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Optimization of Market Clearing Process in Power System with NSGA Algorithm

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ABSTRACT

Reactive power and voltage control are one of the most important ancillary services that is a very important role in network stability and optimum utilization of the market. If the independent power system operators, uncertainties in levels of generation, transmission, and distribution in order not to be considered reactive power market clearing, events may lead to drastic changes in the reactive power system voltage instability and even resulting network will be off. In this paper, the objective function that is used in the process of reactive power market clearing optimization constraint that they have been reviewed and modified scenarios. Finally, to settle the right to enter the market despite the lack of definitive reactive activities, the NSGA algorithm is presented that the purpose of this algorithm, creating a compromise between the technical and economic objectives and targets system. This structure introduced by more realistic and reactive power distribution is done in such a way that in case of contingency, interest independent system operator will be better prepared to overcome them, and they sustained fewer expenses due change contracts with market participants.

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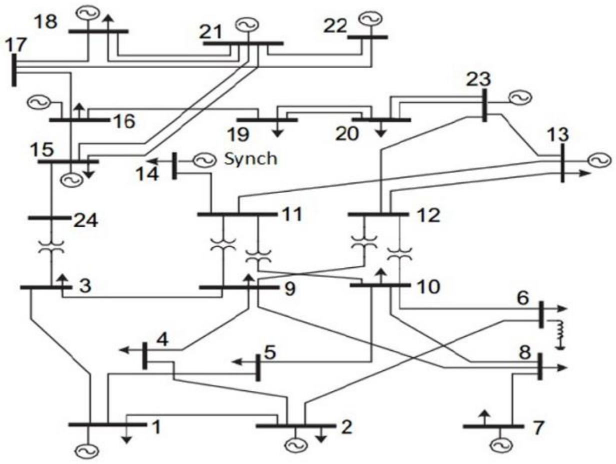
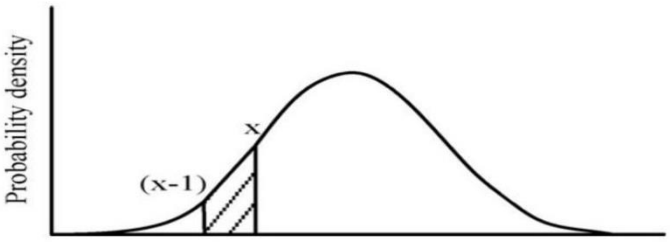
GRAPHICAL ABSTRACT





Introduction

Effective methods in optimum utilization of the network are particularly the pricing right side reactive power. In this regard, one of the best methods to create competition in the provision of services through the establishment of an independent market for each of them. It has to calculate fairly the cost of reactive power produced by the generator and the cost of reactive power consumed by the consumer rather than consumer and producer had reactive property motivation for Participation in reactive power marketing. Despite the flow of reactive power load is the effective only the effect of transmission losses and size of bus voltage, on flow active power load and its price, but unfortunately has been little attention to the cost of production and transmission power [1-5]. Technical and economic cases have made new objective function for identifying optimal utilization of reactive power market introduced. Some of these functions can be targeted to antecedent voltage security margin and antecedent load ability power system, to minimize transmission loss, to minimize diversion of trade agreements Closed and to the minimum amount of money paid by farmers reactive power system for the main purpose of the function that is in most of these studies, it can be noted [6]. In the power system, any type of structure of control and operation for transmission of power from the generator to the consumer is needing for network transmission. In a deregulated power industry, transport systems are often unique and remain in government hands. Essentially independent of the energy market, transmission, and power generation have been separated from each other. Power generation with companies in other competition company formed a competitive market. On the other hand, the utilization of the transmission system remains exclusively. So that accessibility is provided to everyone in it. Access to the Open and non-discriminatory transmission system allows the elderly by ISO to the commission, control, and utilization of the transmission system [7-12]. Reactive power production cost modeling is difficult for several reasons such as the difference of power production reactive equipment, to local production and the relationship between voltage and reactive power. The survey also shows that power pricing power reactive power base on coefficient power limitation loud of the consumer is not fair. The reactive power price is dependent on the place of production. Because it may not desire with low cost but be far from of consumer. Therefore, the implementation of reactive power market not suitable as active power and look to the market not to consider the reasonable shape, although in some shops these methods have been used. Needless to say, it can not use for reactive power pricing from a normal loud, Because the cost of this model power not be considered and in the best distribution also cost of reactive generation enters in problem and for this reason of best distribution use for pricing of reactive power [13-16].

