COMPARISON OF TWO STANDARD POWER NETWORKS FOR GENERATION AND LOAD PATTERNS IN POWER SYSTEM

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***ABSTRACT:**: Network structure and active power generation pattern are effective factors on static loadability limit and buses and voltage stability. This paper has been considered IEEE 14-bus and 34-bus test network in order to create generation and load patterns. Creating generation and load patterns in these two test networks like almost uniform distribution of generation, generation dispersion, the allocate value from the sharing of centralized generation to distributed generations (DGs) and change generation values on the buses, especially putting generation on buses of weak network is investigated. The conducted analyzes on the obtained results from the desired generation patterns, the authors have realized that the generation uniform distribution between buses or change of generations centralized location or allocate percent from generations centralized sharing to distributed generations and putting these generations on load bus, in the event that with accurate and comprehensive investigation is associated improved voltage stability and loadability limit. By analyzing the different modes and review the results of similar patterns in these two systems, the different generation and load patterns effect mechanism of* distributed generation units over the behavior of the system in terms loadability limit and voltage stability is achieved.

Keywords: 14-Bus Network, 33-Bus Network, Generation Pattern, Load Demand, Load Pattern, Voltage Stability.

INTRODUCTION:

In modern times, the term voltage instability has been used to describe many situations which result in systems where voltages are not automatically restored to acceptable levels. These situations have virtually all been associated with reactive power capabilities [1]. The electric power utility is being insistently stressed by government, heavy industries, and investors to privatize, restructure, and deregulate. Hence, the power utilities are operating closely to their voltage stability and loadability limits. As a result, the incorporation of voltage collapse criteria and tools in the operation of power systems are becoming an essential part of new energy management systems. Therefore, the voltage stability and loadability limit are important study in the operation and planning of a power system [2-3]. Estimating loadability of a generation and transmission system is of practical importance in power system operations and planning. Analytically, estimating the loadability of power systems is somewhat similar to the so called generation rescheduling problem [4].

On the other hand, since the distributed generation unit (DG) is a small capacity compared to centralized power plants, it has a small impact on power systems such as voltage profile, power flow, power quality, stability, reliability [5] and protection against its infiltration level that is between one and five percent. However, if the level of penetration of DG units increases according to forecasts by 20-30 percent, DG units will be profound effect on power systems [6].

In [6] at the first stage, an algorithm is used to search possible solution area and reach tradeoff between secure and economic direction of real power generations. In the second stage of

proposed approach to each generation pattern, power system voltage stability margin and generation cost respectively are evaluated during search algorithm. Rezaie Estabragh and Mohammadian [7] states that the simulations are performed on IEEE 14 and IEEE 30 bus test systems to find best generation direction.

Rajaram and Selvaperumal [2] presents Particle Swarm Optimization (PSO) [3] with parallel mutation (PMPSO) to determine the maximum loadability point of the power system.

It can be admitted that voltage instability in power systems has been known as load instability for decades [8]. In [9] the authors conducted a practical study on the effects of DG units on voltage stability. They have examined the effects of the position and size of DG units under variations in loading conditions due to the imbalance occurrence possibility in distribution systems [10], also, the effects of capacity and position of DG units on the voltage stability performance of distribution networks [11]. As well, in [12], and [13] Methods have been proposed to locate DG units for improving the voltage profile and voltage stability of distribution systems [14], and [15].

In [11], DG units are located on buses that are sensitive to voltage collapse, and it led to an improvement in voltage profile as well as a losses reduction. In [13] the authors developed the paper of Hemdan and Kurrat [12] to maximize loading conditions in critical situations and routine conditions. Voltage stability analysis is done in both statically and dynamically method. Furthermore, the static method uses received voltage and power relations in a specific bus of system that is under a title of a – curve or nose curve [16].

So, the authors in this paper have taken two test networks to validate the results of simulation and expand the achieved results; An IEEE 14 bus standard network and second, a 34 bus network. The two networks are intended to create generation and load patterns. In creating the generation and load patterns in these two test networks has been studied almost uniform distribution of generation, the generation dispersion, assigning a value of the share of concentrated generations to distributed generation (DG), and changing the generation values on the buses, especially placing the generation on the weak buses of the grid. By analyzing the obtained results from the intended generation patterns, the authors have found that the uniform generation distribution between buses, changing the location of concentrated generation, or allocating a percentage of the share of concentrated generation to distributed generations, and placing these generations on the load buses, if it associates with an accurate and comprehensive study, it improves voltage stability and loadability limits. By analyzing different states and studying the results of similar patterns in these two systems, the effect mechanism of different patterns of distributed generation on the behavior of the system is obtained from the point of view of loadability and voltage stability.

