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GENERATOR PRIORITIZATION BASED ON BUS VOLTAGE SENSITIVITY

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GENERATOR PRIORITIZATION BASED ON BUS VOLTAGE SENSITIVITY

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Abstract

The modern electrical grid faces evolving system conditions due to the out of ordinary increase in renewable energy resources, such as, wind and solar. This surge is driven by the move towards a green future, electrification of transportation, and the expansion of large-scale data centers for activities such as crypto mining and Artificial Intelligence (AI) model training. With the considerable increase in loads it has become unmistakably important to efficiently dispatch resources.

Monitoring system voltage within tolerances and proper use of reactive power resources for voltage control is paramount as seen in the North American Electric Reliability Corporation’s (NERC) reliability standards. With a limited number and controllability of capacitors and reactors, structured usage of generators is of growing importance. System Operators sometimes face difficulties in identifying the most effective generators for voltage control, resulting in delayed response times and potential System Operating Limit (SOL) exceedances if not addressed properly in a timely manner. Traditionally, operators rely on their experience to make these decisions, which may not always be the most practical as the system continually develops.

To overcome this limitation, this study proposes a method to prioritize generators for voltage control by assessing their voltage control sensitivities. Specifically, this approach is based on the use of a small voltage set point variation at selected generator’s buses and calculation of the voltage magnitude changes to the selected monitored load buses by using alternating current (AC) power flow calculations.

During the calculation process, to properly evaluate the impact each unit solely has on the overall system, all other voltage/volt-ampere reactive (VAr) control devices (e.g., generators, transformer Load Tap Changers (LTCs), switchable reactors/capacitors) are locked and unable to inject/withdraw VArs from the system.

The efficacy of the proposed method has been validated using a realistic system model of Oklahoma Gas and Electric's (OG&E) transmission system. For the various system's regions, it has shown that the generators can be properly prioritized by referring to the calculated voltage control sensitivity indices. The results are consistent with System Operator's operation experience as well as the electrical connectivity between the selected buses and generators.

The conventional method for voltage sensitivity analysis involves balancing voltage and reactive power to maintain grid stability. Typically, this involves assessing how changes in reactive and active power affect voltage levels across the grid. However, in this study, the influence of generators with an ability to inject or withdrawal real or reactive power are frozen in a default state to isolate the impact of a sole generator's voltage variations alone. Despite this simplification, the results remain consistent with traditional grid operations, demonstrating that the proposed method can effectively prioritize generators for voltage control without compromising accuracy. This consistency suggests that the approach is a reliable method for identifying the most effective use of generator resources in the shortest amount of time, providing a streamlined yet effective means for prioritizing generators for voltage control in complex power systems.

Glossary of Abbreviations

AC	Alternating Current
AI	Artificial Intelligence
AVR	Automatic Voltage Regulator
BES	Bulk Electric System
kWh	Kilowatt-Hour
LTC	Load Tap Changer
NERC	North American Electric Reliability Corporation
OG&E	Oklahoma Gas and Electric
SOL	System Operating Limit
VAR	Volt-Ampere Reactive

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1. INTRODUCTION

In today's electrical grid, we are facing evolving system conditions, partly due to an unprecedented increase in the number of renewable energy resources, such as wind and solar generations [1]. The increase has been driven by the heavy load increase due to electrification of transportation and commercialization of large-scale data centers for crypto mining and AI model trainings, etc. Power systems have been subjected to significantly more challenging operating conditions than those typically encountered in the past [5].

To ensure system reliability, the North American Electric Reliability Corporation (NERC) issued a series of reliability standards that specify the needs of monitoring system voltage performance and appropriate use of reactive power resources for voltage control. For example, the NERC's standard VAR-001 reinforces it is crucial for transmission operators to monitor, manage, and sustain voltage levels, reactive flows, and reactive resources within defined System Operating Limits (SOLs) in real-time to safeguard equipment and ensure the Bulk Electric System (BES) operates reliably [6]. Additionally, the NERC's standard VAR-002 enforces the responsibility of generators to provide reactive support and voltage control in the same manner as VAR-001 for Transmission Operators [2, 7].

In the operation horizon, just because a given generator can adhere to a voltage or volt-amperes reactive (VAr) schedules does not inherently mean it is the most efficient. The usage of those resources will depend on a variety of factors, including but not limited to VAr capability, controllability of generators, system topology, availability of other local VAr control devices, etc.

To meet the increasing needs of voltage control, acquiring additional VAr resources through placements of new generating units, discrete VAr control devices (e.g., reactors and capacitor), and other VAr compensation devices (e.g., SVC, STATCOM) is the most straightforward solution, but it has become difficult to keep up with the increasing demand given the industry's regulatory environment.

In comparison with capacitors/reactors, generators can provide better regulation of system voltage through the Automatic Voltage Regulator (AVR). Not only a wider range of VAr variation, but also a faster response time and more granular control which makes generators critical VAr control resources in operations [3]. Since there will only be a limited number of generators, it is of upmost importance to use generators in an efficient way for voltage control, in which their effectiveness in terms of regulating voltage needs to be taken into account. This will allow System Operators to keep up with the increasing demand and to meet compliance requirements.

My Contribution

For years, System Operators have been challenged with identifying the most effective generators among a variety of candidates to help with system voltage control which can often result in prolonged response time and potential exceedance of SOLs. To address the needs, System Operators develop an aptitude for selecting appropriate generators for various situations mainly based on their experiences, therefore those decisions in most cases are not straightforward and might not necessarily be the most effective. Numerous efforts have been made using localized approaches that consider both real and reactive power for voltage control [4, 8, 9, 10]. However, they lack an efficient system-wide assessment that produces accurate results for localized use. In this study, local reactive power is frozen to evaluate only the voltage contribution from each generator and its impact on the overall system. Through the assessment of the impact of generators' voltage control on selected system buses (or bus voltage sensitivity) using power flow solutions, this study has proposed an effective strategy for prioritizing generators for voltage control which has been validated using a realistic system model.

2. GENERATOR PRIORITIZATION METHODOLOGIES

Generator prioritization is a critical aspect of managing power systems effectively. It involves selecting and scheduling generators based on various factors that ensure the reliable and efficient delivery of electricity. Historically, the most significant factors influencing generator prioritization are economic dispatch, frequency regulation, dependability, and system configuration.

Economic Dispatch

The economic dispatch model is a well-established method used by utilities. This method involves selecting generators based on operational cost to fulfill utilities' demand, ensuring that the total cost of electricity production is minimized. Since Public Utility Commissions in the United States regulate the rates utilities can charge consumers, utilities will seek efficient ways of generating power to maximize profit margins within the regulated framework. This efficiency helps utilities and benefits consumers through reduced electricity prices.

In practice, a utility will establish a merit order system to rank power generators by their marginal cost of production. Marginal cost refers to each generator's heat rate or the cost incurred to generate one kilowatt-hour (kWh) of electricity. Lower heat rates indicate more efficient generators, while higher heat rates suggest less efficiency and greater fuel consumption. The generators with the lowest marginal costs, often wind or solar plants, would be dispatched first. Renewables occupy the lowest cost tier in the merit order because their marginal costs are nearly zero once the infrastructure is established, as they do not require fuel to operate. In contrast, fossil fuel generators, such as coal and natural gas plants, often have higher marginal costs due to the fuel they consume, and the maintenance costs associated with their operation.

Frequency Regulation

As renewable energy sources continue to increase exponentially and become more integrated into the grid, their impact on economic dispatch will likely grow, further reducing high-cost, high-emission generators. However, renewables alone are unable to provide frequency regulation, a fundamental aspect of successful power flow. The power grid operates at a specific frequency, 60 Hz, in the United States of America, and deviation from this frequency can cause system instability. Frequency regulation involves continuously controlling the balance between electricity supply and demand to keep the grid frequency within narrow limits of +/- 0.5%. When there is an imbalance, whether due to sudden changes in load or generation, the frequency can fluctuate, risking disruptions, equipment damage, or even large-scale blackouts.

There are fast-response and slow-response units to control frequency. Fast-response units, such as gas turbines, hydropower, and battery storage systems, can swiftly ramp up or down on command. Wind and solar units fall under the slow-response category due to the uncontrollability of cloud movements and wind speed. With the placement of battery storage systems, which can respond nearly instantaneously in conjunction with wind and solar plants, there is the added bonus of economic dispatch and frequency regulation.

Dependability

Economic dispatch and frequency regulation are useful models, but dependability is another factor that must be included. A generator's dependability ensures that electricity is available whenever needed, without interruptions or failures, which is critical for both economic stability and societal functioning. Historically, generator units such as coal, nuclear, and hydro are the most dependable. As more renewable energy sources like wind and solar are exponentially integrated into the grid, the dependability of the overall system becomes more strenuous. These renewables are variable and intermittent, so grid operators must depend on a balance of fast-response technologies like batteries or flexible gas turbines to quickly adjust generation when renewable output fluctuates. Beyond simply preventing blackouts, dependability also ensures the quality of the electricity supplied. Voltage stability, frequency consistency, and minimal harmonic distortion are all aspects of power quality that can be impacted by unreliable generation or grid operation. Grid operators must act swiftly to address sudden changes in load or generation to prevent possible cascading. Reducing time delays to make key decisions is of the utmost importance. Poor power quality management can damage equipment and infrastructure on the supply side and even consumer equipment. For example, industrial settings rely on precise electrical conditions for manufacturing processes.

System Configuration

The next challenge that utilities must factor into their models is system configuration. The implementation of new power generation and transmission lines is a protracted process, involving extensive planning, regulatory approvals, and significant construction efforts. The way generators are configured and interconnected within the grid directly impacts the system's efficiency, cost-effectiveness, and stability. Power flow congestion can be an expensive problem for consumers. This complication often occurs when power generation is too consolidated compared to the demand or when line outages or SOLs restrict the available options. Since wind and solar plants do not have direct control over the amount of output they generate at any given time, the System Operators attempt to use all available supply as it is the most economical option. However, there are often instances where generation must be curtailed. Generation curtailment refers to the deliberate reduction of electricity output from power generators, even when they are capable of producing more power, due to limitations in the grid or market conditions.

Voltage Sensitivity

As power systems become more complex due to the integration of renewable energy sources and the growing demand for grid stability in light of the foreseeable future of exponentially increasing load, it is vital to accurately determine, in real-time, which generators to use with the least amount of loss. This bus voltage sensitivity study examines how small changes in generation affect voltage levels at various buses within a power network. By analyzing the voltage sensitivity of buses, grid operators can make informed decisions in real-time about which generators to dispatch to maintain voltage stability, improve system efficiency, and ensure reliable power delivery.

3. POWER FLOW EQUATION & VOLTAGE SENSITIVITY

The power flow calculations are being widely used by System Operators to study the state of the grid and potential issues when the system is subject to disturbances. For a given bus, the active power (*P*) and reactive power (*Q*) injections can be calculated using the following equations:

$$P_k = \sum_{j=1}^{N} (|V_k||V_j| \left(G_{kj}\cos(\theta_k - \theta_j) + B_{kj}\sin(\theta_k - \theta_j)\right)$$
$$Q_k = \sum_{j=1}^{N} (|V_k||V_j| \left(G_{kj}\sin(\theta_k - \theta_j) - B_{kj}\cos(\theta_k - \theta_j)\right) \tag{1}$$

where

$P_k -$ Real power at bus *k*

$Q_k -$ Reactive power injection at bus *k*

$|V_k|$ – Voltage magnitude at bus *k*

θ_k – Phase angle at bus *k*

G_{ij} – Real part of the admittance matrix element Y_{ij}

B_{ij} – Imaginary part of the admittance matrix element Y_{ij}

The mathematical model of power flows allows for a comprehensive view of the condition of power transmission grid. This information can then be built upon for further applications such as Load Flow Studies, Contingency Analysis, Voltage Stability Assessment, and Economic Dispatch, among others.

Given a solution of the power flow case, the system can be linearized to obtain the system Jacobian matrix as below:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} \frac{\partial P}{\partial \theta} & \frac{\partial P}{\partial V} \\ \frac{\partial Q}{\partial \theta} & \frac{\partial Q}{\partial V} \end{bmatrix} \begin{bmatrix} \Delta \theta \\ \Delta V \end{bmatrix} \tag{2}$$

In the system Jacobian matrix, the submatrices, namely $\partial P/\partial \theta$, $\partial P/\partial V$, $\partial Q/\partial \theta$, and $\partial Q/\partial V$, reveal the relationship between active/reactive power and voltage magnitude and phase angles at buses. For example,

$$[\Delta Q] = \left[\frac{\partial Q}{\partial V}\right][\Delta V] \tag{3}$$

reveals the relationship between reactive power injection and bus voltage magnitudes. Inverse of ΔQ over ΔV reveals the voltage magnitude changes due to reactive power injections variations:

$$[\Delta V] = \left[\frac{\partial Q}{\partial V}\right]^{-1} [\Delta Q] \tag{4}$$

Specifically,

$$\begin{bmatrix} \vdots \\ \Delta V_i \\ \vdots \\ \Delta V_j \\ \vdots \end{bmatrix} = \begin{bmatrix} \vdots \\ \partial V_i / \partial Q_j \\ \vdots \\ \partial V_j / \partial Q_j \\ \vdots \end{bmatrix} \left[\Delta Q_j \right] \tag{5}$$

where $\partial V_i/\partial Q_j$ reflects the voltage magnitude change at bus *j* due to reactive power injection change at bus *i* [4].

