Effect of Distributed Generation Units on Stability Improving Trend of IEEE 14 and 34 Bus Test Network Voltage

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Abstract

Background/Objectives: Reactive power sources, network structure and active generation algorithm of power network buses are effective factors on voltage stability and static loadability extent of standard power network. Methods/Statistical analysis: Simulation programming for the paper has been done through FORTRAN which is a strong programming language in solving mathematic issues. By creating different status of generation and investigating results of 50 generation patterns in this network, it has been observed that increment in generation of some controlled existing buses improve loadability limit in comparison to other buses (3 and 6 buses to 2 and 8 buses) Findings: In this paper, the effect of Distributed Generation (DG) placement on voltage stability trend and static loadability extent of IEEE 14-bus and Iran 34-bus test standard power networks has been investigated. In order to determine places of distributed generations for improving loading extent and voltage stability, at first equivalent reactance of Thevenin buses has been recognized; Then, weak buses of the network has been identified. It should be mentioned, this research has indicated that placing DGs on these buses has an effective role on improving static loadability extent and voltage stability. Three different generation algorithms have been created in this paper in order to observe research mentioned aims. Then, static loadability extent and voltage stability have been investigated in these three cases, the most desirable and most optimum one have been chosen from them. Application/Improvements: By investigating three different states in creating generation pattern, it has been observed that placing DG on weak load buses is more proper than other ways for increasing loadability limit and voltage stability improvement.

Keywords: Distributed Generation Optimum Placement, Generation Pattern, IEEE 14-Bus Network, 34-Bus Network, Power Network Structure

1. Introduction

Voltage stability is power system ability to retain (maintain) acceptable lasting voltage for all buses of system in performance normal condition and after being exposed to an involvement. Main reason for instability is disability of power system in supplying reactive needed ability. Core of issue usually is voltage decline which is resulted during real and reactive power transmission from transition lines reactance. In recent decades, presence of Distributed Generation (DG) resources in distribution networks has have growing trend due to being compatible with nature and not having pollution. Also, all of renewable energies have had and will have more contributions in universe energy supplement system gradually. Especially, this issue has severely increased due to increment in energy renew-

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able resources which have less power and low voltage. Therefore, usage of rotating generators such as asynchronous generator have had remarkable increment due to their applying capability in thermal small powerhouses and hydro-powerhouses, even in wind fields as well as direct control possibility of their injective active and reactive power.

In the field of DG effects on power system, it can be referred to important cases as: preventing from increment in network capacity, decreasing electric damages in transmission and distribution section, delaying and updating transmission and distribution networks, supplying reactive power, decreasing demand density and energy transmission, improving power quality and increasing power reliability\(^1\). Changing generation patterns and creating diverse generation patterns by identifying proper buses in order to place DGs on them\(^1\), as well as, optimum designation of the network using DGs in order to increase voltage stability and decrease network damages\(^2\). In this field, some researchers have investigated effects of DGs’ direct and indirect connections (through power electronic generators) on power network and changes in resulted generative power from DGs during a day as well as their effects on load curve\(^7\). In this paper, effects of DGs on increment of loadability limit and improving stability of power networks have only been investigated. In order to validate paper simulation results, two 34-bus and 14-bus test networks have been investigated.

The paper has been categorized as follow; description on effect of DGs place on loadability limit and voltage stability of power networks has been done in part two. Issue formulating such as creating generation patterns in Iran 34-bus and IEEE 14-bus power networks as well as determining loadability limit and voltage stability margin for each generation patterns have been done in part three. Simulation Results studies on two 34-bus and 14-bus test networks have been presented in part four. Conclusion has been presented in part five.

2. **Effect of Distributed Generation Placement on Loadability Limit and Voltage Stability of Power Networks**

Nowadays, distributed or decentralized generation units have been connected to power transcontinental system as active power resource or reactive and active power resource in two transmission and distribution levels. DG is related to usage of installed small generative units close to the consumption place. In the other word, DG should be put on the place which can have the most effect on network\(^3\). One of problems of current power systems is voltage instability. One criterion for measuring power system is voltage stability safety margin. Load ability point distance of power system to its static loadability limit is as Voltage Stability Margin (VSM). It is one of effective factor on safety, configuration and generation distribution of powerhouses for each level of load as it is possible that proper safety degree for some generation configuration is weak or is proper and sufficient for some of them. DGs are placed on level of distribution network and beside users, provide network electricity support if needed\(^10\). Various technologies in DGs have made possible usage of this kind of generation at each network bus place. DGs are such that can be increased or decreased after installing in a place. So, it can be said that in an existing network generation various patterns can exist in the presence of DGs.

