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# Analysis of Requirement Reactive Power for a Restructured Power System Using Monte Carlo Method

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**ABSTRACT**

Due to the amount of reactive power required for power system for operator, by using probabilistic load flow as a useful method for evaluation of system behavior, We can gain the exact value of requirement reactive power of system in a pool market. In this paper the main object is the examination of effect of random changes in load, generation and price on all requirement reactive power of system and also the amount of reactive power of each bus. Effective parameters in reactive power distribution are determined and an effective probable model for each of parameters is presented. The simulation results are used by network management for reactive power and voltage control service contracts. In order to arrive to the aim, Monte Carlo method that is quite practical and useful method for engineering problems, and MATLAB software is used, and studies are done on 30 buses IEEE system that is modeled by MATPOWER software.

**KEYWORDS**—Reactive power, Probabilistic load flow, Monte Carolo simulation

## 1. INTRODUCTION

Reactive power is one of the most important ancillary services that is considered in designing and operation of AC power systems. In many restructured power systems. reactive power is buying while long contracts from reactive power suppliers. Estimation of exact reactive power from two respects is important:

1.Inadequate estimated reactive power will cause decrease of voltage control sources.

2.Estimation of reactive power more than requirement value will cause additional costs and will occupy capacity of reactive power sources that have other capabilities, like generators.

For the above reasons, evaluation of requirements of reactive power for system is very important. In the other hand a lot of probabilistic parameters in power network are affected on reactive power distribution, for example different loadings, presence or absence of generators, lines and etc.

In past researches, in evaluation, management, and pricing of reactive power, input parameters are less supposed probable. And for example loading of system is specifically intended, as heavy, medium or light loading.

In this paper, the primary aim is determining and introducing effective parameters in reactive power distribution, presentation of effective probable model for each of the parameters and considering a set of probabilistic parameters. In order to determine optimum for reactive power sources, Monte Carlo simulation approach that is quite practical and useful method for engineering problems, including the probabilistic parameters is used.

Paper is organized as follows: In section 2 we will review the probabilistic load flow, In Section 3. Examines the optimal load flow, Monte Carlo simulation in Section 4, Section 5. probabilistic optimal load flow using Monte Carlo method, In section 6 and in section 7 the results of the case study will be described.

## 2. Probabilistic load flow

Probabilistic load flow is a macroscopic random method under steady-state operating conditions of the power system, which considers different random factors on the performance of power system.[1] To consider the uncertainty in the power system probabilistic load flow is a proper way that in it uncertainty in the system parameters are considered as random variables. In this paper probabilistic load flow using Monte Carlo simulation is done.

## 3.Optimal load flow

Optimal load flow is a nonlinear optimization to determine the optimum parameters in a power system that has an objective function and number of constraints. Here the objective function is total cost of production of active or reactive power or both. These costs may be patchy or linear functions of the output of the generator polynomial functions are defined. The formulation is as follows:

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$$\min_{Pg,Qg} \sum f_{1i}(P_{gi}) + f_{21}(Q_{gi}) \quad (1)$$

$$P_{gi} - P_{Li} - P(V,\theta) = 0 \quad (2)$$

$$Q_{gi} - Q_{Li} - Q(V,\theta) = 0 \quad (3)$$

$$\widetilde{S_{ij}^{f}} \leq S_{ij}^{max} \quad (4)$$

$$\widetilde{S_{ij}^{t}} \leq S_{ij}^{max} \quad (5)$$

$$V_t^{min} \leq V_t \leq V_t^{max} \quad (6)$$

$$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max} \quad (7)$$

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max} \quad (8)$$

In this paper, by using probabilistic optimal load flow
production changes , load changes and active and reactive cost changes in a power system are considered. And also Monte Carlo simulation method is used to determine amount of reactive power demand in a pool market .