This is important to understand the impacts of generator VAr inputs on the system from the voltage control perspective. Most generators are equipped with AVR for conventional units or power plant controllers for renewable generating resources that regulate targeted voltage by controlling their reactive power outputs.

In a power grid, which consists of multiple interconnected buses, voltage sensitivity analysis is widely used. Voltage sensitivity refers to the degree to which the voltage at a particular bus in a power system responds to changes in bus voltage magnitude. It can be used to assess how changes at one bus affect voltages at other buses. It provides readily available information to deploy adequate reactive power resources to mitigate voltage issues on the system. The generic voltage sensitivity matrix can be formulated as below:

$$\begin{bmatrix} \Delta V_{L1} \\ \vdots \\ \Delta V_{Lk} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & 1_{1n} \\ a_{21} & \ddots & \vdots \\ a_{k1} & \cdots & a_{kn} \end{bmatrix} \begin{bmatrix} \Delta V_{G1} \\ \vdots \\ \Delta V_{Gn} \end{bmatrix} \tag{6}$$

where

ΔV_{Lk} – voltage magnitude deviation at load bus *k*

ΔV_{Gn} – voltage magnitude deviation at generator bus *n*

a_{kn} – voltage sensitivity index between load bus *k* and generator bus *i*.

According to equation (5), when it comes to evaluating the impact of the reactive power output from a specific generator, it is important to control the reactive power outputs from the remaining generators in order to prevent them from responding to voltage changes caused by the selected generator when formulating the voltage sensitivity matrix.

Therefore, a more controlled system approach is taken in this study. This approach is based on the use of small voltage set point variation at selected generator's buses and calculation of the voltage magnitude changes to the selected monitored load buses. For example, if generator at bus *k* is selected, the voltage setpoint for the generator at bus *k* will be changed by a certain percentage. When solving the new power flow solution, the reactive power output from other units, say ΔQ_j ($j \neq k$) is set to zero. Therefore, any voltage magnitude changes at the monitored buses can be considered as the result of the only impact of generator k. The computed voltage deviation will be used to formulate the sensitivity matrix. The same calculation will be iterated on all the selected generators until the sensitivity matrix is formulated.

4. STUDY APPROACH

The goal of this study is to approach voltage sensitivity in a traditionally unconventional way and assess the effectiveness of any one given generator in the overall system for regulating bus voltages. To achieve this, the following assumptions have been made.

1) Generators with an ability to inject or withdrawal real or reactive power are frozen in a default state, except for the selected generator for sensitivity calculation; and
2) All other voltage/VAr control devices (e.g., transformer LTCs, switchable reactors/capacitors, SVC) are locked.
3) The system topology remains unchanged throughout all iterations of the study.

The step-by-step process is as follows:

Step 1: Perform a base case power flow of given network.

Step 2: Increase a single generator of interest voltage setpoint by 5% after relaxing its VAr output limits and re-solve power flow.

Step 3: Compile voltage magnitude changes at all selected busses.

Step 4. Calculate the bus voltage sensitivity with respect to a specific generator as $\frac{\Delta V_{Bus}}{\Delta V_{Gen}}$.

Step 5: Categorize generator voltage control efficacy for all selected busses in the network.

Step 6: Reset generator voltage setpoint and VAr capacity limit to base case and repeat from step 2 for the next selected generator.

Furthermore, the system's grid is divided into six distinct regions, mirroring the way OG&E segments its service territory. These regions are delineated based on geographical location and the proximity of system configurations. This regional division facilitates a more targeted analysis and system management. By structuring the grid in this manner, the results can be effectively analyzed on a region-to-region basis, providing valuable insights into localized performance and enabling more efficient resource allocation and problem-solving. Additionally, this regional division reinforces the validation processes, as each region is likely to have similar generator candidates.

5. CASE STUDY

This case study involved a system with 1,306 buses and 118 generators from a real-time network snapshot. The real-time network provides an accurate data set for analyzing voltage sensitivity and generator performance. To protect company confidential information, all network buses and generators were renamed and given approximate geographical locations. After solving the base case, each generator's output was systematically increased by 5%, and its' efficacy of voltage regulation for each selected bus in the network was computed. A 5% increment was chosen to take into factor the non-linearity of the power system. This approach enabled the individual assessment of how effectively each generator could stabilize voltage for any given bus on the power system.

A color-coded chart can be seen in Table 1 to visually illustrate the relationship between each generator and bus voltage sensitivity for a more straightforward interpretation of the results. The color gradient helped quickly identify which busses in the network had effective generators to support voltage levels while others had less available voltage support. By providing this visual representation, the study may also be implemented as a visual reference to grid operators so they can quickly depict which generators should be dispatched in real-time operations.

TABLE 1

Color Coding for Generator Efficiency

Range	Color
Most Effective	
Least Effective	

In order to validate the study's findings, Ohm's Law, seen in equation (7), was applied. Ohm's Law states that the voltage (V) across a conductor is directly proportional to the current (I) flowing through it and the resistance (R) of the conductor, which is expressed as:

$$V = I \cdot R \tag{7}$$

In the context of the power grid, the resistance of transmission lines increase with the length of the line, meaning that over longer distances, more energy is lost as heat due to the resistance in the wires. This leads to a reduction in the efficiency of power transmission and the generators potential output. However, to minimize losses and improve efficiency, high-voltage transmission lines are often used because it allows the same amount of power to be transmitted with a lower current, and according to Ohm’s Law, lower current reduces the voltage drop and power lost to resistance. By analyzing the buses on a regional basis, we should observe similar patterns due to electrical proximity and the levels of transmission voltage.

This study encompases a real-time grid spanning from most parts of oklahoma and branches into Fort Smith, Arkansas. The territory was divided into six different regions following utility practice. For each of the six regions, ten of the most closely located buses will be seperated for analysis, along with each bus's top three most effective generators based on the voltage sensitivity indices calculated during the simulation. By organizing the network's buses into different geographical regions, closely located generators should appear as the best canidates to the buses in their respective region. Additionally, a relationship of transmission voltage level in the region to efficiency should be present.

Southern region

Starting with the Southern Region, as seen in Figure 1, the buses are located in southern Oklahoma. The voltage levels of the transmission lines in the region are summarized in Table 3. The distribution is as follows: 37% at 69 kV, 56% at 138 kV, 0% at 161 kV, and 7% at 345 kV. This indicates that 138 kV and 345 kV have the second highest percentage in the system, while 161 kV has the lowest percentage. Twelve different generators lie among the top five recommended generators in Tables A.1-3.

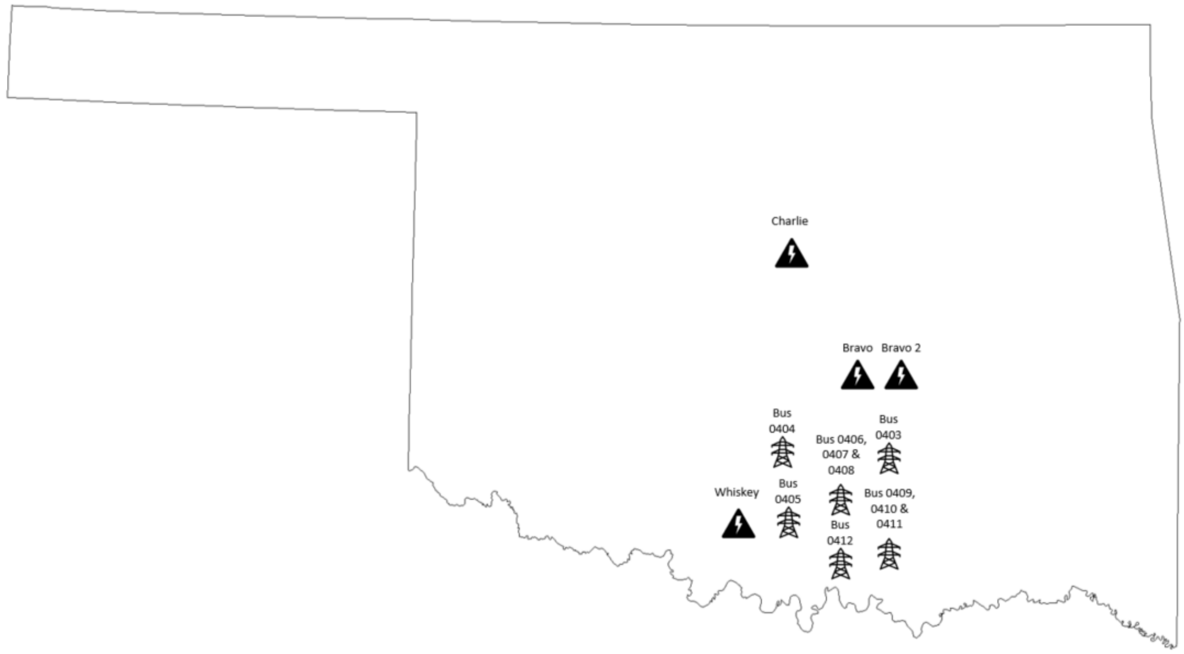

Fig. 1 Geographic Display of Southern Region

When assessing each region, ten buses are isolated from the total data set that has the closest geographical location, and their top three generator recommendations are noted. All ten isolated buses for the Southern Region, in Table 2, are located on the 69 kV level. Among the three best candidates for these isolated ten buses are four generators: Bravo, Bravo 2, Whiskey, and Charlie. Any generators with a number attached (Bravo and Bravo 2) represent co-located generators. The approximate geographical location of these generators is primarily towards central Oklahoma, as seen in Figure 1. The generators are connected to the following bus voltage levels: Bravo 345 kV, Bravo 2 138 kV, Charlie 345 kV, and Whiskey 138 kV.

For the isolated buses, every recommended top-three generator has mid-tier efficiency. With all ten buses on the 69 kV level, upgrading these lines to 138 kV or 161 kV would boost efficiency and minimize loss. Secondly, given that three out of the four regionally located generators are located to the north, adding more reactive devices in the south would also prove effective. Although these generators have similar efficiency ratings for the designated buses, they allow operators to prioritize the slightly more efficient models. Additionally, they offer a reliable alternative if the current system configuration does not support the highest-rated option.

TABLE 2

Ranked Generators based on Their Voltage Sensitivity with respect to the Selected Buses in Southern Region

Bus	Gen 1	Gen 2	Gen 3
Bus 0403	Bravo 2	Bravo	Charlie
Bus 0404	Bravo	Bravo 2	Whiskey
Bus 0405	Bravo	Bravo 2	Whiskey
Bus 0406	Bravo	Bravo 2	Whiskey
Bus 0407	Bravo	Bravo 2	Whiskey
Bus 0408	Bravo	Bravo 2	Whiskey
Bus 0409	Bravo	Bravo 2	Whiskey
Bus 0410	Bravo	Bravo 2	Whiskey
Bus 0411	Bravo	Bravo 2	Whiskey
Bus 0412	Bravo	Bravo 2	Whiskey

The data from Tables A.1-3 indicates that the Southern Region's efficiency is primarily mid-tier. However, there are exceptional cases, such as Bus 0274, which lacks effective generators to adhere to voltage issues effectively. Additionally, there are no reactive devices at Bus 0274's location. When a utility determines the need or placement location for a new reactive device in their system, this study would provide easy-to-interpret results and highlight the need for one at Bus 0274.

In retrospect, System Operators and utilities now have guidance for generator prioritization for immediate use. For example, Bus 0832 has the highest efficiency rating with generator Kappa and steeply declines for the following available alternatives.

TABLE 3

Percentage Distribution of Transmission Voltage Levels in Southern Region

Region	69	138	161	345
Southern	37%	56%	0%	7%

Northwest region

The Northwest Region buses, as seen in Figure 2, are located in northwest Oklahoma. The voltage levels of the transmission lines in the region are summarized in Table 5. The distribution is as follows: 37% at 69 kV, 41% at 138 kV, 0% at 161 kV, and 22% at 345 kV. This indicates that the 345 kV is the highest percentage in the system, while 161 kV is the lowest. Thirty-three different generators lie among the top five recommended generators in Tables A.4-7.