The remainder of this part is organized as follows. In section tow, an outline of the studied power networks explanation. Section three states problems of mathematic modeling. Experimental results on two standard IEEE 14-bus and 34-bus networks are presented in section four before concluding in section five.

2. The explaining of studied power networks:

Different kind of technologies in distributed generation makes it possible to use these types of products at the site of each network buses. DGs are such that they can increase or decrease their capacity after installation in any location. Also, these types of generations, compared to centralized generation, are more reliable in the transmission from one location to another within the network. By this description, in an existing network, various patterns of generation can be found in the presence of distributed generation. Therefore, to study the effect of different patterns of distributed generation on voltage stability and loadability limit, the size of the system should be so that both may be provided in a variety of generation patterns in it, and follow-up of the process of work, it makes the possibility of finding the proper pattern of generation in the given network.

It should be noted that the network structure and active generation pattern of the power network buses are affecting factors on the static loading and voltage stability. Accordingly, regarding the importance of the topic, we have described the structure of studies on the 14 bus and 34 bus tests networks.

2-1. Studies on the 14-bus test network:

This system is one of the IEEE test standard systems. It is considered an appropriate case, given that, it is not simply testing 3-bus or 6-bus test systems, and on the other hand, it has not the complexity of the large test systems, for checking the change of generation pattern, and finding the relationship between the generation pattern, the loadability limit, and the voltage stability. In total, the following system consists of 14 buses and 20 lines: a slack bus (bus number 1), four generation bus (buses number 2, 3, 6, and 8), nine load bus (buses number 4, 5, 7, 9, 10, 11, 12, 13, and 14). Also, the obtained results [14] from load flow of 14 buses IEEE network are expressed in loadability limit point for each of the generation patterns, the values of system buses generation and consumption, loadability limit and losses.

2-2. Studies on the 34-bus test network:

In a specified system, many production patterns can be created according to different generation modes in terms of the generation location and amount of the desired generation and the percentage change of buses generation share relative to each other. Each of these generation patterns has its own effect on voltage stability and loadability limit. Another test system for test network is the 34-bus test network. This system is in terms of size and topology corresponding to a real power system, it seems appropriate in order to investigate the change in the generation pattern and its effect on loadability limit, and voltage stability. Therefore, in this paper, it has been selected as an another test system. The specifications of this system are provided in the appendix section.

In total, the following system consists of 34 buses and 73 lines: a slack bus (bus number 1), thirteen generation bus (buses number 3, 6, 8, 11, 12, 14, 19, 20, 21, 24, 27, 30, and 32), twenty consumption bus (buses number 2, 4, 5, 7, 9, 10, 13, 15, 16, 17, 18, 22, 23, 25, 26, 28, 29, 31, 33, and 34).

3. Mathematic Modeling:

3-1. The creation of load patterns:

Considering the effect of load growth on voltage stability, to simulate the voltage, the load must be increased. Therefore, according to a specific pattern, the load should grow. Accordingly, the formulas (1), and (2) are used here for this purpose (The load pattern corresponding to each load level is established on different buses according to (1) and (2)).

$$P_{Li}^{K} = P_{Li}^{0}(1 + k\lambda) \quad (1)$$

$$Q_{Li}^{K} = Q_{Li}^{0}(1 + k\lambda) \quad (2)$$

Thus, Q_{Li}^{0}, P_{Li}^{0} are the active and reactive power values of load respectively on the i-th bus in the initial state of load. So that, λ is the coefficient of increasing the growth stairs of the load at different load levels which varies from zero (base load) to maximum value (loadability limit). The λ value can be in the form that starts from steps 0.01 and it selected by approaching to the collapse point to achieve a smaller convergence. The K value is the number of growth stairs of the load until the collapse point.

