Investigation of Power Networks and their Patterns by Mathematical methods in order to Voltage Stability Enhancement

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Abstract. Authors in the research paper has considered IEEE 14-bus and 34-bus test network for creation generation and load patterns. This paper aims at analysing the potential impacts that distributed generation (DG) might have on voltage stability of electrical power networks. It is expected that increasing amounts of new generation technologies will be connected to electrical power systems in the near future. Most of these technologies are considerably smaller scale than conventional synchronous generators. In this paper, the impact of DG pattern (size and location of DG) on the voltage stability of two test system is investigated. The simulation methodology is discussed as well. It is found that the effects of DG the voltage stability of a power system strongly depend on the size and location of the distributed generators. The results show that install of DG on the weak bus, improve loadability limit and voltage stability and decrease loss of system. By investigating and reviewing the results of similar patterns in these two systems, the different generation and load patterns impact mechanism of DG units over the behaviour of the systems in terms loadability limit and voltage stability is achieved.

1. Introduction
Voltage collapse for the most part happen on power framework which are intensely loaded or blamed or have deficiency of reactive power. The voltage collapse is a framework shakiness including many power framework segments. Truth be told, a voltage collapse may include a whole power system. The voltage collapse alludes to the capacity of power systems to keep up consistent voltages at all buses in the framework in the wake of being exposed to an unsettling influence from a given introductory operating point [1-2]. The framework state enters the voltage instability district when an unsettling influence or an expansion in load demand or modification in framework state results in a variable and consistent drop in system voltage [3-5].
In this section, the authors consider some research papers related to the alleged idea. In [6] at the primary stage, a special algorithm is utilized to look through conceivable arrangement territory and arrive at a tradeoff among secure and monetary bearing of genuine power generations. In the second phase of proposed way to deal with every generation pattern, power system voltage stability edge and the generation cost individually are assessed during search algorithm. The authors in [7] affirm that the simulations are performed on IEEE 14 and IEEE 30 buses test frameworks to discover best generation direction. The authors in [2] describe Particle Swarm Optimization (PSO) [3] with parallel transformation (PMPSO) to decide the most extreme loadability apex of the power system.

It very well may be conceded that voltage instability in power systems has been known as a load instability for a considerable length of time [8]. The authors in [9] led a down to operable study on the impacts of Distributed Generation (DG) units on voltage stability. To illustrate that, they have inspected the impacts of the position and size of DG units under varieties in load conditions because of the unevenness event probability in distribution systems [10], likewise, the impacts of limit and position of DG units on the voltage dependability execution of the distribution systems [11]. Also, in [12], and [13] methods have been proposed to find DG units for improving the voltage profile and voltage stability of distribution frameworks [14-15]. The authors in [11] asserted that DG units are situated on buses that are delicate to voltage collapse, and it prompted an improvement in voltage profile just as a loss decreasing. In [13] the researchers built up the paper [12] to amplify load conditions in basic circumstances and routine conditions. The voltage stability investigation is done in both statically and powerfully technique. Besides, the static strategy operates got voltage and power connections in a particular system bus that is under a title of a – curve or nose curve [16].

After the reviewing and analyzing some aspects in the regard of the supposed idea and concept by the authors in the paper, the paper targets breaking down the potential effects that distributed generation may have on the voltage stability of electrical power systems. It is expected that increasing amounts of new generation technologies will be connected to electrical power systems in the near future. Most of these technologies are of considerably smaller scale than conventional synchronous generators. In this paper, the impact of distributed generation pattern (size and location of DG) on the voltage stability of two test system is investigated. The simulation methodology is discussed as well. It is found that the effects of distributed generation on the voltage stability of a power system strongly depend on the size and location of the distributed generators. The results show that install of DG on the weak bus, improve loadability limit and voltage stability and decrease loss of system.