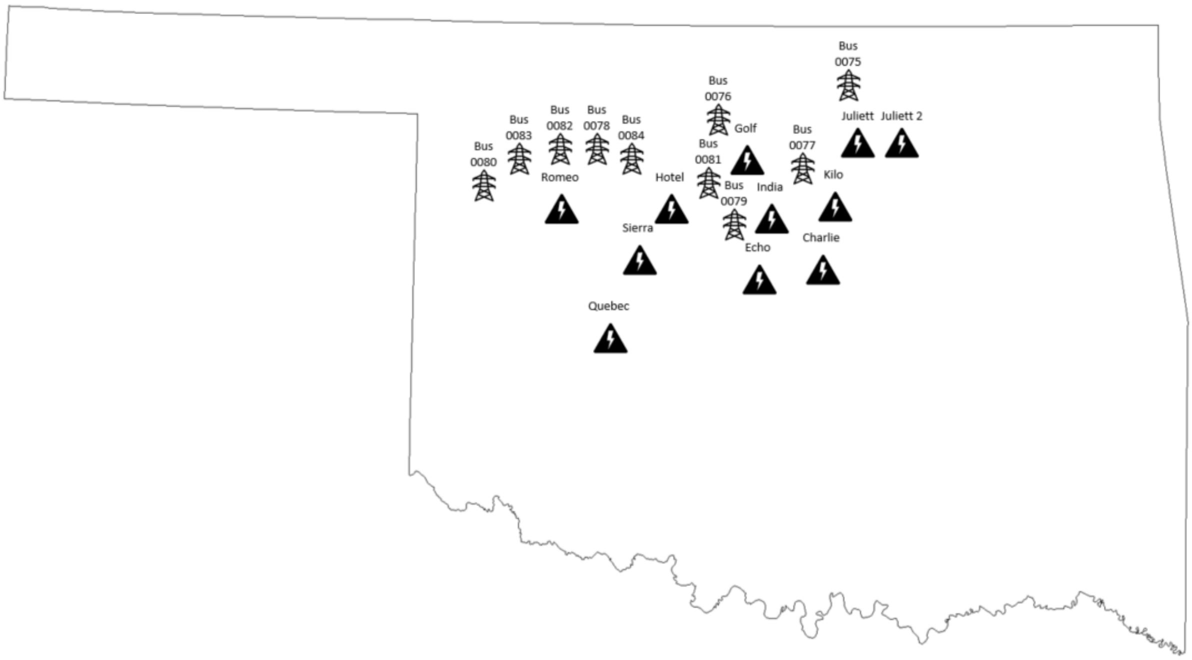

Fig. 2 Geographic Display of Northwest Region

For the ten isolated buses of the Northwest Region, in Table 4, they are split between the 69 kV and 138 kV levels. This region exemplifies the numerous generator options available for a given bus, with 11 different generator choices among the buses in Table 4. The approximate geographical location of these generators spans from Northwest to Central Oklahoma, as seen in Figure 2. The eleven generators for the isolated buses are primarily wind sources and connected to the following bus voltage levels: Juliett, Kilo, India, Echo, Quebec, Sierra, Charlie on 345 kV and Juliett 2, Hotel, Golf, Romeo on 138 kV.

For the isolated buses, the recommended top-three generators range from high-tier to mid-tier efficiency. With more generator candidate options than the list of selected buses, it can be unclear which resource to dispatch in the correct order. Reinforcing the need for a tool to quickly address the common question of generator priority.

TABLE 4

Ranked Generators based on Their Voltage Sensitivity with respect to the Selected Buses in Northwest Region

Bus	Gen 1	Gen 2	Gen 3
Bus 0075	Juliett 2	Juliett	Kilo
Bus 0076	Hotel	Golf	India
Bus 0077	Juliett 2	Juliett	Kilo
Bus 0078	Quebec	Romeo	Sierra
Bus 0079	Echo	India	Charlie
Bus 0080	Quebec	Romeo	Sierra
Bus 0081	Hotel	India	Echo
Bus 0082	Quebec	Romeo	Sierra
Bus 0083	Quebec	Romeo	Sierra
Bus 0084	Hotel	India	Juliett

The data from Tables A.4-7 showcases that the Northwest Region has the highest percentage of high-tier efficiency options. However, there are exceptional cases, such as Bus 1061, where Zulu is the best candidate with mid-tier efficiency and then falls to low tier for all subsequent options. In retrospect, Bus 0891 is generator-rich with the top three options providing high-tier efficiency.

TABLE 5

Percentage Distribution of Transmission Voltage Levels in Northwest Region

Region	69	138	161	345
Northwest	37%	41%	0%	22%

Eastern Region

The Eastern Region buses, as seen in Figure 3, are located in Eastern Oklahoma and span into Arkansas. The voltage levels of the transmission lines in the region are summarized in Table 7. The distribution is as follows: 30% at 69 kV, 0% at 138 kV, 69% at 161 kV, and 1% at 345 kV. This indicates that the 161 kV is the highest percentage in the system, while the 138 kV and 345 kV are the lowest. There are only three different generators among the top five recommended generators in Tables A.8-9. If any given recommended generator does not have a candidate that meets a pre-set threshold, then it will be categorized with a black box.

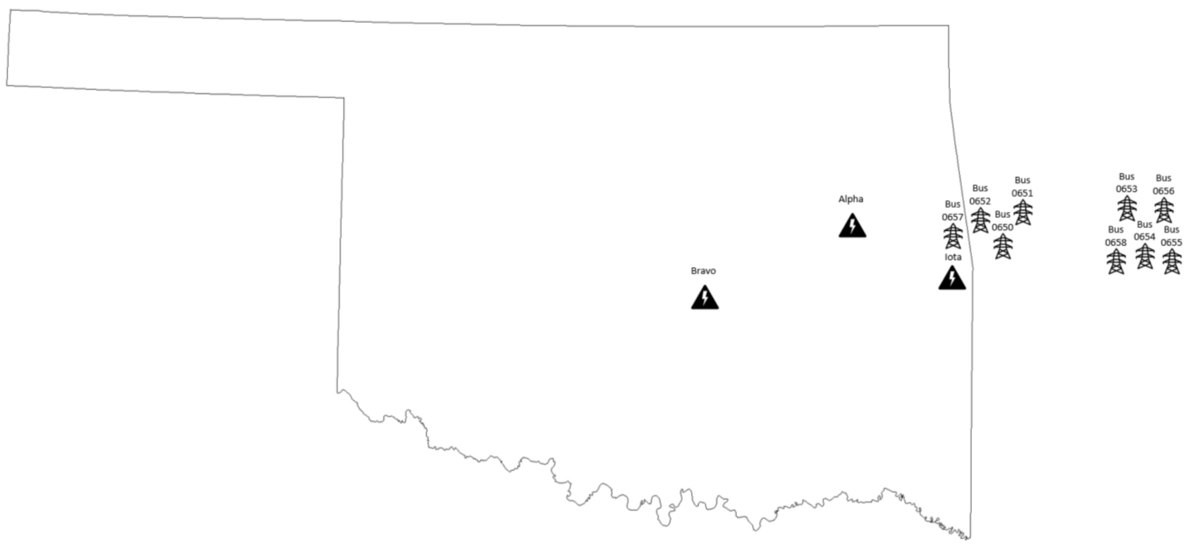

Fig. 3 Geographic Display of Eastern Region

For the ten isolated buses of the Eastern Region, in Table 6, they are all located at the 161 kV level. This region indicates a significantly weak area of the system with only 3 low tier rated generators for the entire region and, in many cases, such as Bus 0653-0656, zero generators that meet the preset threshold. The approximate geographical location of these generators is in Eastern Oklahoma. The three generators for the isolated buses are connected to the following bus voltage levels: Alpha 345 kV, Iota 161 kV, and Bravo 345 kV.

For the isolated buses, the recommended top-three generators range from low-tier to near-zero efficiency. From an operator perspective, there are not many candidates to choose from, limiting potential delays in response. However, the study has highlighted the immediate need for improvements in the Eastern systems territory.

TABLE 6

Ranked Generators based on Their Voltage Sensitivity with respect to the Selected Buses in Eastern Region

Bus	Gen 1	Gen 2	Gen 3
Bus 0649	Iota	Alpha	
Bus 0650	Iota	Alpha	Bravo
Bus 0651	Iota	Alpha	
Bus 0652	Iota	Alpha	
Bus 0653			
Bus 0654			
Bus 0655			
Bus 0656			
Bus 0657	Iota	Alpha	
Bus 0658	Iota	Alpha	

The data from Tables A.8-9 emphasize that the Northwest Region has the highest percentage of low-tier to near-zero efficiency options. The most notable aspect of the Eastern Region is that it would be in the best interest of system stability to incentivize or focus on new generator resources, battery storage systems, or reactive devices in this region. Additionally, the minimal number of 138 kV and 345 kV lines compared to the other regions in this system.

TABLE 7

Percentage Distribution of Transmission Voltage Levels in Eastern Region

Region	**69**	**138**	**161**	**345**
Eastern	30%	0%	69%	1%

Central Region

Figure 4 shows that the Central Region buses are more tightly connected around central Oklahoma. The voltage levels of the transmission lines in the region are summarized in Table 9. The distribution is as follows: 22% at 69 kV, 73% at 138 kV, 0% at 161 kV, and 4% at 345 kV. This indicates that the region's 138 kV is the highest percentage in the overall system, while the 69 kV is the lowest. Eighteen different generators are among the top five recommended generators in Tables A.10-13.

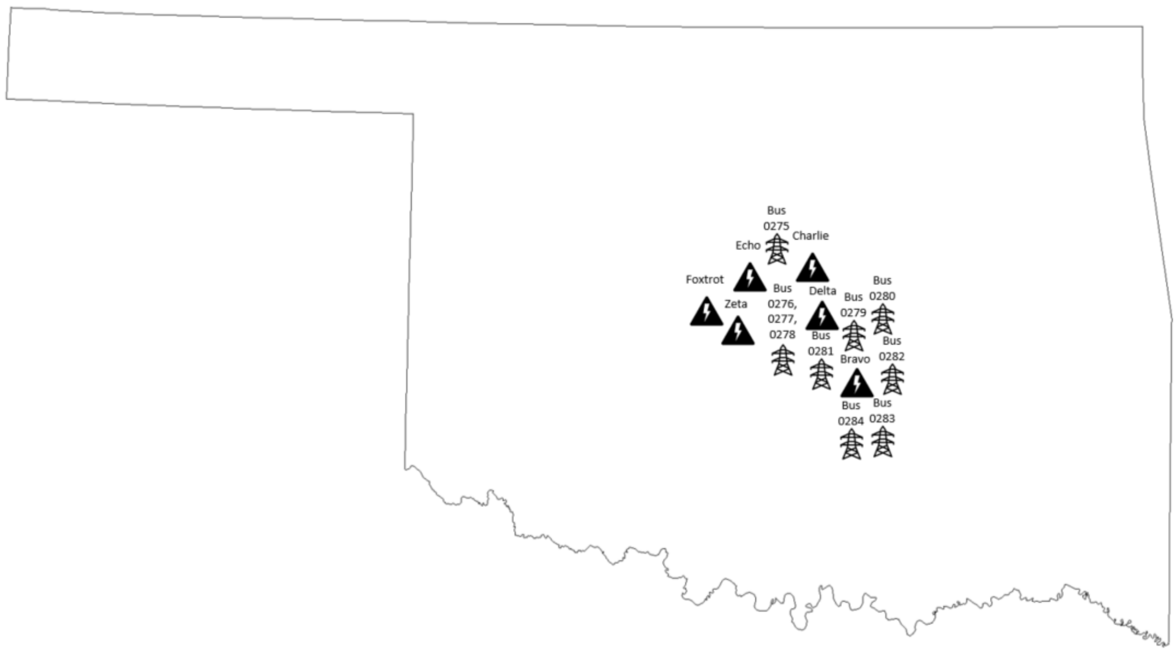

Fig. 4 Geographic Display of Central Region

The ten isolated buses of the Central Region, in Table 8, are all located at the 69 kV level. This region showcases the strongest region of the system, with the majority of the buses having higher-tier-rated generator options. The approximate geographical location of these generators is in Central Oklahoma. The six generators for the isolated buses are connected to the following bus voltage levels: Foxtrot, Zeta, Delta at 138 kV, and Echo, Bravo, and Charlie at 345 kV.

For the isolated buses, the recommended top-three generators are the highest of any region's overall efficiency. From an operator perspective, many candidates are closely located to choose from, resulting in potential delays in response. However, the study has highlighted the generator ranking priority for buses in the Central Region territory.

TABLE 8

Ranked Generators based on Their Voltage Sensitivity with respect to the Selected Buses in Central Region

Bus	Gen 1	Gen 2	Gen 3
Bus 0275	Delta	Foxtrot	Bravo
Bus 0276	Foxtrot	Echo	Zeta
Bus 0277	Foxtrot	Echo	Bravo
Bus 0278	Foxtrot	Echo	Bravo
Bus 0279	Foxtrot	Echo	Delta
Bus 0280	Foxtrot	Delta	Bravo
Bus 0281	Foxtrot	Delta	Bravo
Bus 0282	Foxtrot	Delta	Bravo
Bus 0283	Foxtrot	Delta	Bravo
Bus 0284	Delta	Bravo	Charlie

The data from Tables A.10-13 exemplify the robustness of the Central Region with the highest percentage of upper-tier efficiency options. The most notable aspect of the Central Region is that it contains the highest percentage of 138 kV transmission lines. That, combined with the region's strong interconnection routes, resulted in this region receiving an average efficiency rating.