It should be noted that the consumption share of buses from the total system consumption in all cases is constant. If we show this value for i-th bus with a_i, we will have:

$$a_i = \frac{P_{Li}}{\sum P_{Li}} \quad (3)$$

So that, a_i for every bus, always has a fixed amount.

3-1. The creation of generation patterns:

Different generation patterns need to be created. To investigate the effect of the generation patterns on voltage stability and also the loadability limit of the 14-bus test network for each of the generation patterns. This generation patterns can create for different levels of load. The generation pattern of buses is determined according to formula (4):

$$P_{Gi}^{K} = \beta_i P_{Total}^{K} \quad (4)$$

So that, P_{Gi}^{K} is i-th bus generation of K-th load level, β_i is i-th bus generation share for supporting K-th load level, that means P_{Total}^{K} and P_{Total}^{K} are total network active load in K-th loading level.

It should be noted that the share of reactive power generation of generators by their induction control system determine automatically according to the AVR function and voltage regulation of terminal and the reactive power constraints of generator. By determining β_i values for network generation buses, we can extract the generation pattern of buses.

Various patterns [14] have selected in order to we can create relatively wide variety and dispersion in buses generation patterns. Each of the patterns can be applicable to all load levels, and the relationship, and always formula (5) is available:

$$\sum_{i=1}^{NB} \beta_i = 1 \quad (5)$$

4. Network loadability limit Effecting from generation and load pattern:

In order to achieve a suitable generation pattern for improving voltage stability and loadability limit, in addition to conducting multiple simulations to find the best value of relative generation on generation buses should be identified weak buses of the systems. As well, the balance between load and generation must be taken into account in each part of the network.

Ladability limit and voltage stability of the network can be improved considerably by optimally selecting of the generation location, in particular by putting some amount of generation on weak buses of the network.

In addition,

The proper forecast of load growth in the future, and given the fact that the amount of distributed generation (DG) can be increased after installation in one place, it is possible to select DGs location in parts of the network where their consumption load is associated with high growth. In this case, DGs can cause reverse loading in those locations. Likewise, this problem is effective in voltage stability improving of the network.

The time of power transferring from a power network transmission line, because of the voltage drop in the resistance and the line reactance, The bus voltage of the end of the line changes both in size and phase relative to the bus voltage at the beginning of the line. The major part of the change in voltage is due to a change in the voltage level. The relationship of voltage variation is given in terms of the short circuit level, and the using of appropriate approximations and simplification by formula (6).

$$\frac{\partial V}{\partial Q} = \frac{-E}{S_{SC}} \quad (6)$$

So that E is the power supply bus voltage, and S_{SC} is the short-circuit level of bus. This formula shows that short-circuit high level of S_{SC}, Leads to a decrease in voltage sensitivity, the loading line is flattened, and as a result, the system is said to be sturdy.

Since the reactance equivalent of a bus of network X_{TH_i} is a larger, the short-circuit level of that bus is shorter, in other words, S_{SC} has a reverse relation with the value of X_{TH_i}. Therefore, X_{TH_i} can be the weaknesses and the strengths indication of that network buses, which means that generally what X_{TH_i} of a bus be larger, that bus is weaker is the weakest. The calculation of X_{TH_i} is also obtained from the voltage calculation.

Given the fact that the reactance equivalent value of every buses of the network of X_{TH_i} for can be a can be the weaknesses and the strengths indication of that network buses, it seems that by determining X_{TH_i} for each of the network buses can be found a relationship between these values, and generation value on buses in the various generation patterns on loadability limit. To this end, we have been investigated various models to find out the relationship between the loadability limit and the place of the generation:

Five relation has been considered as formulas (7.1-7.5):

$$\begin{cases} F = \left(\left(\frac{(P_G - P_L)^2}{X_{TH}}\right) \times a + \left((P_G - P_L)^2 \times X_{TH}\right) \times b\right) \\ P_G - P_L \langle 0;\ a = 1, b = 0 \\ P_G - P_L \langle 0;\ a = 1, b = 0 \end{cases} \quad (7.1)$$

$$\begin{cases} F = \left(\left(\frac{(P_G - P_L)^2}{X_{TH}}\right) \times a + \left((P_G - P_L)^2 \times X_{TH}\right) \times b\right) \\ P_G - P_L \langle 0;\ a = 0, b = 1 \\ P_G - P_L \geq 0;\ a = 1, b = 0 \end{cases} \quad (7.2)$$