The rest of this part is sorted out as pursues. In section tow, power networks description is described. Section three stated problems of mathematic modeling. Network loadability limit Effecting from generation and load patterns is asserted in section four. Results on two standard IEEE 14-bus and 34-bus networks are presented in section five before concluding in section five.

2. Power networks description

It ought to be noticed that the system structure and active generation pattern of the power system buses are influencing parameters on the static loading and voltage stability. As needs be, with respect to the significance of the theme, we have depicted the structure of concentrates on the 14-bus and 34-bus tests systems.

2.1. Supposed 14-bus network

This framework is one of the IEEE test standard systems. This framework comprises of 14-bus and 20 lines including a slack bus (buses 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).

It is mentioned that the obtained result about load flow of 14-bus IEEE system are communicated in loadability limit point for every one of the generation patterns, the estimations of framework buses generation and operation, losses and loadability limit [14].
2.2. Supposed 34-bus network
It is referenced that every one of these generation patterns has its very own impact on voltage stability and loadability limit. In this way, another alleged framework is the 34-bus test network. This framework is in terms of size and topology relating to a real power system, it appears to be fitting so as to explore the adjustment in the generation pattern and its impact on loadability limit, and voltage stability. Thusly, in this paper, it has been chosen as an another test framework. The specifications of this framework are given in the following sections. Altogether, the following system comprises of 34-bus 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. Mathematical Modelling

3.1. The creation of load patterns
Proposing the impact of load development on voltage stability, to simulate the voltage, the load must be expanded. In this manner, as per a particular pattern, the load ought to develop. As needs be, the equations (1), and (2) are utilized here for this reason (the load pattern comparing to each load level is built up on various buses as indicated by (1) and (2)).

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

Along these lines, \( Q_{Li}^0, P_{Li}^0 \) are the active and reactive power amounts of load on the i-th bus in the underlying condition of load. So that, \( \lambda \) is the coefficient of expanding the development stairs of the load at various load levels which changes from zero (base load) to most extreme worth (loadability limit). The \( \lambda \) amount can be in the structure that begins from steps 0.01 and it chosen by drawing nearer to the collapse point to accomplish a littler convergence. The \( K \) amount is the quantity of development stairs of the load until the collapse point. It ought to be noticed that the consumption portion of buses from the total system consumption in all cases is steady. On the off chance that we demonstrate this incentive for i-th bus with \( \alpha_i \), we will have:

\[ \alpha_i = \frac{P_{Li}}{\sum P_{Li}} \quad (3) \]

Then, \( \alpha_i \) for every bus, always has a fixed amount.

3.1. The creation of generation patterns
Different generation patterns should be made. To examine the impact of the generation patterns on voltage stability and furthermore the loadability limit reaches of the 14-bus test system for every one of the generation patterns. This generation patterns can make for various degrees of load. The generation patterns of buses are resolved by equation (4):

\[ P_{Gi}^K = b_i P_{Total}^K \quad (4) \]
In this regard, $P_{Gi}^K$ is i-th bus generation of K-th load level, $\beta_i$ is I-th bus generation share for supporting K-th load level, that implies $P_{Total}^K$ and $P_{Total}^K$ are absolute system active load in K-th loading level.

It ought to be noticed that the portion of reactive power generation of generators by their acceptance control framework decide automatically as per the Automatic Voltage Regulation (AVR) capacity and voltage regulation of terminal and the reactive power limitations of generator. By deciding $\beta$ amounts for system generation buses, the authors can extract the buses generation pattern.