TABLE 9

Percentage Distribution of Transmission Voltage Levels in Central Region

Region	69	138	161	345
Central	22%	73%	0%	4%

East-Central Region

Figure 5 shows the East-Central Region buses are connected around central east-central Oklahoma. The voltage levels of the transmission lines in the region are summarized in Table 11. The distribution is as follows: 60% at 69 kV, 15% at 138 kV, 20% at 161 kV, and 5% at 345 kV. This indicates that the region's 69 kV and 161 kV are the second-highest percentages in the overall system, while the 138 kV is the second lowest. Ten different generators are among the top five recommended generators in Tables A.14-15.

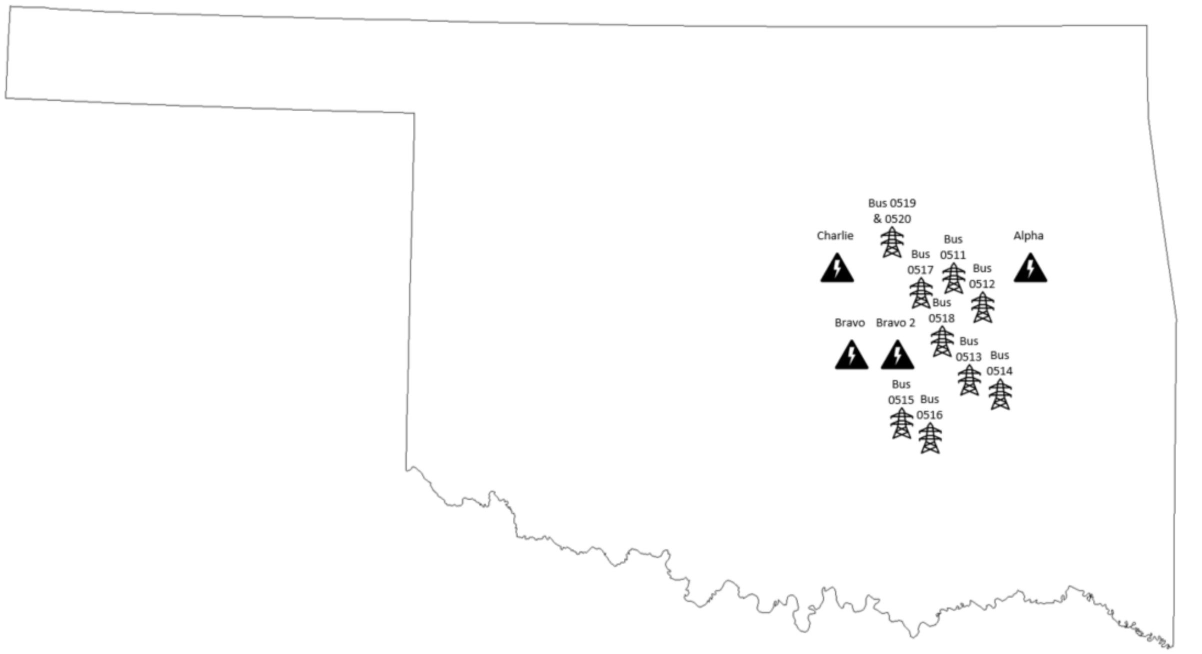

Fig. 5 Geographic Display of East-Central Region

The ten isolated buses of the East-Central Region, in Table 10, are mainly located at the 69 kV level, with two on the 138 kV. This region is the second weakest region of the system, as it also leads to the East Region. The approximate geographical location of these generators ranges from East to Central Oklahoma. The four generators for the isolated buses are connected to the following bus voltage levels: Bravo 345 kV, Bravo 2 138 kV, Charlie 345 kV, and Alpha 345 kV.

The recommended top three generators for the isolated buses are extremely poor compared to most other regions' efficiency. From an operating perspective, the study's results prove particularly interesting as every bus represented in Figure 5 favors generator Alpha. The efficiency difference between Alpha and subsequent options is pretty steep for the cases here. This indicates that these rankings are beneficial in eliminating the potential operator assumption that generator Bravo would supersede generator Alpha due to geographical closeness.

TABLE 10

Ranked Generators based on Their Voltage Sensitivity with respect to the Selected Buses in East-Central Region

Bus	Gen 1	Gen 2	Gen 3
Bus 0511	Alpha	Bravo	Charlie
Bus 0512	Alpha	Bravo	Charlie
Bus 0513	Alpha	Bravo	Charlie
Bus 0514	Alpha	Bravo	Bravo 2
Bus 0515	Alpha	Bravo	Bravo 2
Bus 0516	Alpha	Bravo	Bravo 2
Bus 0517	Alpha	Bravo	Charlie
Bus 0518	Alpha	Bravo	Charlie
Bus 0519	Alpha		
Bus 0520	Alpha		

The data from Tables A.14-15 show an additional weak East-Central Region of the system with similar results to the Eastern Region. A common denominator from previously is the lacking percentage of 138 kV transmission lines and the dominant 69 kV ratio. Another reason for the diminished efficiency is the limited transmission routes available. Improving the interconnectivity could prove beneficial.

TABLE 11

Percentage Distribution of Transmission Voltage Levels in East-Central Region

Region	**69**	**138**	**161**	**345**
East-Central	60%	15%	20%	5%

North-Eastern Region

The last region of the system is shown in Figure 6, North-Eastern, located around north-eastern Oklahoma. The voltage levels of the transmission lines in the region are summarized in Table 13. The distribution is as follows: 64% at 69 kV, 35% at 138 kV, 0% at 161 kV, and 1% at 345 kV. This indicates that the region's 69 kV is the highest percentage in the overall system, while the 161 kV and 345 kV are the lowest. Eleven different generators are among the top five recommended generators in Tables A.16-17.

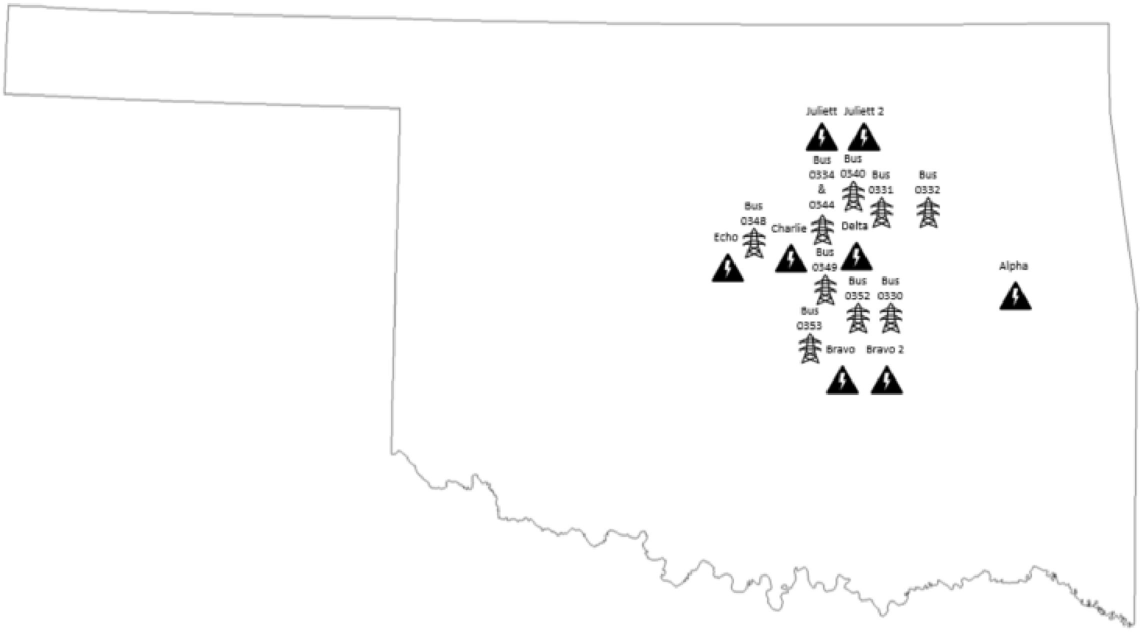

Figure 6 Geographic Display of North-Eastern Region

The ten isolated buses of the North-Eastern Region, in Table 12, are split between the 69 kV and 138 kV levels. The approximate geographical location of these generators ranges from East to Central Oklahoma. The six generators for the isolated buses are connected to the following bus voltage levels: Bravo 345 kV, Bravo 2 138 kV, Alpha 345 kV, Delta 138 kV, Charlie 345 kV, and Echo 345 kV.

The recommended top three generators for the isolated buses are on the lower end compared to most other regions' efficiency. From an operating perspective, the region's generators are intermittent between the selected buses, demonstrating another example of how this study would simplify the process for an operator to choose the appropriate generator per any given bus. The efficiency difference between subsequent options is more minor overall for this region, but minimizing loss is always a priority to consumers and providers.

TABLE 12

Ranked Generators based on Their Voltage Sensitivity with respect to the Selected Buses in North-Eastern Region

Bus	Gen 1	Gen 2	Gen 3
Bus 0330	Bravo	Bravo 2	Delta
Bus 0331	Delta	Juliett	Echo
Bus 0332	Juliett	Delta	Echo
Bus 0334	Juliett	Juliett 2	Delta
Bus 0340	Juliett	Juliett 2	Echo
Bus 0344	Delta	Juliett	Echo
Bus 0348	Delta	Bravo	Charlie
Bus 0349	Delta	Bravo	Charlie
Bus 0352	Delta	Bravo	Charlie
Bus 0353	Bravo 2	Bravo	Delta

The data from Tables A.16-17 vary from high-tier areas to areas with only low-tier areas in the north-eastern region of the system. A common denominator from previous regions is the dominant portion of 69 kV transmission lines. For further improvements in this region, upgrading a greater percentage of the transmission lines to the 138 kV level would decrease the system's loss.

TABLE 13

Percentage Distribution of Transmission Voltage Levels in North-Eastern Region

Region	69	138	161	345
North-Eastern	64%	35%	0%	1%

6. FUTURE WORK

The work presented in this document provides a solid foundation for future research and development, offering many potential areas to expand upon in real-time applications, forward looking planning, and methodology approaches.

The results of this study could be directly integrated into real-time operations for a practical application by providing operators with immediate insights into which generators should be prioritized based on the current system configuration. In a system constantly undergoing changes, such as maintenance, unplanned outages, the addition of new transmission lines, or the integration of new generators, it is increasingly difficult to know exactly which unit to use immediately. The application of this study would help proactively address bus voltage issues by providing the best generator candidates that can reduce potential instability. The need for real-time decision-making is growing in importance as more variable renewable energy sources, such as solar and wind, continue to integrate into our energy grid. These sources have the potential to create sudden fluctuations in both voltage and frequency, necessitating swift and accurate responses to maintain grid stability and reliability.

In conjunction with real-time operations, the current online generators will change based on system demand, weather conditions, and other factors. Each unit's cost can fluctuate depending on its ramp rate, which is influenced by the unit's type, age, and the weather. Analyzing the system and incorporating economic factors related to different combinations of units could yield even more valuable insights.

Bus voltage sensitivity studies can be a forward-looking tool to identify areas in the network that require additional generation or have limited transmission capability. These insights guide the placement of new generators or storage systems in locations with the most significant impact on enhancing voltage stability. Furthermore, understanding the voltage sensitivity of various buses allows utilities to make targeted investments in infrastructure upgrades rather than implementing broad, unfocused solutions. By continuously monitoring voltage sensitivity, renewables can be better integrated by identifying the area’s most prone to instability. Alternatively, prone areas can incorporate storage solutions to mitigate these issues, ensuring more stable operation. Improved voltage control also reduces the need for renewable energy curtailment, allowing for higher renewable penetration without compromising grid stability. This methodology supports the grid's shift toward cleaner energy and lower energy costs, all while maintaining operational reliability.

Before each operating day, detailed studies of the system's configuration are performed, identifying potential issues such as congestion, weak voltage points, or instability. Generators are then scheduled to meet forecasted demand. However, this traditional scheduling can be further enhanced by conducting a voltage sensitivity analysis based on the present system configuration. This analysis will provide further insights into how different generators affect voltage levels at key buses of interest, enabling the forward planning of generation in a more efficient manner.

Lastly, there are opportunities to enhance the current methodology to improve the accuracy of the results. In this study, the Q (reactive power) limits were relaxed to investigate a single generator's contribution. In real-time operations, generators follow a D curve, illustrating the relationship between maximum reactive capability and megawatt output. The term "D curve" is derived from the shape formed by the unit's limits on a graph, where megawatts are plotted on the x-axis and reactive power on the y-axis. The study can be repeated by resetting the units to their standard restrictive settings, and the results can be compared to identify any potential differences.

7. CONCLUSION

In conclusion, we observed strong correlations between voltage control regions and candidate generators using a system from a real-time snapshot. This is consistent with Ohm's law, which exemplifies that geographically grouped regions are generally electrically closer, resulting in less voltage drop. The growing need to know precisely which generator is the most efficient lies in the increasingly limited resources as demand grows. The obtained results were also consistent with the experience of System Operators. Even though our test environment limited the influence of neighboring generators and their VAr injection or withdrawal from the system, our results still aligned with utility practice.