$$\begin{cases} F = \left(\left(\frac{(P_G - P_L)^2}{X_{TH}}\right) \times a + \left((P_G - P_L)^2 \times X_{TH}\right) \times b\right) \\ P_G - P_L \langle 0;\ a = 1, b = 0 \\ P_G - P_L \geq 0;\ a = 1, b = 0 \end{cases} \quad (7.3)$$

$$\begin{cases} F = \left(\left(\frac{(P_G - P_L)^2}{X_{TH}}\right) \times a + \left((P_G - P_L)^2 \times X_{TH}\right) \times b\right) \\ P_G - P_L \langle 0;\ a = 0, b = 1 \\ P_G - P_L \geq 0;\ a = 0, b = 1 \end{cases} \quad (7.4)$$

$$\begin{cases} F = \left(\left(\frac{(P_G - P_L)^2}{X_{TH}}\right) \times a + \left((P_G - P_L)^2 \times X_{TH}\right) \times b\right) \\ P_G - P_L \langle 0;\ a = 1, b = 1 \\ P_G - P_L \geq 0;\ a = 1, b = 1 \end{cases} \quad (7.5)$$

By choosing different coefficients for each term of the formula, five models have been extracted and these models are applied to the first ten generation patterns of the 14-bus network. Finally, the results are investigated (for facilitation of checking, the values multiplied by the coefficients).

5. Modeling Considerations:

A description of the models of power system elements that have a significant effect on voltage stability is described as follows:

Loads: The load characteristics are important in the voltage stability analysis. Contrary to conventional analyzes of transient stability and load propagation, it may be necessary to display the extended expansion system in a weak voltage region. The display of the system should include ULTC transformer, reactive power compensation, and voltage regulator in the system under the transfer.

It is important to consider the dependence of the loads on the voltage and frequency. Also, modeling of induction motors may be necessary. In some cases, proper display of load characteristics at low voltages may also be necessary.

Generators and their stimulation controls: For the voltage stability analysis [3], it may be necessary to consider the AVR dropping characteristics instead of the dropping zero. If load regulation (line dropping) is available, then it should show its effect, and it should be displayed in a specific way instead of assuming that the armature and the excitation current are in the form of a constant value of the upper limit of reactive power.

Reactive power static systems (SVS): When the SVS operates within the normal voltage control range [17], it maintains the bus voltage with a low-dropping characteristic. When it operates at reactive power levels, the SVS displays in the form of a capacitor or reactor, which can have a dramatic effect on voltage stability. Therefore, SVS characteristics should are adequately represented in voltage stability studies.

Self-Generation Control (AGC): For events that lead to an important mismatch between the generation and load, the primary speed control function and the additional control of the communication link bias frequency may substantially will change the system generation, which in some cases it may be at the expense of the voltage stability. Hence, these functions should be properly displayed.

Protection and controls: This section covers the protection and controls of the generation unit and the transmission network. For example, it can be used to protect of the generator excitation, armature overcurrent protection, the transmission line overcurrent protection capacitor assembly controls, phase-regulating regulators, and the voltage-defective charging.

6. Simulation results:

Determining the load limit and voltage stability generated by the program for each generation pattern is derived by using the input data, which is the same information for performing load flow, the generation buses are first specified. Then, depending on the amount of the generation placed on each of the buses, proportional to that amount of the generation, the reactive power control interval is defined for that bus. Here, the control range of reactive power is about $\left(-0.4P_n \leq Q_n \leq 0.6P_n\right)$. Which P_n and Q_n are the active power and the reactive power of the bus generation respectively. In this program, the initial values and total power of the load are first stored. It is worth mentioning that the programming of this program is written in Fortran's programming environment. Also, the results of the load flow are obtained by the Newton-Raphson method for achieving great convergence.

6-1. Investigating mechanism of network loadability limit effect on the generation and load pattern:

Since the analyzes carried out on the results of the relationship between different generation patterns, and in particular DG patterns, are more general in terms of loadability limit and voltage stability, two different systems for simulation and analysis have been selected.

In generating patterns in these two test networks the examination of the almost uniform distribution of the generation, dispersion of the generation, the allocation of a proportion of the share of concentrated generations to distributed generation (DG) and the change in the generation values on the buses, especially the placement of the generation on the buses of weak network had been studied.