**4. Monte Carlo simulation method**

The most important Monte Carlo method feature is based on a probabilistic samples and symbols. [6] Monte Carlo simulation is a process that occurrence of modes in all its aspects is purely coincidental. In Monte Carlo simulation, a random number generator is used to model the occurrence of events. This behavior is desirable, because By repeating the simulation, a probability distribution of random numbers will be obtained. And the mean, median, variance and statistical parameters will be calculated. In this paper, using a Monte Carlo method, uncertainty of the system production and loads are modeled as random variables And with running the program and probabilistic optimal load flow for about 8000 times, probability distribution of parameters of system be obtained and the amount of requirements reactive power of the system in a pool market are obtained. MATLAB software was used to generate normal random numbers and the required random numbers are generated.

**5. Probabilistic optimal load flow using Monte Carlo method**

Probabilistic optimal load flow using Monte Carlo method is the most comprehensive tool to evaluate different scenarios for uncertainty in a system. In Monte Carlo simulation at first the base network that in it the network structure is characterized by the production of generator and load bus is selected, then to the following and the flowchart as provided in section 6, Optimal load flow is done:

1. Using a random normal distribution function a random amount of load for a load bus is selected.
2. The selected bus is modified with the new value selected
3. Using Newton-Raphson load flow network status can be evaluated and the amount of output parameters are characterized
4. If the stopping criterion is provided by the simulation, the simulation ends, Otherwise, items 1 to 3 are repeated. Stopping criterion can determine the number of iterations for
5. Monte Carlo simulation or the specific coefficient of variation is.[9]
6. With the finishing Monte Carlo simulation, average value of the output parameters obtained from the following equation can be used as the best estimation:

$$\bar{M} = \frac{1}{N}\sum_{k=1}^{N} M_k \quad (9)$$

And the variance of output parameters can be obtained from the following equation:

$$VAR = \frac{1}{N}\sum_{k=1}^{N}(M_k - \bar{M})^2 \quad (10)$$

Where $\bar{M}$ average output parameters, $M_k$ simulation output parameter at the k th iteration and N is the number of samples tested.

In this paper that the output parameter is the system reactive power, Formulas 9 and 10 are as follows:

$$\bar{Q} = \frac{1}{N}\sum_{k=1}^{N} Q_k \tag{11}$$

$$VAR = \frac{1}{N}\sum_{k=1}^{N}(Q_k - \bar{Q})^2 \tag{12}$$

Where $\bar{Q}$ average reactive power output, $Q_k$ amount of reactive power at the k th iteration and N is the number of samples tested.

**6.case study**

The study is done on 30 buses IEEE system, that has 6 generator buses and 24 load buses. It is shown in figure 1:

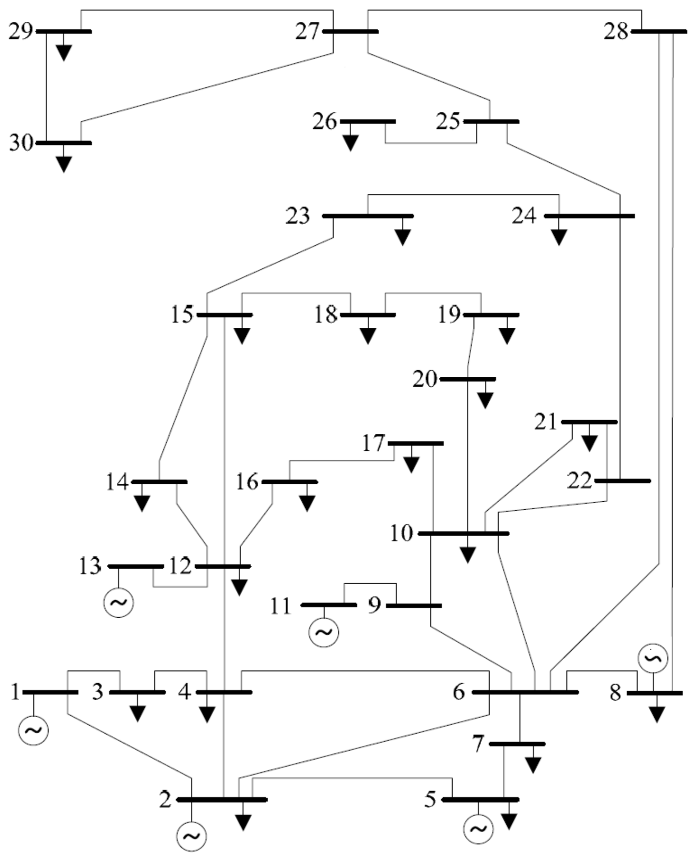


Fig. 1 30 buses network diagram

algorithm based on Monte Carlo simulation according to the flowchart in Figure 2 that the process is as follows:

1. Count=0
2. generate uncertainty random numbers of production or load
3. Insert random numbers in the original system and modify system now
4. Do load flow
5. Count+1.
6. If converged, go to step 8.
7. If does not converge, count-1, now and Go to Step 2
8. Do Monte Carlo simulation to saturate system parameters
9. If converged, go to the last step
10. If not converged, go to step 2
11. Compute the average reactive power requirements of the network

To evaluate the system in a restructured system and in a pool market, in the above algorithm, optimal load flow is used instead of the ordinary load flow. And moods of production, load and price changes are considered as a normal random distribution. A number of moods are shown in Table 1. Cost function is a function of polynomial systems (13) considered. Where the coefficients are shown in Appendix Tables 2 and 3.

$$f(p) = C_3P^3 + C_2P^2 + C_1p + C_0 \quad (13)$$

Also Figures 3, 4 and 5 are shown some examples of the diagrams of mean changes of reactive power generation at bus 1, 2, 5, 8, 11, 13, and the whole system, result of random changes in the parameters .

Reactive power output variation diagrams in Figure 3, 4, and 5, respectively, are $2.61 \times 10^{-5}$, $1.19 \times 10^{-8}$ and $2 \times 10^{-3}$. These small values show that Monte Carlo simulation has been successful in reducing variance.