In this paper, four important uncertainty modeling outages paper that means unforeseen outage of generation unit, unforeseen outage of transmission lines, probabilistic nature of wind power and the possible nature of the active and reactive load system is expressed and framework provided to create scenarios that consider the uncertainty at the same time. Also, the objective functions that are used in the reactive power market clearing process optimization with constraints that have been reviewed and amended to insert reformed scenarios.

Modeling of Uncertainties

There are many sources of uncertainty at all levels of utilization of the system's power generation, transmission, and distribution of electrical energy. This uncertainty was not reserved only for reactive and active power market and all markets, that also includes the active power and effects on market impression. Despite the uncertainties, the distance especially in that their reliability is low. Despite the uncertainties especially in low reliability the distance from the actual behavior of the power system market modeling in throughput. Uncertainties usually due to created changes in throughput climatic factors including temperature and humidity environment, economic growth, new types of electrical loads, and power factor loads [17].

Modeling of forced outage of generation units and transmission lines

In conventional methods of manufacturing plants repair schedule, the possibility of forced exit of production units is considered the fixed amount. Intended to enter exist of force rats the production units of reactive power market clearing, usually is used from a simulation. MCS methods are actually a bunch of algorithms that are based on repeated random sampling to compute the results of the use of a virgin. MCS methods are used in the simulation of physical and mathematical systems. Due to reliance on these methods on repeated calculations of random numbers and is suitable for calculating by the computer. And usually are used to calculate the not to be the exact result with an algorithm. In each MCS scenario, a random number between zero and one for each unit of production picked, and it compares with the force rates of our production unit. If the selected random number unit is greater than the rate of going out production unit, this unit can participate a suggesting in the reactive power market. Otherwise, this unit can not bid in the market and will be removed from the market. The above number of scenarios will follow better modeling of uncertainties, but also it has a heavier computing load is. Therefore, a method reduction of scenario to reduce the number of scenarios should be make work to while a reasonable approximate estimate of the probable behavior and the system [18]. The probability of each scenario can be calculated from the following Equation:

$$\Pi_s = \prod_{i=1}^{NB} \prod_{u=1}^{NU_i} (Z_{(i,u,s)}.(1-FOR_{(i,u)}) + (1-Z_{(i,u,s)}).FOR_{(i,u)})$$

(1)

In this case $Z_{(i,u,s)}$ there is a binary variable and indicates that the unit *u* was connected to the Shin i $(Z_{(i,u,s)}=1)$ that have been available and in this case reactive power can offer of the market that simulation with MCS and determines for each scenario.

Modeling of reactive power wind power plant

Reactive power consumed or generated by the wind plant is calculated based on the amount of generation of active power and voltage. At a constant speed wind turbine, which is installed extensively throughout the world, the generator was a type of inductive and uses reactive power to produce active power consumption. So the type of inductive generator can not control bus voltage than buses with a constant speed wind turbine at loud distribution model studies with P-Q [18]. The present paper study the impact of constant speed wind turbines. Equation (2) to calculate reactive power used by fixed speed wind turbines. With awareness of active output, Terminal voltage (V), and other parameters of the induction machine, the reactive power has been used can be calculated by the following Equation [19, 20]:

$$Q_e = \frac{\left[X_m X_{l2} S^2 X_2 + X_{l1} S^2 {X_2}^2 + R_2^2 X_1\right] |V|^2}{\left[R_1 R_2 + S(X_m^2 - X_2 X_1)\right]^2 + \left[R_2 X_1 + S R_1 X_2\right]^2}$$