In the following figures (Figure 1-5) have been showed the obtained results of models 1-5 for the first ten generation patterns of the 14-bus network.

Regarding the diagrams of figures 1 - 5, it is observed that the model 5 predicts a fairly reasonable behavior of the loadability limit of generation patterns.

By performing multiple simulations on the 14-bus network, four different modes have been investigated. The results are summarized as follows:

- Displacement of the generation from one generation bus to another generation bus (concentrating the generation at lower points).
- Displacement of the generation from one generation bus to a load bus.
- Displacement of the load from one generation bus to a load bus.
- Displacement of the load from one load bus to a load bus.

In the first mode, due to the reduction of the generator bus, as expected the loadability limit in most modes decreases according to table 2. Exception modes are related to load balancing and generation in different areas of the network.

Also, by assigning a share of generation to load buses in the second mode, it has been observed that the loadability limit has increased. In the second case, generally the generation on the weaker buses leads to a higher loading rate. Therefore, the development of the generation pattern in most modes leads to an increase in the loadability limit. This problem is due to load balancing and the generation, and the proximity of the generation centers to the load and reduction of network losses.

In the third mode, also due to the imbalance of the generation and load, as well as the distance from the generation centers from the load and the increase in losses (on the contrary of second mode), in general the loadability limit decreases.

In the fourth mode, generally, when the load shifts from a weak bus to a stronger bus, the loadability limit increases and in the reverse mode, the loadability limit decreases. The results of this state are shown in table 3 and figures 6 - 8:

From the simulation results obtained the above figures and table, it can be concluded that by analyzing the results obtained from the related generation patterns, the uniform distribution of the generation between the buses will improve the voltage stability and the static loadability limit of the power networks.

CONCLUSION

In this paper, by analyzing the results of the related generation patterns, the uniform distribution of generation between the buses, or the changing of the place of concentrated generation, and or by allocating a percentage of the share of concentrated generation to distributed generation (DG) and placing this generation on load buses, it improves voltage and loadability limit, which is accompanied by a thorough and comprehensive study. Otherwise, reverse results may be obtained. Therefore, considering the proper prediction of load growth and the correct selection of the place of generation, the potential for loadability limit and voltage stability of the network can be significantly improved.

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APPENDIX

The load flow results of this system in the initial condition are as follows.
Clearly from the system's load flow, the total system load is 259 MW, which had been s set as the base load value.
As shown in tables 5, the total load of the system is 16524 MW.

Table 1. The values obtained from the different models for the first ten generation patterns of the 14-bus network

G.P.	Load Level	1	2	3	4	5
1	827	1932	1043	890	2085	2975
2	614	2153	2467	2259	2361	4620
3	733	738	735	616	858	1473
4	984	2775	1107	954	2928	3882
5	506	4699	1528	1320	4907	6228
6	553	5065	1426	1218	5274	6491
7	1024	1682	760	636	1807	2443
8	655	2599	730	605	2724	3330
9	783	2239	1873	1664	2447	4112
10	593	3156	1843	1635	3364	5000

Table 2. The values obtained from investigation of the first mode for a specific generation pattern of the 14-bus network (loadability limit at base mode: 733)

No.	From	To	Load Level
1	2	3	698
2	2	6	1000
3	2	8	648
4	3	2	574
5	3	8	420
6	6	2	570
7	6	3	560
8	6	8	585
9	8	2	635
10	8	3	624
11	8	6	755

Table 3. The values obtained from the investigation of fourth mode for a specific generation pattern of the 14-bus network

No.	From	To	Load Level
1	11	14	709
2	11	12	729
3	11	9	730
4	11	5	745
5	11	4	744
6	10	14	671
7	10	13	715
8	10	12	717
9	10	9	735
10	10	5	772
11	10	4	769
12	9	14	519
13	9	13	597
14	9	12	560
15	9	11	651
16	9	10	671
17	9	5	824
18	9	4	818

Table 4. X_{TH} values of buses of 14-bus system in descending order

Bus No.	X_{TH}
12	0.0035
8	0.0035
14	0.0035
11	0.0029
13	0.0029
10	0.0026
6	0.0023
9	0.0021
7	0.0018
3	0.0011
4	0.0007
5	0.0006
2	0.0005