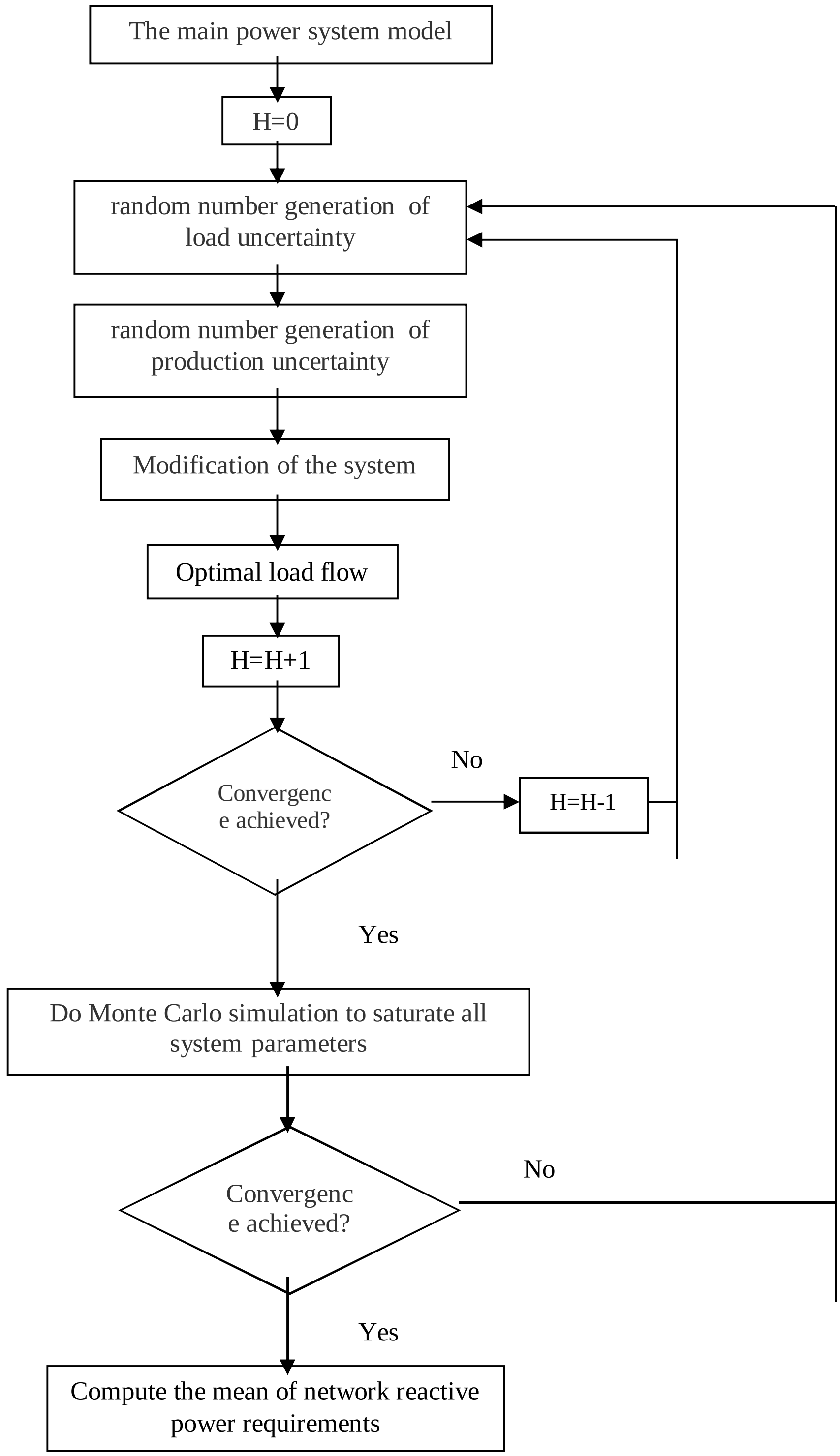


Fig. 2 Flowchart of proposed method

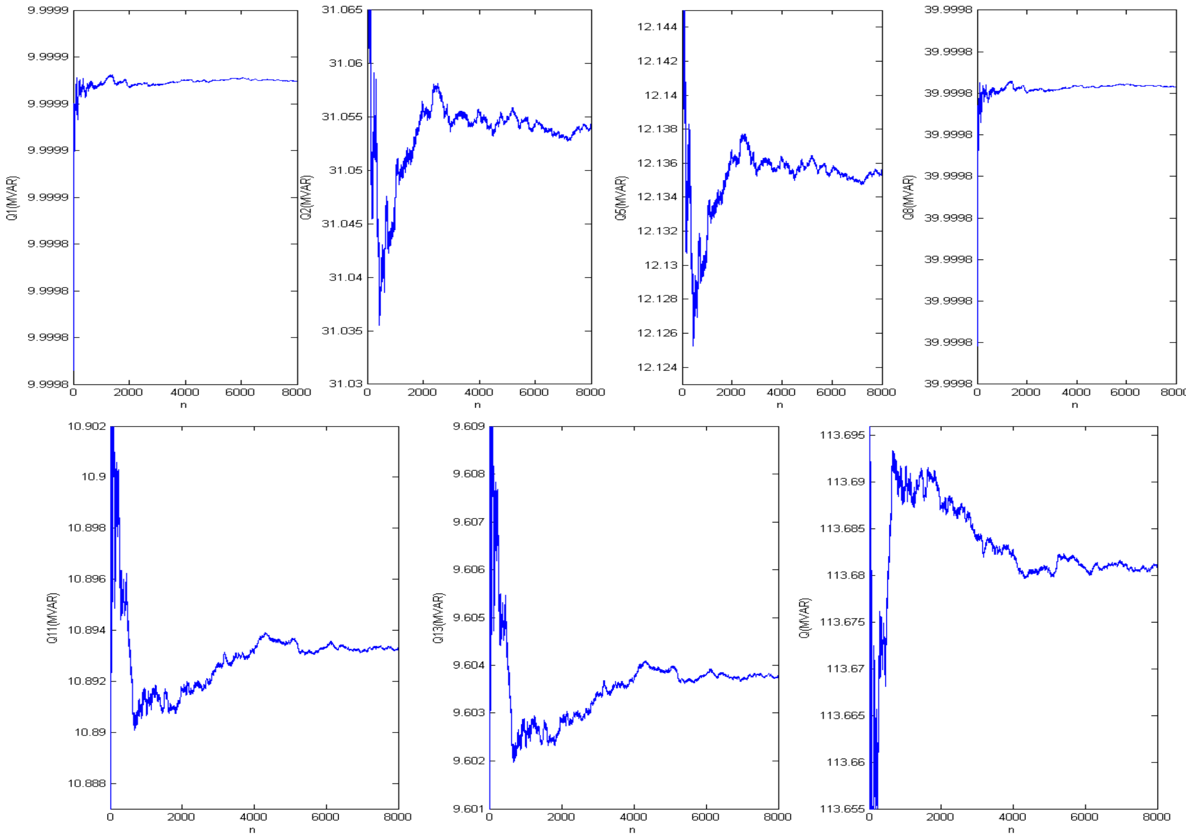


Fig. 3 Diagram of the system reactive power changes in a pool market due to random variations in the load at bus 5