(2)

$$S = \min \left| \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \right|$$

$$X_1 = (X_m + X_{l1})$$

$$X_2 = (X_m + X_{l2})$$

$$a = P_e {R_1}^2 X_2^2 + P_e (X_m X_{l2} + X_{l1} X_2)^2 - |V|^2 R_1 X_2^2$$

$$b = 2P_e R_1 R_2 X_m{}^2 - |V|^2 R_2 X_m{}^2$$

$$c = P_e R_2^2 X_1^2 + P_e (R_1 R_2)^2 - |V|^2 R_1 R_2^2$$

The process of entering of uncertainties is thus from the wind turbine market-clearing so that the first set to predict of possible wind speed. In most studies in this field, set the selection of speed in the form of a normal probability distribution. Therefore we recommend [18], that is better that be used the rail probability distribution. After the coming of selection wind speeds, the amount of active power turbine generation obtained for each wind turbine power curve using the purpose of market-clearing function will be formed and all these series. How the formulation of the objective function will be explained in the next sections.

Modeling of uncertainty loud

The conventional method for the prediction of uncertainties loud, the use of a probability distribution function (generally normal probability distribution function) for different scenarios. To expedite the process of reactive power market planning predicted probability distribution function (PFL) will be divided. As is also shown in Figure 1, the possibility of predicting the x-th time is equal to predicted the cumulative probability of the x-th and (x-1)th time. In this paper, based on papers presented at uncertainties disposable system, is used for the normal probability distribution [21].

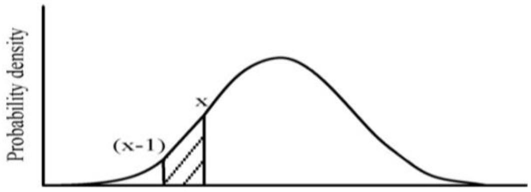


Figure 1. Probability density function

Besides, all possible scenarios must need to be evaluated and who have little probability, be removed. This work causes of reduction in the number of scenarios and therefore reactive power market clearing process will be expedited. What the number of scenarios is more, it will result in better modeling uncertainty, but parallel in time will increase the computational bulk system.

Production of Scenario

As mentioned earlier, different scenarios could affect the power system. It is not possible that all of these scenarios together and at the same time be considered. The framework requires that be considered a range of uncertainties system to simulate the best behavior in the power system. The basic idea for this action is the choice of probable scenarios and delete duplicate and similar scenarios. The assumption is made of the following scenarios resulting from generation units were forced outages.

$$SCN^{Gen} = \left\{ SCN_1^{Gen}, SCN_2^{Gen}, \ldots SCN_n^{Gen} \right\} \quad (3)$$

Which n is the number of possible scenarios resulting from the forced outage of generation units. Note that this number must cover the possibility of entire space. Each of these scenarios is likely:

$$P(SCN_k^{Gen}) = \prod\nolimits_{i=1}^{Gen} (Z_{i.k}.(1-FOR_i) + (1-Z_{i.k}).FOR_i) \quad (4)$$

In the above equation, $Z_{i.k}$ binary variable indicates that the unit *i* in the *k-th* scenarios in or out. Scenariois caused by the forced outagetransmission lines of the same.

$$SCN^{Line} = \left\{ SCN_1^{Line}, SCN_2^{Line}, \ldots SCN_m^{Line} \right\} \quad (5)$$

Which *m* is the number of possible scenarios resulting is forced outage from transmission lines. This number also must cover the possibility of entire space. Each of these scenarios is likely:

$$P(SCN_k^{Line}) = \prod_{h=1}^{Line} (Z_{h.k}.(1 - FOR_h) + (1 - Z_{h,k}).FOR_h) \quad (6)$$

In this regard, the $Z_{h,k}$ binary variable specifies the transmission line *h* in *k* scenario have been in orbit or beyond.The following scenarios will be set for each of them is likely to be achieved on the basis of normal probability distribution:

$$SCN^{wind} = \left\{ SCN_1^{wind}, SCN_2^{wind}, \ldots SCN_L^{wind} \right\} \quad (7)$$

