereas the total loss by using evolutionary programming (EP) is27.117MWandthe results from the graphin figure 9, it is clearly that the result obtained from (EP) is much better than normal load flow.

Conclusion

A study on reactive power planning had been conducted considering the voltage stability improvement as a single objective function. Evolutionary programming (EP), a stochastic optimisation

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technique was employed as the optimisation approach in determining the optimum values for the reactive power to be dispatched to establish voltage stability. Five parameters were considered in the optimisation process namely Qg2, Qg3, Qg4, Qg5 ,Qg 11and Qg27 which are the reactive power generated by generators 2, 3, 4, 5, 11 and 27 (in Libyan network27- bus system).Five parameters Qg2, Qg5, Qg8, Qg11, and Qg13, were considered (in IEEE-30 bus system) Results had shown that taking FVSI as the fitness function for the reactive power dispatch optimisation problem was able to improve voltage stability condition along with loss minimisation in the system. The application of EP in this study as a stochastic optimisation technique was acceptably a fast and accurate method when compared with normal load flow. The developed algorithm was simple and quite flexible since controllable constraints could be adapted in performing the desired task. Results obtained from the optimization process could be taken by the power system operators in order to be used for voltage stability improvement in the electric power system.

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