Due to the variable scheduling combination of generators and the efficiency rating of individual units being in line with operators' experience, ranking them by their individual contributions to the system has shown to be a valuable reference for any combination of online generators. Thus, the results have been shared with System Operators, enabling them to leverage new information to operate the transmission system in real-time. Also, it provides good information for training new System

Operators to help them familiarize themselves with the system. Looking forward, the results of this study can be integrated into day-to-day operations and other aspects further developed for future applications. With generator priority lining up with operators' experience, we can integrate this information into their voltage control page and provide real-time updates and straightforward guidance when voltage control is needed, or system conditions are changed. Additionally, ideal locations can be assessed when new units are in the planning stages from the standpoint of voltage control.

The conventional method for voltage sensitivity analysis involved balancing voltage and reactive power to maintain grid stability. Typically, this involved assessing how changes in reactive power affect voltage levels across the grid. However, in this study, the influence of generators with an ability to inject or withdrawal real or reactive power was frozen in a default state to isolate the impact of a sole generator's voltage variations alone. Despite this simplification, the results remained consistent with traditional grid operations, demonstrating that the proposed method can effectively prioritize generators for voltage control without compromising accuracy. This consistency suggests that the approach is a reliable method for identifying the most effective use of generator resources in the shortest amount of time, providing a streamlined yet effective means for prioritizing generators for voltage control in complex power systems.

8. APPENDIX

Broad Overview of Region Data

All the different region’s data are compiled for reference.

Southern Region

The Southern Region data is seen in Tables A.1-3 with the selected buses used in Table 2 highlighted in yellow.

TABLES A.1-3

Ranked Generators Based on Their Voltage Sensitivity in Southern Region

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
Southern	Bus 0107	345	Zulu	Zulu 2	Echo	Charlie	Bravo
Southern	Bus 0120	138	X-Ray	Bravo	Whiskey	Bravo 2	Yankee
Southern	Bus 0273	345	Zulu	Zulu 2	Echo	Bravo	Charlie
Southern	Bus 0274	138	Zulu	Zulu 2	Echo	Bravo	Charlie
Southern	Bus 0305	69	Bravo	Bravo 2	Delta	Charlie	Echo
Southern	Bus 0398	138	Bravo	Bravo 2	Echo	Charlie	Delta
Southern	Bus 0399	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0403	69	Bravo 2	Bravo	Charlie	Echo	Delta
Southern	Bus 0404	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0405	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0406	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0407	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0408	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0409	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0410	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0411	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0412	69	Bravo	Bravo 2	Whiskey	Charlie	X-Ray
Southern	Bus 0419	138	X-Ray	Whiskey	Bravo	Bravo 2	Yankee
Southern	Bus 0422	138	Bravo	Yankee	Bravo 2	Whiskey	X-Ray
Southern	Bus 0423	138	Bravo	Yankee	Bravo 2	Whiskey	X-Ray
Southern	Bus 0424	138	Whiskey	Bravo	Bravo 2	X-Ray	Yankee
Southern	Bus 0425	138	Bravo	Bravo 2	Charlie	Echo	Delta
Southern	Bus 0427	69	Bravo	Bravo 2	Yankee	Kappa	Whiskey
Southern	Bus 0428	69	Bravo	Bravo 2	Yankee	Kappa	Whiskey
Southern	Bus 0432	138	Bravo	Yankee	Kappa	Bravo 2	X-Ray
Southern	Bus 0433	138	Bravo	Yankee	Bravo 2	Kappa	X-Ray
Southern	Bus 0434	138	Bravo 2	Bravo	Whiskey	Charlie	Echo
Southern	Bus 0435	138	Bravo	Bravo 2	Yankee	Kappa	Charlie
Southern	Bus 0437	69	Bravo	Bravo 2	Charlie	Echo	Delta
Southern	Bus 0438	138	Bravo	Yankee	X-Ray	Bravo 2	Whiskey
Southern	Bus 0439	138	X-Ray	Bravo	Yankee	Bravo 2	Whiskey
Southern	Bus 0440	138	Bravo	Bravo 2	Charlie	Echo	Delta
Southern	Bus 0441	69	Bravo	Yankee	Bravo 2	Kappa	X-Ray
Southern	Bus 0442	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0443	138	Yankee	Bravo	Bravo 2	X-Ray	Whiskey
Southern	Bus 0444	138	Yankee	Bravo	Bravo 2	X-Ray	Whiskey
Southern	Bus 0445	138	Yankee	Bravo	Bravo 2	X-Ray	Whiskey
Southern	Bus 0446	69	Bravo	Yankee	Bravo 2	Kappa	X-Ray
Southern	Bus 0447	69	Bravo	Yankee	Bravo 2	Kappa	X-Ray
Southern	Bus 0448	138	Yankee	Bravo	Bravo 2	Whiskey	X-Ray
Southern	Bus 0449	69	Bravo	Bravo 2	Yankee	Kappa	Whiskey
Southern	Bus 0450	138	Yankee	Bravo	Bravo 2	Whiskey	X-Ray
Southern	Bus 0451	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0452	138	Bravo	Yankee	Bravo 2	Whiskey	Charlie
Southern	Bus 0453	138	Bravo	Yankee	Bravo 2	Whiskey	Charlie
Southern	Bus 0454	138	Bravo	Yankee	Bravo 2	Whiskey	Charlie
Southern	Bus 0455	138	Bravo	Yankee	Bravo 2	Whiskey	Charlie
Southern	Bus 0456	138	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0458	138	Yankee	Bravo	Bravo 2	Whiskey	X-Ray
Southern	Bus 0459	138	Yankee	Bravo	Bravo 2	Whiskey	X-Ray
Southern	Bus 0460	138	Bravo	Yankee	Bravo 2	Whiskey	Charlie

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
Southern	Bus 0462	138	Bravo	Bravo 2	Whiskey	X-Ray	Yankee
Southern	Bus 0463	345	Yankee	Bravo	Bravo 2	Alpha	Charlie
Southern	Bus 0464	69	Bravo	Whiskey	Bravo 2	X-Ray	Charlie
Southern	Bus 0465	138	Whiskey	Bravo	Bravo 2	X-Ray	Yankee
Southern	Bus 0466	138	Yankee	Bravo	Bravo 2	Whiskey	X-Ray
Southern	Bus 0467	69	Bravo	Bravo 2	Yankee	Kappa	Whiskey
Southern	Bus 0468	69	Bravo	Bravo 2	Yankee	Kappa	Whiskey
Southern	Bus 0469	138	Bravo	Bravo 2	Kappa	Yankee	Charlie
Southern	Bus 0470	138	Bravo	Bravo 2	Whiskey	X-Ray	Yankee
Southern	Bus 0471	138	Bravo	Kappa	Yankee	Bravo 2	X-Ray
Southern	Bus 0472	138	Yankee	Bravo	Bravo 2	X-Ray	Whiskey
Southern	Bus 0473	138	Bravo	Yankee	X-Ray	Bravo 2	Whiskey
Southern	Bus 0474	138	Bravo	Whiskey	Whiskey	X-Ray	Yankee
Southern	Bus 0475	138	Bravo 2	Bravo	Whiskey	Charlie	Echo
Southern	Bus 0476	69	Bravo 2	Bravo	Charlie	Echo	Whiskey
Southern	Bus 0477	138	Bravo	Yankee	Bravo 2	Whiskey	Charlie
Southern	Bus 0478	345	Yankee	Bravo	Bravo 2	Zulu	Echo
Southern	Bus 0479	69	Bravo	Yankee	Bravo 2	Kappa	X-Ray
Southern	Bus 0480	69	Bravo 2	Bravo	Charlie	Echo	Delta
Southern	Bus 0483	138	Bravo	Yankee	Bravo 2	Kappa	X-Ray
Southern	Bus 0484	69	Bravo 2	Bravo	Charlie	Echo	Delta
Southern	Bus 0490	69	Bravo 2	Bravo	Charlie	Echo	Delta
Southern	Bus 0491	69	Bravo 2	Bravo	Charlie	Echo	Delta
Southern	Bus 0492	138	Yankee	Bravo	Bravo 2	Whiskey	X-Ray
Southern	Bus 0493	138	Bravo	Yankee	Bravo 2	Whiskey	Charlie
Southern	Bus 0494	138	Bravo	Yankee	Bravo 2	Whiskey	Charlie
Southern	Bus 0495	69	Bravo	Bravo 2	Whiskey	Charlie	X-Ray
Southern	Bus 0497	138	Bravo	Yankee	Bravo 2	Whiskey	X-Ray
Southern	Bus 0498	69	Bravo 2	Bravo	Charlie	Echo	Delta
Southern	Bus 0522	138	Bravo	X-Ray	Yankee	Bravo 2	Whiskey
Southern	Bus 0523	69	Bravo	Yankee	X-Ray	Bravo 2	Whiskey
Southern	Bus 0525	138	Bravo	Yankee	Bravo 2	X-Ray	Whiskey
Southern	Bus 0528	138	Bravo	X-Ray	Bravo 2	Yankee	Whiskey
Southern	Bus 0529	69	Bravo	X-Ray	Yankee	Bravo 2	Whiskey
Southern	Bus 0530	69	Bravo	X-Ray	Yankee	Bravo 2	Whiskey
Southern	Bus 0531	69	Bravo	X-Ray	Yankee	Bravo 2	Whiskey
Southern	Bus 0535	69	Bravo	X-Ray	Yankee	Bravo 2	Whiskey
Southern	Bus 0536	138	Bravo	X-Ray	Yankee	Bravo 2	Whiskey
Southern	Bus 0537	69	Bravo 2	Bravo	Charlie	Echo	Whiskey
Southern	Bus 0547	138	Bravo 2	Bravo	Charlie	Echo	Whiskey
Southern	Bus 0548	69	Bravo 2	Bravo	Charlie	Echo	Delta
Southern	Bus 0564	69	Bravo 2	Bravo	Charlie	Echo	Delta
Southern	Bus 0565	138	Bravo	Bravo 2	Charlie	Echo	Delta
Southern	Bus 0583	138	Bravo	Yankee	Bravo 2	Whiskey	Charlie
Southern	Bus 0584	138	Bravo 2	Bravo	Charlie	Echo	Delta
Southern	Bus 0603	138	Bravo	Yankee	Bravo 2	Whiskey	Charlie
Southern	Bus 0619	138	Bravo 2	Bravo	Charlie	Echo	Whiskey
Southern	Bus 0671	138	Bravo	Yankee	Bravo 2	Whiskey	Charlie
Southern	Bus 0673	138	Bravo	Yankee	X-Ray	Bravo 2	Whiskey
Southern	Bus 0685	69	Bravo 2	Bravo	Charlie	Echo	Delta
Southern	Bus 0716	138	Yankee	Bravo	Bravo 2	X-Ray	Whiskey
Southern	Bus 0720	69	Bravo	X-Ray	Yankee	Bravo 2	Whiskey
Southern	Bus 0721	69	Bravo	X-Ray	Yankee	Bravo 2	Whiskey

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
Southern	Bus 0743	345	Zulu	Zulu 2	Echo	Charlie	Bravo
Southern	Bus 0795	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0801	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0809	138	Bravo 2	Bravo	Whiskey	Charlie	Echo
Southern	Bus 0819	345	Zulu	Zulu 2	Echo	Charlie	Bravo
Southern	Bus 0828	138	Whiskey	Bravo	Bravo 2	X-Ray	Yankee
Southern	Bus 0830	138	Bravo	Kappa	Yankee	Bravo 2	X-Ray
Southern	Bus 0832	138	Kappa	Bravo	Yankee	Bravo 2	X-Ray
Southern	Bus 0837	138	Bravo	Yankee	Bravo 2	Whiskey	Charlie
Southern	Bus 0839	138	Bravo	Bravo 2	Charlie	Echo	Delta
Southern	Bus 0844	138	X-Ray	Bravo	Whiskey	Bravo 2	Yankee
Southern	Bus 0847	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0849	69	Bravo	Bravo 2	Whiskey	Charlie	Echo
Southern	Bus 0900	138	X-Ray	Bravo	Whiskey	Bravo 2	Yankee
Southern	Bus 0955	138	Bravo 2	Bravo	Charlie	Echo	Delta
Southern	Bus 1046	69	Bravo	Bravo 2	Yankee	Kappa	Whiskey
Southern	Bus 1049	138	Bravo 2	Bravo	Charlie	Echo	Delta
Southern	Bus 1072	138	Bravo	Yankee	X-Ray	Bravo 2	Whiskey
Southern	Bus 1131	138	Bravo	Yankee	Bravo 2	X-Ray	Whiskey
Southern	Bus 1133	138	Bravo	Bravo 2	Charlie	Echo	Alpha
Southern	Bus 1138	345	Zulu	Zulu 2	Echo	Charlie	Bravo
Southern	Bus 1143	138	Bravo	Yankee	Bravo 2	Whiskey	Charlie
Southern	Bus 1175	345	Zulu	Zulu 2	Echo	Charlie	Bravo
Southern	Bus 1195	345	Yankee	Bravo	Bravo 2	Alpha	Charlie
Southern	Bus 1218	138	Bravo	Yankee	Bravo 2	Whiskey	Charlie
Southern	Bus 1284	138	Whiskey	Bravo	Bravo 2	X-Ray	Yankee
Southern	Bus 1291	138	Bravo	Kappa	Yankee	Bravo 2	X-Ray

Northwest Region

The Northwest Region data is seen in Tables A.4-7 with the selected buses used in Table 4 highlighted in yellow.