In this series, *L* is the number of steps chosen for wind speeds. Finally, a normal probability distribution system will be used to produce scenarios for the system loud. In a power system, both the active and reactive systems are under great uncertainty. A reactive power market that runs after the active market, should be considered active and reactive load times of uncertainty, both in terms of the system. If that is favorable closed energy contracts in the energy market, reactive power will remain unchanged in the market. In this case, the objective function deviation from energy deals closed not enter the changes Active load of full system will take the reference generator power system. Scenarios of uncertainty system will be created as follows:

$$SCN^{Load} = \left\{ SCN_1^{Load}, SCN_2^{Load}, \ldots SCN_k^{Load} \right\} \quad (8)$$

In this series, *k* is the number of step choices for the reactive load. *M* and *Q* the mean and standard deviation are also probability distribution functions. As it turns view, these steps also should cover the entire space of possibility. The amount of probability of each scenario on the charts will be achieved according to the selected number. It should choose probability scenarios from all the scenarios. Therefore, the selection of possible scenarios removes scenarios that are the least likely, and hence the probability space will be distributed on the remaining scenarios. The possibility of putting together a scenario will be as follows a combination of each scenario:

$$P(SCN) = P(SCN_n^{Gen}) * P(SCN_m^{Line}) * P(SCN_L^{Wind}) * P(SCN_k^{Load}) \quad (9)$$

Standard IEEE 24-bus Network

The network is shown as in Figure 2, including 32 synchronous generators in bus 1, 2, 7, 13, 15, 16, 18, 21, 22, and 23, and one synchronous condenser at bus-14. Also loads are over a fixed time. In this reference system have been bus-13and generator of duty will be charged in compensation the amount of generation and consumption of reactive power for all unbalances. The maximum power of generators produced is considered high enough Shin until in case of an occurrence in the network, the system has not been a problem for suppliers and load shedding not be necessary [22]. Due to the limitations that there is the complexity of the problem fora long time we have to rend optimization of all of them and regardless of the importance select some of them, as an objective function and optimize them. Objective functions that were selected in this paper include the cost of reactive power, active power losses as well as transmission system stability index transmission line. Then each of these functions is considered in any uncertainty together with the case where there is no uncertainty, compared and in the all uncertainties part will consider together and will analyze the results.

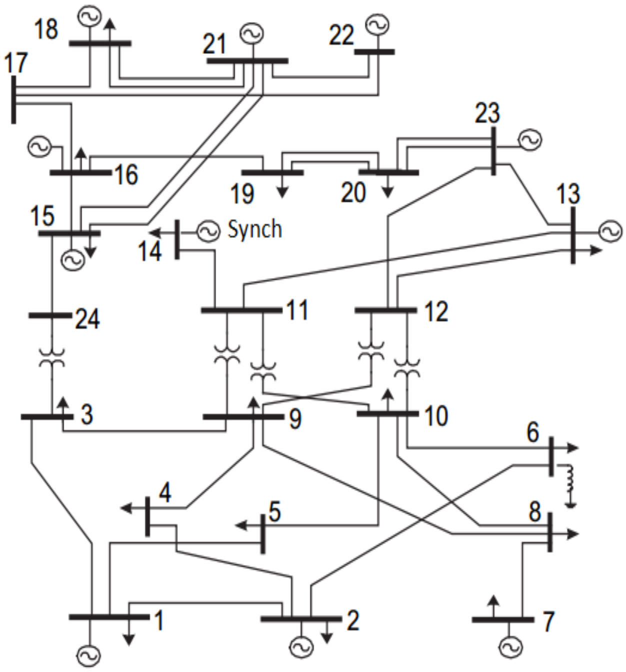


Figure 2. IEEE 24-bus network

Simulation of reactive power with considering of compulsory of units and transmission network lines