3. **Issue Formulation**

3.1 **Creating Generation Patterns**

Two IEEE 14-bus test system and Iran 34-bus test network which have been used for studying steady state have been chosen for investigating effect of generation pattern on system loadability limit and voltage stability. Generation patterns can be created for load different levels. So, a load pattern and several generation patterns should be created for network different loading levels. Then, simulation is done for these patterns and simulation results are investigated. Patterns for bus generation have been determined according to relation (1).

\[
P^K_G = \beta_i \times P^K_{Total}
\]

In where \(P^K_G\) is generation of \(i\)th bus for \(K\)th load level \(\beta_i\). Generation share of \(i\)th bus to provide \(K\)th load level; i.e. \(P^K_{Total} \& P^K_{Total}\) of whole network active load on \(K\)th loading level.

It should be mentioned that generation share of generator’s reactive power has been determined automatically through their motive control system and according to performance of Automatic Voltage Regulation (AVR) and terminal voltage settlement as well as limitations of
generator’s reactive power. Generation patterns of buses can be extracted through determining \( \beta_i \) values for network generation buses. Each of patterns is applicable for all of load levels and below relation always is established.

Possible states to create generation various patterns:

1. Changing generation share among generation buses.
2. Creating centralized generation through decreasing some of existing generation buses’ generation shares.
3. Creating some DG on load buses (especially weak buses) through decreasing some of generation buses’ generation shares.

\[
\sum_{i=1}^{NB} \beta_i = 1
\]

### 3.2 Determining Loadability Limit and Voltage Stability Margin for Each of Generation Patterns

Load distribution program has been done through using input related data to test systems and system working point has been determined. Then, active and reactive power of buses has been increased proportional to consumption primitive increasing coefficient. After that, generation of buses has been increased in terms of their share percentage. Control interval of buses reactive power has been determined according to mentioned generation amount. Then, Load distribution program is done through using input related data to calculate system real working point correspond to increased load at the next stage. In fact, these points are points on network P-V curve. When, loadability is growing gradually, authors achieve to a point finally that load distribution doesn't become convergent. This point is approximately close to system loadability limit or voltage breaking point (peak of P-V curve).

According to continuous and monotone increment of system load, weak bus is a bus which its voltage changes through loadability increment are more than other buses. An index can be resulted for determining voltage stability value according to this bus. Also, by determining system weak bus, if changes in voltage of weak bus in each stages of load increment become more than its determined value, load increment coefficient in new stage become half. This will cause to more convergence in calculations during the loadability growth on the network and increment in loadability limit near to accurate point of voltage breaking. An index has been extracted through using the mentioned way for voltage stability and determining network weak buses. If in ith bus, slope of the mentioned (V-P) curve is indicated by \( T_i \), relation (3) is resulted.

\[
T_i = \frac{dV_i}{dP_{Total}} \equiv \frac{\Delta V_i}{\Delta P_{Total}}
\]

In where \( P_{Total} \) is active power of whole system load which voltage changes of each buses in (V-P) curve are measured through it and is equal for all buses.

\[
\text{Max}\left(\left[\frac{\Delta V_1}{\Delta P_1}, \frac{\Delta V_2}{\Delta P_1}, \ldots, \frac{\Delta V_i}{\Delta P_1}\right]\right) \rightarrow \text{Weak Bus}
\]

\[
\text{Max}\left(\left[\Delta V_1, \Delta V_2, \ldots, \Delta V_i\right]\right) \rightarrow \text{Weak Bus}
\]

Value of \( \frac{dV_i}{dP} \) has equaled to infinite by voltage reaching to stability limit, i.e. \( \frac{dP}{dV_i} \) has become zero, \( \frac{dP}{dV_i} \), is the most proper index for system voltage of whole stability because its calculation is easy. It is defined as relation (6).

\[
VSI = -\frac{dP_{Total}}{dV_i}
\]