TABLES A.4-7

Ranked Generators Based on Their Voltage Sensitivity in Northwest Region

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
Northwest	Bus 0004	138	Golf	Hotel	India	Juliett	Kilo
Northwest	Bus 0010	138	Hotel	Juliett	Juliett 2	Kilo	India
Northwest	Bus 0011	138	Juliett 2	Juliett	Kilo	Tango	Echo
Northwest	Bus 0014	138	Juliett 2	Juliett	Kilo	Lima	India
Northwest	Bus 0015	138	Lima	Juliett	Hotel	Kilo	Juliett 2
Northwest	Bus 0016	138	Hotel	India	Kilo	Juliett	Mike
Northwest	Bus 0017	138	Hotel	India	Juliett	Kilo	Echo
Northwest	Bus 0018	138	Hotel	India	Kilo	Juliett	Mike
Northwest	Bus 0020	138	Juliett 2	Lima	Juliett	Kilo	India
Northwest	Bus 0023	69	Hotel	India	Juliett	Kilo	Kilo
Northwest	Bus 0024	69	Hotel	Mike	India	Juliett	Kilo
Northwest	Bus 0025	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0026	69	Novembe	Mike	Hotel	Juliett	India
Northwest	Bus 0027	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0028	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0029	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0032	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0034	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0035	69	Oscar	Novembe	Mike	Papa	Juliett
Northwest	Bus 0039	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0040	138	Hotel	India	Juliett	Echo	Kilo
Northwest	Bus 0041	138	Hotel	India	Juliett	Kilo	Golf
Northwest	Bus 0042	69	Echo	India	Charlie	Hotel	Juliett
Northwest	Bus 0043	69	Hotel	Mike	Novembe	India	Juliett
Northwest	Bus 0044	138	Juliett 2	Juliett	Kilo	Tango	Echo
Northwest	Bus 0046	69	Novembe	Mike	Oscar	Juliett	Kilo
Northwest	Bus 0047	69	Oscar	Novembe	Mike	Juliett	Kilo
Northwest	Bus 0048	69	Oscar	Novembe	Mike	Juliett	Kilo
Northwest	Bus 0051	69	Juliett 2	Juliett	Kilo	Mike	India
Northwest	Bus 0052	69	Juliett 2	Juliett	Kilo	Mike	India
Northwest	Bus 0053	69	Juliett 2	Juliett	Kilo	Mike	India
Northwest	Bus 0057	69	Novembe	Oscar	Papa	Mike	Juliett
Northwest	Bus 0058	69	Novembe	Oscar	Papa	Mike	Juliett
Northwest	Bus 0059	69	Juliett 2	Juliett	Novembe	Mike	Papa
Northwest	Bus 0061	69	Novembe	Juliett 2	Juliett	Mike	Oscar
Northwest	Bus 0062	69	Novembe	Oscar	Mike	Mike	Juliett
Northwest	Bus 0066	138	Juliett 2	Juliett	Novembe	Mike	Kilo
Northwest	Bus 0067	138	Juliett 2	Juliett	Novembe	Mike	Kilo
Northwest	Bus 0069	69	Juliett 2	Juliett	Novembe	Mike	Kilo
Northwest	Bus 0071	138	Juliett 2	Juliett	Novembe	Mike	Kilo
Northwest	Bus 0075	69	Juliett 2	Juliett	Kilo	Lima	India
Northwest	Bus 0076	138	Hotel	Golf	India	Juliett	Kilo
Northwest	Bus 0077	138	Juliett 2	Juliett	Kilo	India	Mike
Northwest	Bus 0078	69	Quebec	Romeo	Sierra	Uniform	Victor
Northwest	Bus 0079	69	Echo	India	Charlie	Hotel	Juliett
Northwest	Bus 0080	69	Quebec	Romeo	Sierra	Uniform	Victor
Northwest	Bus 0081	138	Hotel	India	Echo	Juliett	Kilo
Northwest	Bus 0082	69	Quebec	Romeo	Sierra	Uniform	Victor
Northwest	Bus 0083	69	Quebec	Romeo	Sierra	Uniform	Victor
Northwest	Bus 0084	69	Hotel	India	Juliett	Mike	Kilo
Northwest	Bus 0085	138	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0086	69	Quebec	Romeo	Sierra	Uniform	Victor

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
Northwest	Bus 0088	69	Quebec	Romeo	Sierra	Uniform	Victor
Northwest	Bus 0093	138	Gamma	Quebec	Echo	Sierra	Romeo
Northwest	Bus 0094	138	Hotel	India	Echo	Quebec	Juliett
Northwest	Bus 0095	138	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0096	138	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0097	69	Hotel	India	Juliett	Mike	Kilo
Northwest	Bus 0099	69	Hotel	India	Mike	Juliett	Kilo
Northwest	Bus 0100	69	Hotel	Quebec	Quebec	Mike	Echo
Northwest	Bus 0101	138	Hotel	Quebec	Romeo	Sierra	India
Northwest	Bus 0102	138	Quebec	Romeo	Sierra	Uniform	Victor
Northwest	Bus 0103	69	Juliett 2	Juliett	Kilo	Lima	India
Northwest	Bus 0104	138	Juliett 2	Juliett	Kilo	Tango	Echo
Northwest	Bus 0105	138	Juliett 2	Juliett	Kilo	Tango	Echo
Northwest	Bus 0106	69	Juliett 2	Juliett	Kilo	Lima	India
Northwest	Bus 0110	138	Juliett	Juliett 2	Novembe	Mike	Kilo
Northwest	Bus 0119	69	Echo	Charlie	Foxtrot	India	Bravo
Northwest	Bus 0121	138	Hotel	Golf	India	Juliett	Kilo
Northwest	Bus 0131	345	Epsilon	Juliett	Kilo	Tango	Echo
Northwest	Bus 0292	138	Juliett 2	Juliett	Kilo	Lima	India
Northwest	Bus 0606	69	Juliett 2	Juliett	Kilo	Mike	India
Northwest	Bus 0608	138	Juliett 2	Juliett	Kilo	India	Mike
Northwest	Bus 0614	138	Juliett 2	Juliett	Kilo	India	Mike
Northwest	Bus 0617	138	Juliett 2	Juliett	Kilo	India	Mike
Northwest	Bus 0620	69	Novembe	Oscar	Papa	Mike	Juliett
Northwest	Bus 0621	138	Papa	Novembe	Mike	Juliett	Juliett 2
Northwest	Bus 0626	138	Juliett 2	Juliett	Kilo	India	Mike
Northwest	Bus 0628	138	Juliett 2	Juliett	Kilo	Mike	Mike
Northwest	Bus 0637	138	Juliett 2	Juliett	Kilo	Tango	Echo
Northwest	Bus 0640	345	Juliett	Kilo	Tango	Echo	Epsilon
Northwest	Bus 0643	345	Novembe	Mike	India	Kilo	Juliett
Northwest	Bus 0644	138	Novembe	Mike	India	Kilo	Juliett
Northwest	Bus 0663	138	Novembe	Mike	India	Kilo	Juliett
Northwest	Bus 0664	138	Tau	Romeo	Quebec	Sierra	Uniform
Northwest	Bus 0670	138	Delta	Bravo	Charlie	Echo	Foxtrot
Northwest	Bus 0672	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0676	69	Novembe	Mike	Juliett	Kilo	India
Northwest	Bus 0677	69	Juliett 2	Juliett	Kilo	Lima	India
Northwest	Bus 0681	138	Hotel	India	Golf	Kilo	Kilo
Northwest	Bus 0682	138	Juliett 2	Juliett	Novembe	Mike	Kilo
Northwest	Bus 0684	138	Hotel	India	Kilo	Juliett	Mike
Northwest	Bus 0691	138	Gamma	Quebec	Echo	Sierra	Romeo
Northwest	Bus 0695	138	Lamda	Romeo	Quebec	Uniform	Sierra
Northwest	Bus 0699	138	Uniform	Romeo	Quebec	Sierra	Lamda
Northwest	Bus 0701	138	Juliett 2	Juliett	Kilo	Tango	India
Northwest	Bus 0703	69	Juliett 2	Juliett	Kilo	Mike	India
Northwest	Bus 0704	138	Juliett 2	Juliett	Hotel	Kilo	India
Northwest	Bus 0708	345	Quebec	Sierra	Pi	Echo	India
Northwest	Bus 0709	345	India	Kilo	Mike	Juliett	Echo
Northwest	Bus 0713	138	Juliett 2	Juliett	Kilo	Tango	India
Northwest	Bus 0714	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0726	138	Romeo	Quebec	Sierra	Sierra	Lamda
Northwest	Bus 0727	138	Papa	Novembe	Mike	Juliett	Kilo

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
Northwest	Bus 0728	138	Papa	Novembe	Mike	Juliett	Kilo
Northwest	Bus 0741	138	Delta	Bravo	Charlie	Echo	Foxtrot
Northwest	Bus 0747	345	Sierra	Quebec	Pi	Echo	India
Northwest	Bus 0755	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0757	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0771	345	Mike	Novembe	India	Kilo	Juliett
Northwest	Bus 0772	345	Mike	Novembe	India	Kilo	Juliett
Northwest	Bus 0773	69	Oscar	Novembe	Mike	Juliett	Papa
Northwest	Bus 0784	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0788	345	Echo	India	Zulu	Charlie	Bravo
Northwest	Bus 0790	69	Hotel	Mike	India	Juliett	Kilo
Northwest	Bus 0797	69	Oscar	Novembe	Mike	Papa	Juliett
Northwest	Bus 0803	69	Echo	India	Charlie	Hotel	Juliett
Northwest	Bus 0808	69	Oscar	Novembe	Mike	Juliett	Papa
Northwest	Bus 0811	138	Quebec	Romeo	Sierra	Uniform	Echo
Northwest	Bus 0812	138	Juliett 2	Juliett	Kilo	Hotel	India
Northwest	Bus 0813	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0814	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0816	138	Hotel	India	Kilo	Juliett	Mike
Northwest	Bus 0817	138	Hotel	Golf	India	Juliett	Kilo
Northwest	Bus 0823	138	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0824	345	Victor	Theta	Chi	Romeo	Quebec
Northwest	Bus 0829	69	Hotel	India	Mike	Mike	Kilo
Northwest	Bus 0831	138	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 0838	138	Novembe	Mike	Papa	Kilo	India
Northwest	Bus 0845	345	Epsilon	Juliett	Kilo	Tango	Echo
Northwest	Bus 0850	138	Papa	Novembe	Mike	Juliett	Juliett 2
Northwest	Bus 0851	345	Pi	Quebec	Sierra	Echo	India
Northwest	Bus 0854	345	Quebec	Sierra	Pi	Echo	India
Northwest	Bus 0868	345	Omicron	Echo	Zulu	Charlie	India
Northwest	Bus 0880	345	Theta	Victor	Chi	Romeo	Quebec
Northwest	Bus 0883	345	Epsilon	Juliett	Kilo	Tango	Echo
Northwest	Bus 0887	69	Echo	Foxtrot	Charlie	India	Bravo
Northwest	Bus 0891	345	Chi	Victor	Theta	Romeo	Quebec
Northwest	Bus 0892	138	Hotel	Juliett	Juliett 2	Kilo	India
Northwest	Bus 0895	69	Hotel	Mike	Novembe	India	Juliett
Northwest	Bus 0896	69	Hotel	Mike	Novembe	India	Juliett
Northwest	Bus 0897	138	Hotel	Golf	India	Juliett	Kilo
Northwest	Bus 0898	69	Echo	India	Charlie	Hotel	Juliett
Northwest	Bus 0902	345	Novembe	Mike	India	Kilo	Juliett
Northwest	Bus 0933	69	Quebec	Romeo	Sierra	Uniform	Victor
Northwest	Bus 0942	345	Victor	Theta	Chi	Romeo	Quebec
Northwest	Bus 0944	345	Epsilon	Juliett	Kilo	Tango	Echo
Northwest	Bus 0950	138	Lima	Juliett	Hotel	Kilo	Juliett 2
Northwest	Bus 0961	138	Romeo	Quebec	Sierra	Uniform	Lamda
Northwest	Bus 0993	138	Hotel	Golf	India	Juliett	Kilo
Northwest	Bus 1030	138	Phi	Quebec	Romeo	Sierra	Echo
Northwest	Bus 1031	138	Phi	Quebec	Romeo	Sierra	Echo
Northwest	Bus 1041	69	Hotel	India	Quebec	Mike	Echo
Northwest	Bus 1043	345	Romeo	Quebec	Sierra	Victor	Theta
Northwest	Bus 1044	69	Hotel	India	Mike	Juliett	Kilo
Northwest	Bus 1045	69	Hotel	India	Juliett	Mike	Kilo