Table 5. X_{TH} values of buses of 34- bus system in descending order

Bus No.	X_{TH}	Bus No.	X_{TH}	Bus No.	X_{TH}
34	0.00199	5	0.00031	12	0.00009
11	0.00137	6	0.0003	13	0.00008
29	0.00116	7	0.00021	14	0.00008
25	0.00098	2	0.0002	4	0.00007
15	0.00074	10	0.0002	8	0.00007
28	0.00066	33	0.00018	24	0.00006
18	0.00056	32	0.00017	16	0.00004
20	0.00056	26	0.00016	21	0.00003
27	0.00051	31	0.00016	9	0.00002
17	0.00036	30	0.00015	22	0.00002
19	0.00033	3	0.00011	23	0.00001

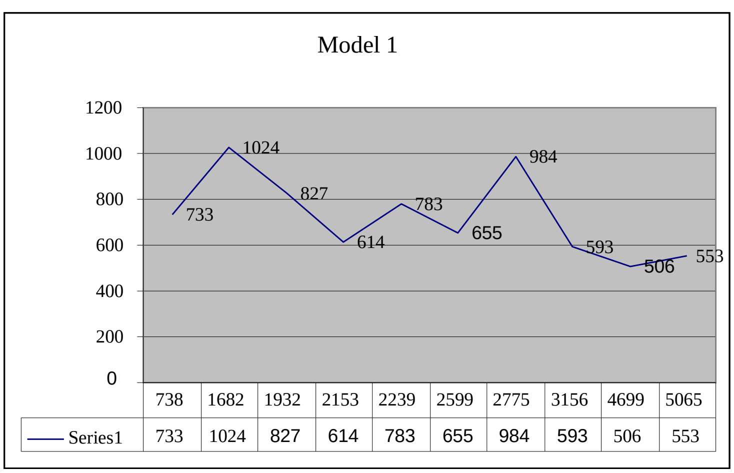


Figure 1. Model 1 for the first ten generation patterns of the 14-bus network

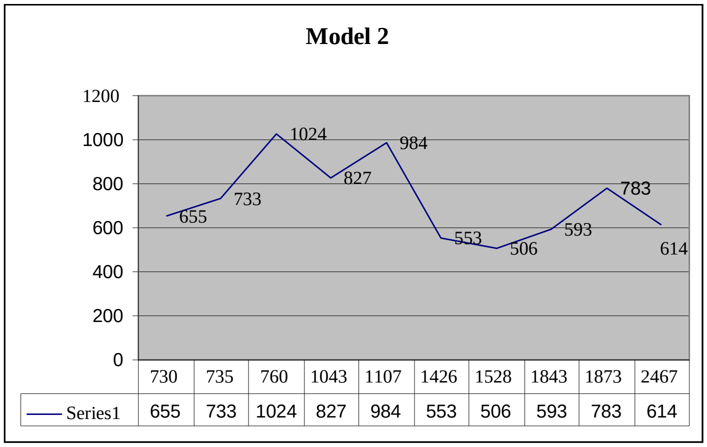


Figure 2. Model 2 for the first ten generation patterns of the 14-bus network