Different patterns [14] have chosen so as to the authors can make moderately wide assortment and scattering in buses generation patterns. Every one of the patterns can be relevant to all load levels, and the relationship, and consistently equation (5) is accessible:

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

4. Network loadability limit Effecting from generation and load patterns

For accomplishing an appropriate generation pattern for improving voltage stability and loadability limit, notwithstanding directing multiple simulation to locate the best estimation of relative generation on generation buses ought to be recognized weak buses of the frameworks. Also, the harmony among load and the generation must be considered in each piece of the system. Also, the ladability limit and the voltage stability of the system can be improved significantly by optimally choosing of the generation allocation, specifically by putting some measure of generation on weak network buses. What is more, the correct predict of load development later on, and given the way that the measure of DG can be expanded after establishment in one location, it is conceivable to choose DGs area in parts of the system where their consumption load is related with high development. For this situation, DGs can cause reverse loading in those areas. In like manner, this issue is successful in voltage stability improving of the system.

The power transferring time from a power arrange transmission line, since the voltage drop in the resistance and the line reactance, the bus voltage of the part of the bargain changes both in size and phase in respect to the bus voltage toward the beginning of the line. The significant part of the adjustment in voltage is because of an adjustment in the voltage level. The relationship of voltage variety is given regarding the short circuit level, and the utilizing of suitable approximations and rearrangements by equation (6):

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

Along these lines, E is the power supply bus voltage, and $S_{SC}$ is the short circuit level of bus.

Equation (6) demonstrates that short circuit high level of $S_{SC}$, leads to a diminishing in voltage sensitivity, the loading line is smoothed, and therefore, the framework is said to be stable.
Since what the reactance equivalent of a network bus is $X_{Th}$ bigger than the short circuit level of that bus. Subsequently, $X_{Th}$ can be the weaknesses and the strengths sign of that system buses, which implies that for the most part what $X_{Th}$ of a bus be bigger, that bus is flimsier is the weakest. The $X_{Th}$ computation is additionally acquired from the voltage estimation.

Given the way that the reactance equivalent amount of each buses of the $X_{Th}$ system can be the weaknesses and the strengths sign of that system buses, it appears that by deciding $X_{Th}$ for every one of the system buses can be discovered a connection between these strengths, and the generation an incentive on buses in the different generation patterns on the loadability limit. To this end, the authors have been examined different models to discover the connection between as far as possible and the generation location:

$$F = \left(\frac{(P_G - P_L)^2}{X_{TH}}\right) \times a + \left((P_G - P_L)^2 \times X_{TH}\right) \times b)$$  \hspace{1cm} (7)

As well, the above equation can have the following condition in itself depending on the different modes:

$$\begin{cases} 
P_G - P_L < 0; a = 1. \ b = 0 & (1) \\
P_G - P_L < 0; a = 1. \ b = 0 & (2) \\
\end{cases}$$

$$\begin{cases} 
P_G - P_L < 0; a = 1. \ b = 0 & (3) \\
\end{cases}$$

By selecting various coefficients for each term of the equation, some models have been extracted and these models are connected to the initial ten generation pattern of the 14-bus networks. At the last, the outcomes are examined.

4.1. Criteria of modelling
The load flow aftereffects of this framework in the underlying condition are as per the following. Unmistakably from the framework’s load flow, the total system is 259 MW, which had been set as the base load amount. Just as, the total load of the system is 16524 MW.

A description of the models of intensity framework components that significantly affect voltage stability is referenced as pursues:

1. Loads including Under-Load Tap Changer (ULTC) transformer, reactive power compensation, and voltage regulator in the system under the transfer.
2. Generators and their stimulation controls.
3. Sollatek Voltage Stabilizer (SVS).
4. Automatic Generation Control (AGC).
5. Protection and controls.
5. Results
Deciding the loadability limit and the voltage stability generated by the program for every generation pattern is inferred by utilizing the input information, which is a similar data for performing load flow, the generation buses are first indicated. At that point, contingent upon the measure of the generation put on every one of the buses, corresponding to that measure of the generation, the reactive power control interval is characterized for that bus. Here, the control range of reactive power is about:

\[-0.4P_n \leq Q_n \leq 0.6P_n\]  \hspace{1cm} (9)

Which $P_n$ and $Q_n$ are the active power and the reactive power respectively for the bus generation.