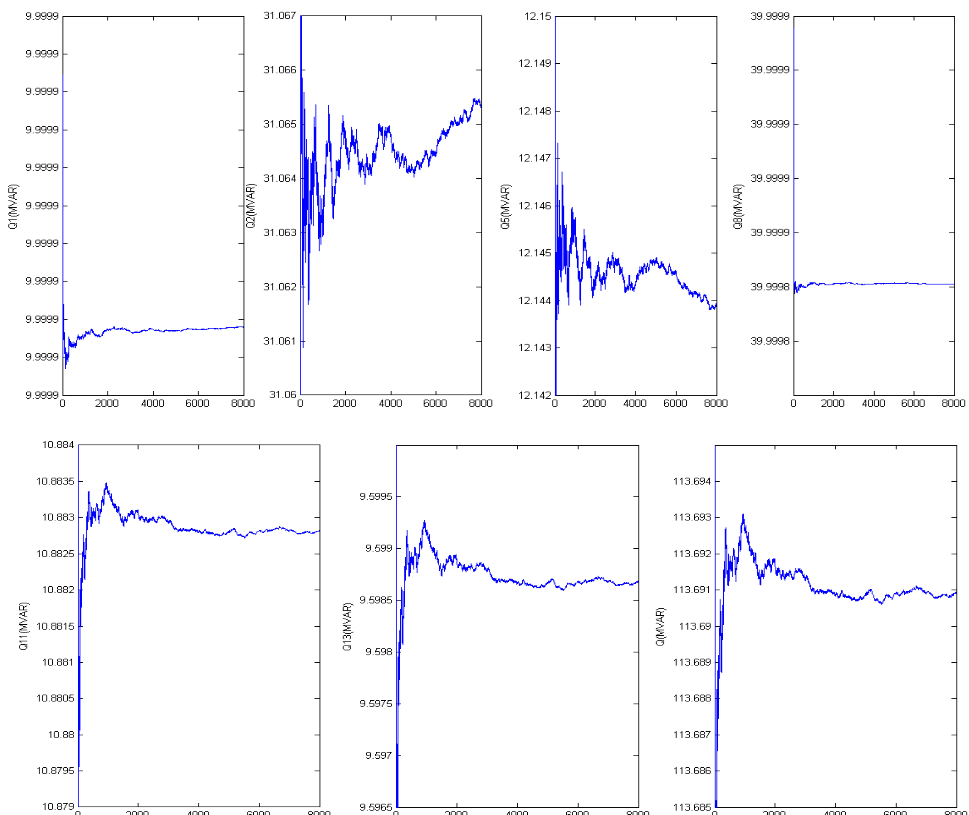


Fig. 4 Diagram of the system reactive power changes in a pool market due to random variations in the price of reactive power at bus 13