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
Northwest	Bus 1056	345	Romeo	Quebec	Sierra	Victor	Theta
Northwest	Bus 1060	138	Romeo	Quebec	Uniform	Sierra	Lamda
Northwest	Bus 1061	345	Zulu	Quebec	Romeo	Sierra	Echo
Northwest	Bus 1070	138	Quebec	Romeo	Sierra	Uniform	Echo
Northwest	Bus 1074	345	India	Echo	Kilo	Juliett	Mike
Northwest	Bus 1076	345	India	Echo	Kilo	Juliett	Mike
Northwest	Bus 1093	345	Juliett	Tango	Kilo	Echo	Epsilon
Northwest	Bus 1129	138	Echo	Charlie	India	Juliett	Hotel
Northwest	Bus 1146	69	Juliett 2	Juliett	Kilo	Mike	India
Northwest	Bus 1150	345	Romeo	Quebec	Sierra	Victor	Theta
Northwest	Bus 1156	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 1157	69	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 1159	138	Hotel	India	Echo	Juliett	Charlie
Northwest	Bus 1160	345	Romeo	Quebec	Sierra	Victor	Theta
Northwest	Bus 1172	345	Victor	Theta	Chi	Romeo	Quebec
Northwest	Bus 1174	138	Juliett 2	Juliett	Kilo	Tango	Echo
Northwest	Bus 1182	345	India	Kilo	Mike	Juliett	Echo
Northwest	Bus 1199	345	Kilo	Juliett	India	Mike	Tango
Northwest	Bus 1208	345	Kilo	Juliett	India	Mike	Tango
Northwest	Bus 1214	138	Hotel	India	Juliett	Kilo	Mike
Northwest	Bus 1225	345	Mu	Echo	India	Zulu	Charlie
Northwest	Bus 1234	345	Mu	Echo	India	Zulu	Charlie
Northwest	Bus 1243	345	Mu	Echo	India	Zulu	Charlie
Northwest	Bus 1248	345	Zulu	Quebec	Romeo	Sierra	Echo
Northwest	Bus 1255	345	Epsilon	Juliett	Kilo	Tango	Echo
Northwest	Bus 1263	345	Victor	Theta	Chi	Romeo	Quebec
Northwest	Bus 1276	345	Romeo	Quebec	Sierra	Victor	Theta
Northwest	Bus 1277	138	Quebec	Romeo	Sierra	Victor	Echo
Northwest	Bus 1283	345	Victor	Theta	Chi	Romeo	Quebec
Northwest	Bus 1300	345	Victor	Theta	Chi	Romeo	Quebec

Eastern Region

The Eastern Region data is seen in Tables A.8-9 with the selected buses used in Table 6 highlighted in yellow.

TABLES A.8-9

Ranked Generators Based on Their Voltage Sensitivity in Eastern Region

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
Eastern	Bus 0193	69	Iota	Alpha	Bravo		
Eastern	Bus 0199	69	Iota	Alpha	Bravo		
Eastern	Bus 0202	345	Alpha	Iota	Bravo		
Eastern	Bus 0208	500	Alpha	Iota			
Eastern	Bus 0209	69	Iota	Alpha	Bravo		
Eastern	Bus 0220	69	Iota	Alpha			
Eastern	Bus 0221	161	Iota	Alpha			
Eastern	Bus 0223	161					
Eastern	Bus 0225	69					
Eastern	Bus 0226	69	Iota				
Eastern	Bus 0228	161					
Eastern	Bus 0234	69	Iota	Alpha			
Eastern	Bus 0235	161	Iota	Alpha			
Eastern	Bus 0242	69	Iota	Alpha	Bravo		
Eastern	Bus 0249	161	Iota	Alpha			
Eastern	Bus 0569	69	Iota	Alpha	Bravo		
Eastern	Bus 0582	69	Iota	Alpha	Bravo		
Eastern	Bus 0585	69	Iota	Alpha	Bravo		
Eastern	Bus 0586	69	Iota	Alpha	Bravo		
Eastern	Bus 0588	69	Iota	Alpha	Bravo		
Eastern	Bus 0589	69	Iota	Alpha	Bravo		
Eastern	Bus 0591	69	Iota	Alpha	Bravo		
Eastern	Bus 0594	161	Iota	Alpha			
Eastern	Bus 0599	69	Iota	Alpha			
Eastern	Bus 0600	161	Iota	Alpha	Bravo		
Eastern	Bus 0601	161	Iota	Alpha	Bravo		
Eastern	Bus 0602	161	Iota	Alpha	Bravo		
Eastern	Bus 0607	161	Iota	Alpha			
Eastern	Bus 0609	161	Iota	Alpha	Bravo		
Eastern	Bus 0610	161					
Eastern	Bus 0611	161	Iota	Alpha	Bravo		
Eastern	Bus 0612	161	Iota	Alpha	Bravo		
Eastern	Bus 0616	161	Iota	Alpha			
Eastern	Bus 0618	69	Iota	Alpha			
Eastern	Bus 0623	69	Iota				
Eastern	Bus 0625	69	Iota				
Eastern	Bus 0627	161	Iota	Alpha			
Eastern	Bus 0630	161	Iota	Alpha			
Eastern	Bus 0633	161	Iota	Alpha			
Eastern	Bus 0634	161	Iota	Alpha			
Eastern	Bus 0635	161	Iota	Alpha			
Eastern	Bus 0636	69	Iota	Alpha			
Eastern	Bus 0638	161	Iota	Alpha			
Eastern	Bus 0641	161	Iota	Alpha			
Eastern	Bus 0642	161	Iota	Alpha			
Eastern	Bus 0646	161	Iota	Alpha	Bravo		
Eastern	Bus 0647	161					
Eastern	Bus 0649	161	Iota	Alpha			
Eastern	Bus 0650	161	Iota	Alpha	Bravo		
Eastern	Bus 0651	161	Iota	Alpha			
Eastern	Bus 0652	161	Iota	Alpha			
Eastern	Bus 0653	161					

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
Eastern	Bus 0654	161					
Eastern	Bus 0655	161					
Eastern	Bus 0656	161					
Eastern	Bus 0657	161	Iota	Alpha			
Eastern	Bus 0658	161	Iota	Alpha			
Eastern	Bus 0659	161	Iota	Alpha			
Eastern	Bus 0661	161	Iota	Alpha			
Eastern	Bus 0707	161	Iota	Alpha			
Eastern	Bus 0739	161	Iota	Alpha			
Eastern	Bus 0740	161	Iota	Alpha			
Eastern	Bus 0769	161	Iota	Alpha	Bravo		
Eastern	Bus 0805	161	Iota	Alpha			
Eastern	Bus 0806	161	Iota	Alpha			
Eastern	Bus 0807	161	Iota	Alpha			
Eastern	Bus 1073	161	Iota	Alpha	Bravo		
Eastern	Bus 1075	161	Iota	Alpha	Bravo		

Central Region

The Central Region data is seen in Tables A.10-13 with the selected buses used in Table 8 highlighted in yellow.

TABLES A.10-13

Ranked Generators Based on Their Voltage Sensitivity in Central Region

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
Central	Bus 0002	138	Echo	Charlie	Foxtrot	Delta	Bravo
Central	Bus 0003	138	Charlie	Echo	Bravo	Delta	Foxtrot
Central	Bus 0012	69	Delta	Bravo	Charlie	Echo	Foxtrot
Central	Bus 0013	138	Delta	Charlie	Bravo	Echo	Foxtrot
Central	Bus 0073	69	Juliett 2	Juliett	Kilo	Lima	India
Central	Bus 0117	69	Echo	Foxtrot	Charlie	Bravo	India
Central	Bus 0123	69	Foxtrot	Echo	Foxtrot 2	Charlie	Bravo
Central	Bus 0126	138	Echo	Foxtrot	Bravo	Charlie	Zulu
Central	Bus 0127	138	Echo	Foxtrot	Bravo	Charlie	Zulu
Central	Bus 0128	138	Echo	Charlie	Foxtrot	Bravo	Zulu
Central	Bus 0129	138	Echo	Foxtrot	Charlie	Bravo	Zulu
Central	Bus 0133	138	Charlie	Echo	Bravo	India	Delta
Central	Bus 0134	138	Echo	Charlie	Bravo	Foxtrot	Delta
Central	Bus 0135	138	Charlie	Echo	Bravo	India	Juliett
Central	Bus 0136	138	Charlie	Echo	Juliett	India	Bravo
Central	Bus 0137	138	Charlie	Echo	Bravo	Delta	Foxtrot
Central	Bus 0138	138	Charlie	Echo	Delta	Foxtrot	Bravo
Central	Bus 0140	138	Echo	Charlie	Bravo	Foxtrot	Delta
Central	Bus 0142	138	Echo	Foxtrot	Charlie	Bravo	Delta
Central	Bus 0143	138	Echo	Charlie	Foxtrot	Delta	Bravo
Central	Bus 0144	138	Echo	Foxtrot	Charlie	Delta	Bravo
Central	Bus 0145	138	Echo	Charlie	Delta	Foxtrot	Bravo
Central	Bus 0146	138	Delta	Charlie	Echo	Bravo	Foxtrot
Central	Bus 0148	138	Delta	Charlie	Echo	Bravo	Foxtrot
Central	Bus 0149	138	Echo	Foxtrot	Charlie	Delta	Bravo
Central	Bus 0151	69	Foxtrot	Echo	Charlie	Bravo	Zeta
Central	Bus 0152	138	Foxtrot	Echo	Charlie	Delta	Bravo
Central	Bus 0153	138	Foxtrot	Echo	Charlie	Bravo	Delta
Central	Bus 0154	138	Foxtrot	Echo	Charlie	Bravo	Delta
Central	Bus 0155	138	Echo	Foxtrot	Charlie	Bravo	Delta
Central	Bus 0156	138	Echo	Charlie	Foxtrot	Delta	Bravo
Central	Bus 0157	138	Echo	Charlie	Foxtrot	Bravo	Delta
Central	Bus 0158	138	Echo	Foxtrot	Charlie	Bravo	Delta
Central	Bus 0160	138	Echo	Charlie	Foxtrot	Bravo	Zulu
Central	Bus 0165	138	Echo	Foxtrot	Charlie	Bravo	Delta
Central	Bus 0166	138	Echo	Foxtrot	Charlie	Bravo	Zulu
Central	Bus 0167	138	Echo	Charlie	Foxtrot	Bravo	Zulu
Central	Bus 0168	138	Foxtrot	Zeta	Echo	Charlie	Bravo
Central	Bus 0170	138	Foxtrot	Echo	Zeta	Charlie	Bravo
Central	Bus 0171	138	Foxtrot	Echo	Charlie	Bravo	Zeta
Central	Bus 0173	138	Foxtrot	Echo	Delta	Charlie	Bravo
Central	Bus 0175	138	Foxtrot	Echo	Charlie	Delta	Bravo
Central	Bus 0176	138	Echo	Charlie	Foxtrot	Bravo	Delta
Central	Bus 0177	138	Foxtrot	Echo	Charlie	Delta	Bravo
Central	Bus 0179	138	Eta	Foxtrot	Bravo	Echo	Charlie
Central	Bus 0182	345	Echo	Charlie	Juliett	India	Zulu
Central	Bus 0185	138	Delta	Bravo	Charlie	Echo	Foxtrot
Central	Bus 0188	138	Eta	Foxtrot	Bravo	Echo	Zeta
Central	Bus 0189	138	Foxtrot	Zeta	Echo	Bravo	Charlie
Central	Bus 0190	138	Foxtrot	Zeta	Echo	Bravo	Charlie
Central	Bus 0192	138	Zeta	Foxtrot	Echo	Bravo	Charlie
Central	Bus 0194	138	Foxtrot	Echo	Zeta	Charlie	Bravo