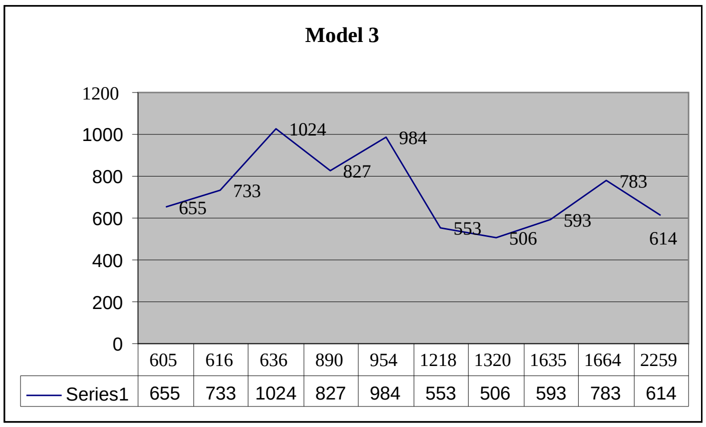


Figure 3. Model 3 for the first ten generation patterns of the 14-bus network

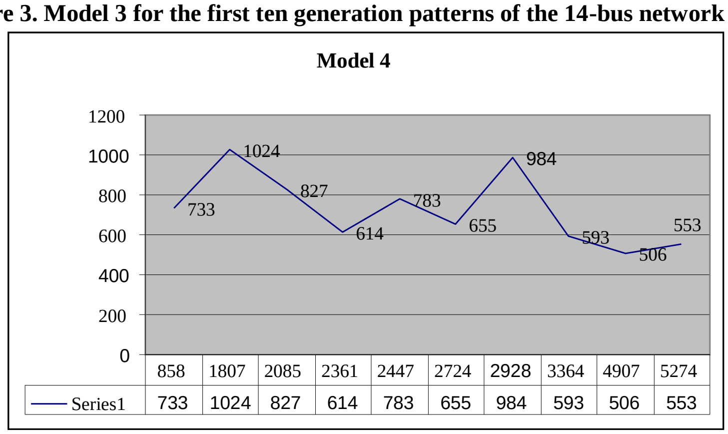


Figure 4. Model 4 for the first ten generation patterns of the 14-bus network

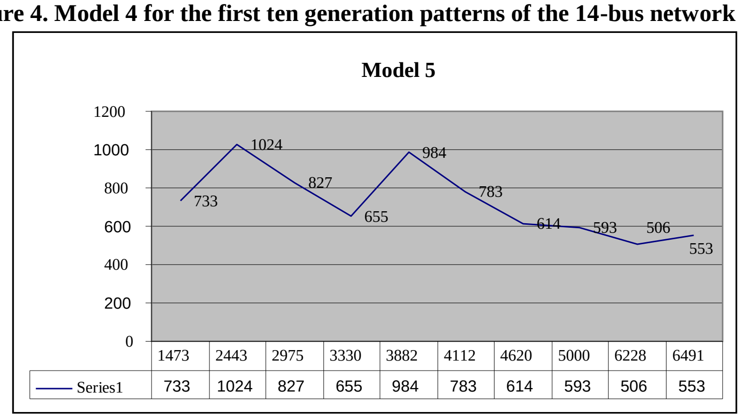


Figure 5. Model 5 for the first ten generation patterns of the 14-bus network

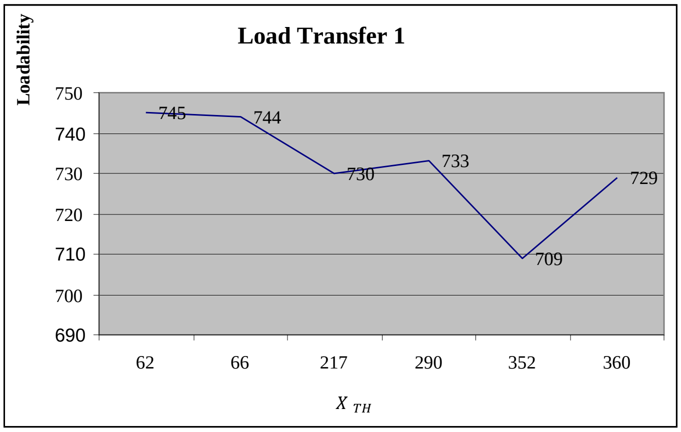


Figure 6. Transferring of load from bus number 11 to other load buses of the 14-bus network

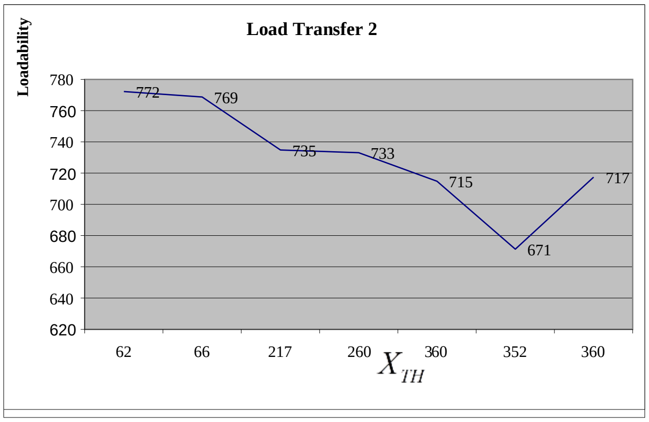


Figure 7. Transferring of load from bus number 10 to other load buses of the 14-bus network