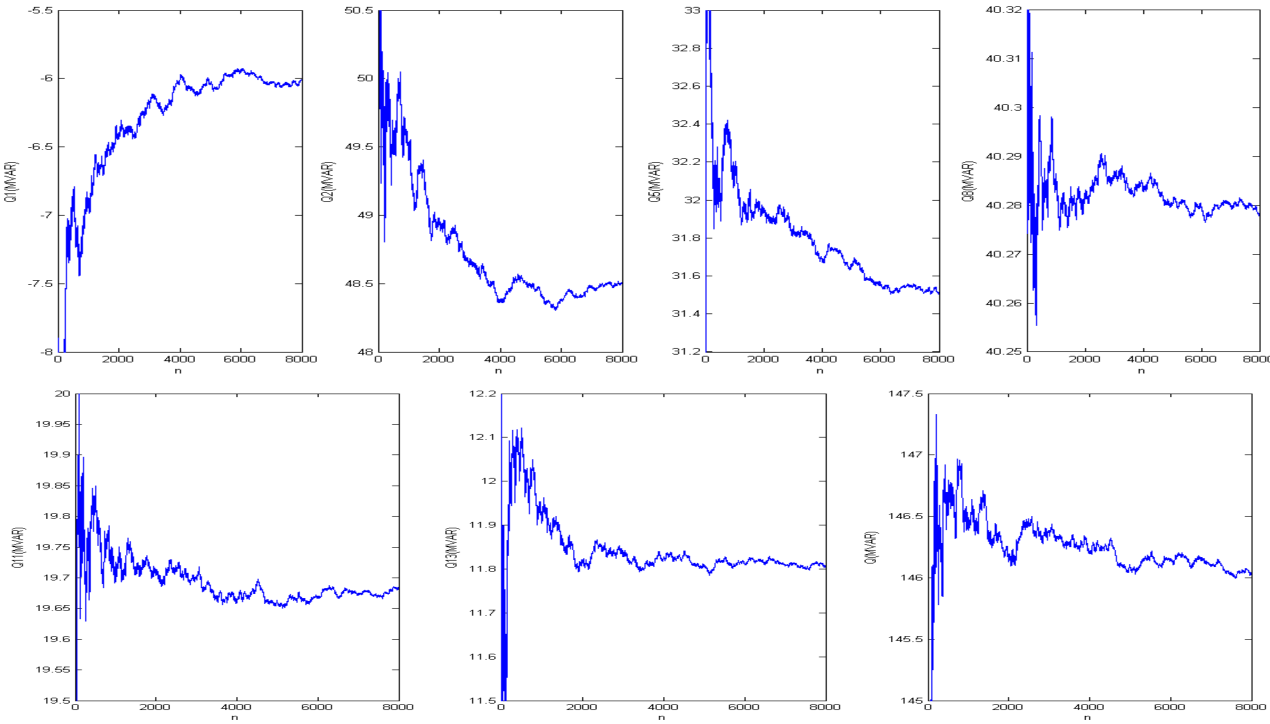

Fig. 5 Diagram of the system reactive power changes in a pool market due to variable random heavy loading