In this program, the initial amount and total power are first put away. It merits referencing that the programming of this program is written in Fortran's environment. Additionally, the aftereffects of the load flow are gotten by the Newton-Raphson technique for accomplishing incredible convergence.

Table 1. $X_{TH}$ amount of buses in 14- bus system in descending order

| Bus No. | $X_{TH}$ | Bus No. | $X_{TH}$ |
|---------|----------|---------|----------|
| 1       | 0        | 8       | 0.0035   |
| 2       | 0.0005   | 9       | 0.0021   |
| 3       | 0.0011   | 10      | 0.0026   |
| 4       | 0.0007   | 11      | 0.0029   |
| 5       | 0.0006   | 12      | 0.0035   |
| 6       | 0.0023   | 13      | 0.0029   |
| 7       | 0.0018   | 14      | 0.0035   |
Table 2. $X_{TH}$ amount of buses in 34-bus system in descending order

| Bus No. | $X_{TH}$ | Bus No. | $X_{TH}$ | Bus No. | $X_{TH}$ | Bus No. | $X_{TH}$ |
|---------|----------|---------|----------|---------|----------|---------|----------|
| 1       | 0        | 10      | 0.0002   | 19      | 0.0003   | 27      | 0.0005   |
| 2       | 0.0002   | 11      | 0.0013   | 20      | 0.0005   | 28      | 0.0006   |
| 3       | 0.0011   | 12      | 0.0000   | 21      | 0.0000   | 29      | 0.0011   |
| 4       | 0.0007   | 13      | 0.0000   | 22      | 0.0000   | 30      | 0.0001   |
| 5       | 0.0003   | 14      | 0.0000   | 23      | 0.0000   | 31      | 0.0001   |
| 6       | 0.0003   | 15      | 0.0007   | 24      | 0.0000   | 32      | 0.0001   |
| 7       | 0.0021   | 16      | 0.0000   | 25      | 0.0009   | 33      | 0.0001   |
| 8       | 0.0007   | 17      | 0.0003   | 26      | 0.0016   | 34      | 0.0019   |
| 9       | 0.0002   | 18      | 0.0005   |         |          |         |          |
Since the examines completed on the aftereffects of the connection between various generation patterns, and specifically DG patterns, are increasingly broad as far as loadability limit and voltage stability, two distinct systems for recreation and investigation have been chosen.

In the generating patterns in these two test networks the assessment of the practically uniform appropriation of the generation, scattering of the generation, the designation of an extent of the portion of concentrated generation to DG and the adjustment in the generation amounts on the buses, particularly the situation of the generation on the buses of weak network had been considered.

![Graph](image1)

**Fig. 1.** Loadability limit result of the simulation result

![Graph](image2)

**Fig. 2.** $X_{TH}$ and power amounts of buses
In the following figure 1 to 5 have been indicated the obtained results of different models by the authors for the generation patterns of the 14-bus and 34-bus networks.

According to the figures, some models have been extracted in our result and these models are connected to the initial ten generation pattern of the 14-bus and 34-bus networks.
By investigating of the obtained result in the paper, it has been seen that as far as possible has expanded for the most part in the majority of status. Likewise, for the most part the generation on the weaker buses prompts a higher loading rate. In this manner, the advancement of the generation pattern prompts an expansion in as far as possible. This problem is because of load balancing, the generation, and the vicinity of the generation focuses to the load and decrease of system losses.

From the obtained results acquired the above figures and tables, it tends to be inferred that by examining the outcomes got from the related generation patterns, the uniform conveyance of the generation between the buses will improve the voltage strength and the static loadability limit of the power systems.

6. Conclusion
In this paper, by investigating the aftereffects of the related generation patterns and their information, the uniform dispersion of generation between the buses, or the changing of the place of concentrated generation, as well as by allotting a level of the portion of concentrated generation to DG and setting this age on load buses, it improves voltage and loadability limit, which is joined by an exhaustive and far reaching study.

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