At IEEE 24-bus network gets involved outage forced Considerations of generation units separately is not a good way as a series of uncertainties, because usually is that the power system, occur not predicted forced outage reference generator as the generator rarely, and therefore it is considered usually very small in stimulation mandatory withdrawal rate. Also forced outage choice causes separately a high number in scenarios that will take a very long time the Performances and We have to choose the number of these scenarios that with attention to limit of choices scenarios have not variety of scenarios. As a result of the forced outage scenario of transmission line and the units will consider together, we are in a simulation conducted of this section, some scenarios the 10 scenarios after reducing the similar scenarios and scenarios with low probability. One of the indicators that are commonly used to assess voltage profile is the total voltage heterogeneity index(TVHI) can be achieved from Equation (10) if we have a more favorable voltage profile however this index be much smaller [1].

$$\mathrm{TVHI} = \sum_{\mathrm{i \epsilon N}} \mathrm{VHI_i} \tag{10}$$

$$VHI_i = \begin{cases} 1 & V_i < V_{min} \; or \; V_i > V_{max} \\ 1 - \dfrac{2 \times (V_i - V_{min})}{V_{max} - V_{min}} & V_{min} \le V_i \le V_{min} + \dfrac{V_{max} - V_{min}}{2} \\ 1 - \dfrac{2 \times (V_{max} - V_i)}{V_{max} - V_{min}} & V_{min} + \dfrac{V_{max} - V_{min}}{2} < V_i < V_{max} \end{cases}$$

The results of the 10 scenarios are shown in Table 1. As specified in the table, the best scenario for the cost of reactive poweris Scenario 4 and the worst-case scenario, Scenario 8. In scenario 4 units 10, 22 and 23 have been exit, but in Scenario 8 has been switched off only unit 13. According to Figure 2, unit 13 on bus-13 is located in the center of the networkand we have to do required reactive power system with remove them of far from network remote parts. This is led to increase in system losses and also an indicator TVHI.

Table 1. The results of the objective functions optimization without incident andsimultaneously

Uncertainties of unforeseen outage of transmission lines and units	Cost ($)	Ploss (MW)	Total voltage heterogeneity index	Stability Transmission Line Index
Scenario 1	237.84	55.84	5.7122	0.122
Scenario 2	194.66	58.32	5.5359	0.103
Scenario 3	232.16	100.91	6.5606	16.597
Scenario 4	190.31	58.85	5.2706	0.238
Scenario 5	242	104.03	7.2426	0.216
Scenario 6	227.91	100.85	6.6469	0.072
Scenario 7	223.85	100.8	6.5723	0.5236
Scenario 8	254.64	101.05	6.5492	0.2842
Scenario 9	190.8	89.72	6.3947	0.4
Scenario 10	224.06	55.84	5.7122	0.112
Deterministic	180.76	51.24	5.2	0.1017

Reactive power market stimulation with considering of uncertainty consumed

For revision, the uncertainty caused by the load is considered the predicted load values in Table 2 as a mean of the-distribution normal probability. Curve With an average load and a standard deviation of six divided into curve normal distribution likely results in 3 levels once predicted. Just as specified in the table, if only to the system without incident and without uncertainty for once do, settling reactive power, we do not consider a large part of the changes of the probability of loud if there be changes and event, the operator will not be prepared to deal with this problem.

Table 2. the entire system loud and the possibility of a normal distribution

System total load	1	0.95	1.05
Probability of normal distribution	0.38	0.3	0.3

As we had expected in Table 3 are shown, when the load increases, in conclusion, also will increase the number of costs for the compensation of reactive power. Also by increasing the amount of stability index is intervened will increase the amount of their optimal. Transmission losses line, with increasing loud disposable, will increase, because of the increasing amount of active and reactive power flowing through the transmission line.