Table1. The results of the required reactive power in a pool market

| **Average random changes Reactive power Random States** | **Bus 8** | **Bus 11** | **Bus 13** | **Total of System** |
|---|---|---|---|---|
| Changes of generator reactive power prices at bus 1 | 39.9998 | 10.8789 | 9.5944 | 113.6874 |
| Changes of generator reactive power prices at bus 2 | 39.9600 | 11.1932 | 9.8342 | 115.3173 |
| Changes of generator reactive power prices at bus 5 | 39.9853 | 10.8413 | 9.5593 | 113.6886 |
| Changes of generator reactive power prices at bus 8 | 39.9998 | 10.8790 | 9.5997 | 113.6912 |
| Changes of generator reactive power prices at bus 11 | 39.9998 | 10.8799 | 9.5990 | 113.6907 |
| Changes of generator reactive power prices at bus 13 | 39.9998 | 10.8828 | 9.5986 | 113.6907 |
| Changes of generator active power prices at bus 1 | 39.5865 | 12.2278 | 10.2809 | 117.1920 |
| Changes of generator active power prices at bus 2 | 39.9965 | 11.0071 | 9.5939 | 115.7293 |
| Changes of generator active power prices at bus 5 | 39.9998 | 10.8067 | 9.4732 | 112.4521 |
| Changes of generator active power prices at bus 8 | 39.9998 | 10.8826 | 9.5947 | 113.6958 |
| Changes of generator active power prices at bus11 | 39.9998 | 11.4074 | 9.5444 | 114.3307 |
| Changes of generator active power prices at bus 13 | 39.9998 | 10.8838 | 9.5922 | 113.6843 |
| Change of Pd5 | 39.9998 | 10.8837 | 9.5991 | 113.6886 |
| Change of Pd7 | 39.9998 | 10.8924 | 9.6026 | 113.7352 |
| Change of Pd8 | 39.9998 | 10.8932 | 9.6029 | 113.7153 |
| Change of Pd10 | 39.9998 | 10.8850 | 9.5994 | 113.6947 |
| Change of Pd12 | 39.9998 | 10.8864 | 9.6133 | 113.7236 |
| Change of Pd14 | 39.9998 | 10.8848 | 9.6041 | 113.7042 |
| Change of Pd15 | 39.9998 | 10.8865 | 9.6060 | 113.7107 |
| Change of Pd16 | 39.9998 | 10.8838 | 9.6002 | 113.6952 |
| Change of Pd17 | 39.9998 | 10.8891 | 9.6026 | 113.7087 |
| Change of Pd18 | 39.9998 | 10.8836 | 9.5997 | 113.6942 |
| Change of Pd19 | 39.9998 | 10.8929 | 9.6090 | 113.7266 |
| Change of Pd20 | 39.9998 | 10.8829 | 9.5986 | 113.6910 |
| Change of Pd23 | 39.9998 | 10.8836 | 9.5999 | 113.6945 |
| Change of Pd24 | 39.9998 | 10.8889 | 9.6039 | 113.7128 |
| Change of Pd26 | 39.9999 | 10.8852 | 9.6014 | 113.7036 |
| Change of Pd29 | 39.9999 | 10.8822 | 9.5983 | 113.6854 |
| Change of Pd30 | 39.9999 | 10.8991 | 9.6166 | 113.8005 |
| Change of all loads | 39.9999 | 10.9198 | 9.5826 | 113.8114 |
| Heavy loading | 40.2744 | 19.6855 | 11.8362 | 146.2001 |
| Result of Monte Carlo simulation | 39.9945 | 11.1717 | 9.6846 | 114.7774 |
| Optimal load flow with a medium value | 40 | 10.88 | 9.6 | 113.69 |

## 7.Conclusion

In this paper by using Monte Carlo simulation, that is a flexible method, we found the exact amount of reactive power is needed for a restructured power system. To do this we used the method of probabilistic optimal load flow and considered the uncertainties of production, load and cost and obtained the results of reactive power changes of different buses and also all buses that is the amount of total requirement of reactive power for system. One of states of uncertainty considered is a variable heavy loading of system. that is shown the maximum need of reactive power in a critical condition and without collapse.
Simulation is down on 30 buses IEEE system. The results is shown in section 6.

## APPENDIX

Table 2 .Active power generation cost coefficients

| Bus | startup | shutdown | $C_2$ | $C_1$ | $C_0$ |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0.038432 | 20 | 0 |
| 2 | 0 | 0 | 0.25 | 20 | 0 |
| 5 | 0 | 0 | 0.01 | 40 | 0 |
| 8 | 0 | 0 | 0.01 | 40 | 0 |
| 11 | 0 | 0 | 0.01 | 40 | 0 |
| 13 | 0 | 0 | 0.01 | 40 | 0 |

Table 3. Reactive power generation cost coefficients

| Bus | startup | Shutdown | C2 | C1 | C0 |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0.02 | 0 | 0 |
| 2 | 0 | 0 | 0.0175 | 0 | 0 |
| 5 | 0 | 0 | 0.0625 | 0 | 0 |
| 8 | 0 | 0 | 0.00834 | 0 | 0 |
| 11 | 0 | 0 | 0.025 | 0 | 0 |
| 13 | 0 | 0 | 0.025 | 0 | 0 |

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