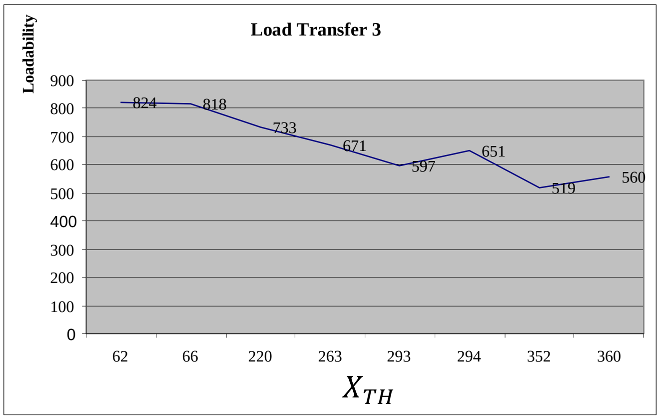


Figure 8. Transferring of load from bus number 9 to other load buses of the 14-bus network

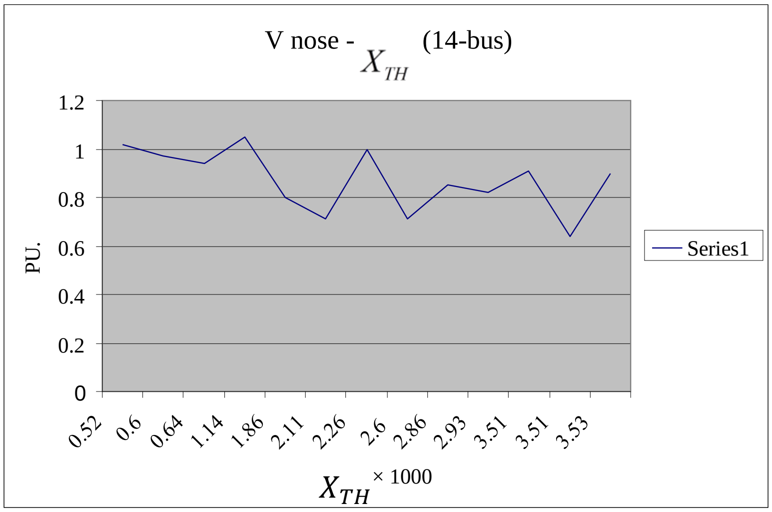
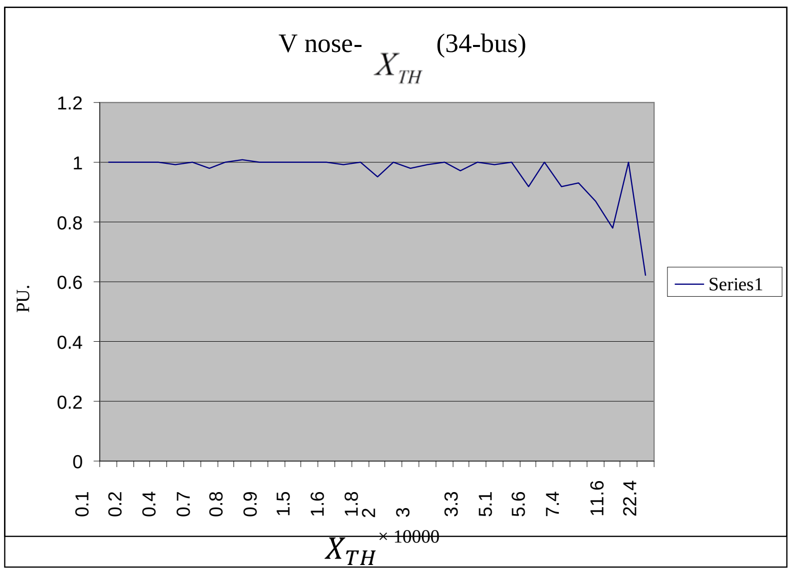


Figure 9. Voltage values of the curvature points of the P-V curve of the buses in terms of the X_{TH} corresponding to 14-bus test network



igure 10. Voltage values of the curvature points of the P-V curve of the buses in terms of the X_{TH} corresponding to 34-bus test network