Table 3. The results of the uncertainty of the loud

Uncertainty of load scenarios	**Cost** ($)	**Ploss** (**MW**)	**TVHI**	**stability transmission line index**
Scenario 1	171.78	49.11	5.314	0.1001
Scenario 2	180.76	51.24	5.2	0.1017
Scenario 3	230.67	53.91	5.424	0.1125

Reactive power market simulation with considering possible nature of wind power generation

To evaluate the effect of uncertainty caused by the wind blowing has been fixed speed in the reactive power market clearing, a wind plant including 100 wind turbines at bus-11. Wind turbines are similar and all parameters required them is shown to calculate the amount of reactive power in the Table 4. At a wind turbine plant that has a constant speed, the generator was a type of inductive reactive power uses for active power generation. So the type of inductive generation does not control bus voltage. For this reason bus modeling with constant speed studies of load distribution and bus turbine. This paper using a normal probability distribution for wind speeds. This distribution parameters are such as mean value (μ) and standard deviation (σ) respectively of 12 meters per second and 1.8 meters per second.

Table 4. Parameters induction generator of wind farm

Generator nominal power (MW)	0.66
Generator nominal voltage (KV)	0.69
R_1(P.U.)	0.005986
R_2(P.U.)	0.01690
X_{11}(P.U.)	0.09212
X_{12}(P.U.)	0.127222
X_M(P.U.)	2.5561

Table 5. All wind speed scenarios and possibility of them

Wind speed (m/s)	(٪)**possibility**
6.6-8.4	2.1
8.4-10.2	13.6
10.2-12	34.1
12-13.8	34.1
13.8-15.6	13.6
15.6-17.4	2.1

Just as shown in Table 6, we find out when the wind scenarios are compared with a definitive, in the case of use wind farms will have to improve the sustainability index transmission.

Because wind power plants will help to generate active power and reactive network security. Also in scenario 4, cause in decreased costs reactive power will be absolute toward the older case.

Table 6. The results of the simulation network in view of the uncertainty caused by wind power plant

Uncertainties Of Wind Scenarios	Cost ($)	Ploss (Mw)	Tvhi	Stability Transmission Line Index
Scenario 1	204.9	51.25	5.85	0.0392
Scenario 2	229.47	51.15	5.849	0.0379
Scenario 3	200.71	51.05	5.848	0.0363
Scenario 4	175.01	50.96	5.14	0.0348
Scenario 5	233.37	50.92	5.846	0.0342
Scenario 6	254.95	50.91	5.846	0.0334
Deterministic	180.76	51.24	5.2	0.1017

Reactive power market simulation by considering uncertainties

In the Table 7 is shown data from the simulation at the situation concerning each of uncertainty alone and also the case that no consider uncertainty. Just as will observe the amount of fee for considering uncertainties cause cost increase will be for reactive power compensation and indicator stability of the transmission lines from optimization. However, considering uncertainties causes an increase in the cost evenly, but the distribution system operator will be considered many events that will occur is much. The operating system is an important part of events that consideration and make the right decision on since lack of getting certainly event.

Table 7. Information obtained from both the synchronous and asynchronous uncertainties, along with certain

Modes	Ploss (MW)	indexWLmn	Cost ($)
Without contingency	51.24	0.1017	180.7
Considering uncertainty of forced outage	81.05	0.233	226.16
Considering uncertainty of load	79.33	0.102	189.24
Considering uncertainty of wind blowing	51.78	0.0355	199.22
Simultaneous uncertainties	100.78	0.629	418.49

Conclusion

The selection of uncertainties has been set modeling discussed with the framework provided for considering the uncertainties simulation in this paper. The results of the settlement market, as well as the results of simulation Monte Carlo, indicate that the use of certain methods in which not consider uncertainty and it is not optimal solutions. The results get of these things are far from the real system. Because of this research, respect the desire system conditions. Results showed

Stability System amount index (WLmn) in the case that enters uncertainties close to number one. The result can get that was the general lack of uncertainties draw the system to the instability and the sources of uncertainty were more will have problem stability of the system. Another advantage of the framework and presented algorithm in this paper is that never is limit and close and will be improved simply. In the proposed framework by making small changes can be added easily the possibility of uncertainties and at a known algorithm add another objective function. However, it should be noted that the increased systems computing volume greatly if be considered the cost of a long-term problem, as a conclusion they are considering uncertainties not only enhances the costs but also creates reduces the costs significantly (especially for systems with low security).

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