In where \( V_i \) is voltage of network weakest bus in specific status of data system. Because value of \( \frac{dP}{dV} \) is negative. So, for Voltage Stability Index (VSI) to be positive, it has been identified with a negative. (It should be noted that in V-P curve, sigh of dV, dPT are opposite of each other); Also, it is possible that network weakest bus is shift in generation different patterns; so, weakest bus of each status must be determined. After that, according to it voltage stability index is calculated. Also, according to that value of Thevenin equivalent reactance for each network bus is \( X_{TH} \), it can be indicator of weakness or strength of the network buses. It seems that authors can find a relation between these values and determined weak buses with the mentioned way through determining \( X_{TH} \). In comparing two buses, that way which its Thevenin equivalent reactance is biggest is weaker.
4. Simulation Results

4.1 Effect of DG Place and Value on Voltage Stability

In this section, the effect of DG place and value on voltage stability is divided following two parts:

4.1.1 Simulation Studies on IEEE Standard-Bus Test Network

Simulation programming for this paper has been done through FORTRAN which is a strong programming language in solving mathematic issues. By creating different statuses of generation and investigating results of 50 generation patterns in this network, it has been observed that increment in generation of some controlled existing buses improve loadability limit in comparison to other buses (3 and 6 buses to 2 and 8 buses). In this case, balance between load and generation is reason for voltage stability improvement. This case has been indicated in Figure 1.

Decreasing existing centralized generations and creating centralized generations in other buses hasn’t had positive effect on loadability limit improvement. Reason of this can be unbalance between load and generation in network different parts. This state has shown in Figure 2. 14-Bush has been determined here as weak system bus. Through calculating Thevenin equivalent reactance of all network buses, it can be observed that according to Thevenin equivalent reactance of 14-bus being high in comparison to other buses, this bus is of weak kind.

As it can be observed in Figure 3, according to that bus number of 14 and 10 have been identified as weak bus, authors have placed amount of generation on them as DG. In this state, it has observed that loadability limit has remarkable growth. Bus generation bus number of 14 has transferred to 13 for comparison. Therefore, effect of placing DG on network weak bus on voltage stability improvement has been observed.

4.1.2 Simulation Studies on 34-Bus Test Network

Result of 27 generation different patterns in this network has indicated that creating generation pattern according to first state, hasn’t created significant changes on loadability limit, but has changed damages a bit. Resulted
loading limit from 5 generation patterns is approximately equal in this state. 34-Bus has been determined here as weak system bus. Through calculating Thevenin equivalent reactance of all network buses, it can be observed that according to Thevenin equivalent reactance of 34-bus being high in comparison to other buses, this bus is of weak kind.

As it can be observed in Figure 4, according to that bus number of 34 and 29 have been identified as weak buss, amount of generation has been placed on them as DG. In this state, it has observed that loading limit has remarkable growth. Placing generation on 14-bus has this result lonely. Generation of 34-bus has transferred to 29-bus; in this case, loadability limit is a less amount. Creating generation patterns in this network and according to third state has been done through allocating percentages of centralized generations to DGs and placing them on load buses. This state which has been indicated in Figure 5 has resulted in voltage stability improvement and loadability limit to other states.

5. Conclusion

In the paper, for optimum placing of DG for improving loadability limit and voltage stability, possible states of generation different patterns in the form of changing negation share among generation buses, creating centralized generation through decreasing some of existing generation buses’ generation shares and creating several DG on load buses especially weak buses with decreasing

Figure 3. Comparing two generation patterns resulted from third state of generation patterns creation.

Figure 4. Comparing two generation patterns resulted from first & second states of generation patterns creation.

Figure 5. Generation pattern resulted from third state of generation patterns creation.
some of existing generation buses’ generation shares has have been created. Then, network weak buses have been determined through presented method and calculating Thevenin Equivalent reactance in order to improve loadability limit and voltage stability. It has been indicated that placing DG on these buses has important role on loadability limit improvement and voltage stability. Also, by investigating three different states in creating generation pattern, it has been observed that placing DG on load buses (especially weak bus) is more proper than other ways for increasing loadability limit and voltage stability improvement. In addition, by proper prediction of growth in the future and according to that amount of DG are changeable after installing in a place, place of DGs can be chosen in parts of network which their consuming load has more growth. In this state, DG scan result in converse loadability on those places; This can affect improvement of network voltage stability itself.

6. References

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