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
Central	Bus 0195	138	Foxtrot	Echo	Zeta	Bravo	Bravo
Central	Bus 0196	138	Eta	Echo	Foxtrot	Bravo	Charlie
Central	Bus 0197	138	Foxtrot	Zeta	Echo	Charlie	Bravo
Central	Bus 0203	138	Eta	Bravo	Foxtrot	Echo	Charlie
Central	Bus 0204	138	Bravo	Eta	Echo	Foxtrot	Charlie
Central	Bus 0205	138	Bravo	Eta	Foxtrot	Echo	Charlie
Central	Bus 0207	138	Charlie	Delta	Echo	Bravo	Foxtrot
Central	Bus 0210	345	Charlie	Echo	Bravo	Delta	India
Central	Bus 0214	69	Foxtrot	Echo	Zeta	Charlie	Bravo
Central	Bus 0215	69	Foxtrot	Echo	Foxtrot 2	Zeta	Charlie
Central	Bus 0216	69	Foxtrot	Foxtrot 2	Echo	Zeta	Charlie
Central	Bus 0217	69	Foxtrot 2	Foxtrot	Echo	Zeta	Bravo
Central	Bus 0218	69	Foxtrot	Foxtrot 2	Echo	Zeta	Bravo
Central	Bus 0219	69	Foxtrot	Echo	Zeta	Bravo	Charlie
Central	Bus 0224	138	Foxtrot	Delta	Delta	Bravo	Charlie
Central	Bus 0227	138	Foxtrot	Bravo	Echo	Eta	Zeta
Central	Bus 0229	138	Eta	Bravo	Foxtrot	Echo	Charlie
Central	Bus 0230	138	Eta	Bravo	Foxtrot	Echo	Charlie
Central	Bus 0231	138	Bravo	Eta	Echo	Foxtrot	Charlie
Central	Bus 0232	138	Bravo	Eta	Echo	Foxtrot	Charlie
Central	Bus 0233	138	Bravo	Eta	Echo	Foxtrot	Charlie
Central	Bus 0238	69	Delta	Bravo	Charlie	Echo	Foxtrot
Central	Bus 0247	138	Bravo	Echo	Charlie	Foxtrot	Eta
Central	Bus 0248	138	Bravo	Echo	Eta	Charlie	Foxtrot
Central	Bus 0250	138	Bravo	Eta	Echo	Foxtrot	Charlie
Central	Bus 0251	69	Foxtrot	Echo	Charlie	Bravo	Zeta
Central	Bus 0252	69	Delta	Bravo	Charlie	Echo	Bravo 2
Central	Bus 0253	138	Bravo	Eta	Echo	Foxtrot	Charlie
Central	Bus 0254	138	Bravo	Eta	Foxtrot	Echo	Charlie
Central	Bus 0255	138	Bravo	Eta	Foxtrot	Echo	Charlie
Central	Bus 0256	138	Bravo	Foxtrot	Echo	Eta	Delta
Central	Bus 0258	138	Bravo	Eta	Foxtrot	Echo	Charlie
Central	Bus 0259	138	Echo	Foxtrot	Bravo	Charlie	Zulu
Central	Bus 0260	138	Foxtrot	Bravo	Delta	Echo	Charlie
Central	Bus 0261	138	Bravo	Foxtrot	Echo	Delta	Charlie
Central	Bus 0262	138	Bravo	Foxtrot	Echo	Charlie	Delta
Central	Bus 0263	138	Echo	Foxtrot	Charlie	Bravo	Zulu
Central	Bus 0264	345	Echo	Zulu	Charlie	India	Bravo
Central	Bus 0265	138	Delta	Xi	Bravo	Charlie	Echo
Central	Bus 0267	138	Delta	Bravo	Charlie	Echo	Xi
Central	Bus 0270	69	Delta	Foxtrot	Bravo	Echo	Charlie
Central	Bus 0271	69	Delta	Foxtrot	Bravo	Echo	Charlie
Central	Bus 0272	69	Delta	Bravo	Charlie	Echo	Foxtrot
Central	Bus 0275	69	Delta	Foxtrot	Bravo	Echo	Charlie
Central	Bus 0276	69	Foxtrot	Echo	Zeta	Bravo	Charlie
Central	Bus 0277	69	Foxtrot	Echo	Bravo	Zeta	Delta
Central	Bus 0278	69	Foxtrot	Echo	Bravo	Delta	Zeta
Central	Bus 0279	69	Foxtrot	Echo	Delta	Bravo	Charlie
Central	Bus 0280	69	Foxtrot	Delta	Bravo	Echo	Charlie
Central	Bus 0281	69	Foxtrot	Delta	Bravo	Echo	Charlie
Central	Bus 0282	69	Foxtrot	Delta	Bravo	Echo	Charlie
Central	Bus 0283	69	Foxtrot	Delta	Bravo	Echo	Charlie

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
Central	Bus 0284	69	Delta	Bravo	Charlie	Echo	Bravo 2
Central	Bus 0285	138	Bravo	Foxtrot	Echo	Delta	Charlie
Central	Bus 0286	69	Delta	Bravo	Charlie	Echo	Bravo 2
Central	Bus 0287	138	Xi	Delta	Bravo	Charlie	Echo
Central	Bus 0290	69	Delta	Bravo	Charlie	Echo	Bravo 2
Central	Bus 0293	138	Eta	Bravo	Foxtrot	Echo	Charlie
Central	Bus 0294	69	Foxtrot 2	Foxtrot	Echo	Zeta	Charlie
Central	Bus 0295	138	Charlie	Echo	Bravo	Delta	Foxtrot
Central	Bus 0296	69	Bravo	Delta	Bravo 2	Charlie	Echo
Central	Bus 0297	69	Bravo	Delta	Bravo 2	Charlie	Echo
Central	Bus 0304	138	Xi	Delta	Bravo	Charlie	Charlie
Central	Bus 0306	69	Bravo	Delta	Bravo 2	Charlie	Echo
Central	Bus 0308	138	Bravo	Echo	Eta	Charlie	Foxtrot
Central	Bus 0310	138	Echo	Charlie	Foxtrot	Delta	Bravo
Central	Bus 0322	138	Foxtrot	Echo	Charlie	Delta	Bravo
Central	Bus 0328	138	Echo	Foxtrot	Charlie	Bravo	Delta
Central	Bus 0333	69	Foxtrot 2	Foxtrot	Echo	Zeta	Bravo
Central	Bus 0335	138	Foxtrot	Zeta	Echo	Charlie	Bravo
Central	Bus 0336	138	Foxtrot	Zeta	Echo	Charlie	Bravo
Central	Bus 0345	138	Foxtrot	Echo	Charlie	Delta	Bravo
Central	Bus 0346	138	Foxtrot	Delta	Echo	Charlie	Bravo
Central	Bus 0347	138	Delta	Bravo	Charlie	Echo	Foxtrot
Central	Bus 0355	138	Echo	Charlie	Bravo	Foxtrot	India
Central	Bus 0356	345	Echo	Charlie	India	Zulu	Bravo
Central	Bus 0359	138	Zeta	Foxtrot	Echo	Bravo	Charlie
Central	Bus 0369	138	Charlie	Echo	Bravo	Delta	Foxtrot
Central	Bus 0378	345	Charlie	Echo	Bravo	Delta	India
Central	Bus 0379	69	Foxtrot	Echo	Zeta	Bravo	Charlie
Central	Bus 0380	138	Foxtrot	Zeta	Echo	Bravo	Charlie
Central	Bus 0382	138	Foxtrot	Echo	Zeta	Bravo	Charlie
Central	Bus 0394	69	Foxtrot	Echo	Bravo	Zeta	Delta
Central	Bus 0400	138	Foxtrot	Bravo	Eta	Zeta	Zeta
Central	Bus 0401	138	Bravo	Echo	Charlie	Delta	Foxtrot
Central	Bus 0402	345	Bravo	Echo	Charlie	Bravo 2	Zulu
Central	Bus 0414	138	Bravo	Eta	Echo	Foxtrot	Charlie
Central	Bus 0415	138	Bravo	Eta	Echo	Foxtrot	Charlie
Central	Bus 0417	138	Bravo	Eta	Echo	Foxtrot	Charlie
Central	Bus 0418	138	Foxtrot	Bravo	Delta	Echo	Charlie
Central	Bus 0420	138	Foxtrot	Delta	Bravo	Echo	Charlie
Central	Bus 0421	69	Delta	Foxtrot	Bravo	Echo	Charlie
Central	Bus 0426	138	Delta	Foxtrot	Bravo	Echo	Charlie
Central	Bus 0429	69	Delta	Bravo	Charlie	Echo	Bravo 2
Central	Bus 0430	138	Xi	Delta	Bravo	Charlie	Echo
Central	Bus 0431	138	Xi	Delta	Bravo	Charlie	Charlie
Central	Bus 0436	138	Bravo	Eta	Foxtrot	Echo	Charlie
Central	Bus 0457	138	Delta	Foxtrot	Echo	Bravo	Charlie
Central	Bus 0615	69	Echo	Foxtrot	Bravo	Charlie	Zulu
Central	Bus 0639	138	Zeta	Foxtrot	Echo	Bravo	Charlie
Central	Bus 0648	138	Echo	Foxtrot	Bravo	Charlie	Zulu
Central	Bus 0668	138	Zeta	Foxtrot	Echo	Bravo	Charlie
Central	Bus 0674	138	Charlie	Echo	Bravo	Delta	Foxtrot
Central	Bus 0675	138	Echo	Charlie	Foxtrot	Bravo	Delta

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
Central	Bus 0678	138	Charlie	Echo	India	Juliett	Bravo
Central	Bus 0688	138	Foxtrot	Delta	Bravo	Echo	Charlie
Central	Bus 0756	138	Bravo	Foxtrot	Echo	Charlie	Delta
Central	Bus 0758	138	Delta	Charlie	Echo	Bravo	Foxtrot
Central	Bus 0759	138	Echo	Foxtrot	Bravo	Charlie	Zulu
Central	Bus 0760	138	Charlie	Echo	Bravo	Delta	Foxtrot
Central	Bus 0761	138	Charlie	Echo	Delta	Bravo	Foxtrot
Central	Bus 0762	138	Echo	Charlie	Bravo	Foxtrot	Delta
Central	Bus 0763	138	Charlie	Echo	Bravo	Delta	Foxtrot
Central	Bus 0764	138	Echo	Charlie	Bravo	Foxtrot	Delta
Central	Bus 0765	138	Charlie	Echo	Delta	Bravo	Foxtrot
Central	Bus 0767	138	Echo	Foxtrot	Bravo	Charlie	Zulu
Central	Bus 0770	138	Bravo	Bravo 2	Echo	Charlie	Eta
Central	Bus 0776	138	Eta	Foxtrot	Bravo	Echo	Charlie
Central	Bus 0791	69	Delta	Bravo	Charlie	Echo	Bravo 2
Central	Bus 0794	69	Echo	Foxtrot	Charlie	Bravo	India
Central	Bus 0802	69	Delta	Bravo	Charlie	Echo	Bravo 2
Central	Bus 0865	345	Omicron	Echo	Zulu	Charlie	India
Central	Bus 0873	345	Omicron	Echo	Zulu	Charlie	India
Central	Bus 1047	138	Xi	Delta	Bravo	Charlie	Echo
Central	Bus 1059	138	Foxtrot	Echo	Delta	Bravo	Charlie
Central	Bus 1071	138	Echo	Foxtrot	Bravo	Charlie	Zulu
Central	Bus 1130	138	Echo	Foxtrot	Bravo	Charlie	Zulu
Central	Bus 1132	138	Echo	Foxtrot	Bravo	Charlie	Zulu
Central	Bus 1158	138	Xi	Delta	Bravo	Charlie	Echo
Central	Bus 1161	138	Echo	Foxtrot	Bravo	Bravo	Zulu
Central	Bus 1162	138	Delta	Foxtrot	Echo	Charlie	Bravo
Central	Bus 1163	138	Echo	Quebec	Gamma	Charlie	India
Central	Bus 1164	138	Foxtrot	Bravo	Echo	Delta	Charlie
Central	Bus 1165	138	Foxtrot	Bravo	Echo	Delta	Charlie
Central	Bus 1220	138	Foxtrot	Zeta	Echo	Bravo	Bravo

East-Central Region

The East-Central Region data is seen in Tables A.14-15 with the selected buses used in Table 10 highlighted in yellow.

TABLES A.14-15

Ranked Generators Based on Their Voltage Sensitivity in East-Central Region

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
East-Central	Bus 0001	69	Alpha	Bravo	Charlie	Delta	Delta
East-Central	Bus 0108	69	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0109	161	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0114	345	Alpha	Bravo	Bravo 2	Bravo 2	Echo
East-Central	Bus 0115	69	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0122	161	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0124	69	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0125	161	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0139	161	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0141	345	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0150	69	Alpha	Bravo	Juliett	Delta	Echo
East-Central	Bus 0159	69	Alpha	Bravo	Juliett		
East-Central	Bus 0163	138					
East-Central	Bus 0169	161	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0172	345	Alpha	Bravo	Bravo 2	Charlie	Echo
East-Central	Bus 0178	161	Alpha	Bravo	Bravo 2	Charlie	Echo
East-Central	Bus 0180	69	Iota	Alpha	Bravo		
East-Central	Bus 0181	161	Iota	Alpha	Bravo		
East-Central	Bus 0315	69	Alpha	Bravo			
East-Central	Bus 0338	69	Delta	Juliett	Echo	Bravo	Charlie
East-Central	Bus 0485	161	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0499	69	Alpha	Bravo	Bravo 2	Bravo 2	Echo
East-Central	Bus 0500	69	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0501	138	Alpha	Juliett	Delta	Bravo	Echo
East-Central	Bus 0502	69	Alpha	Bravo	Bravo 2	Charlie	Echo
East-Central	Bus 0503	69	Alpha	Bravo	Bravo 2	Charlie	Echo
East-Central	Bus 0504	69	Alpha	Bravo	Bravo 2	Charlie	Hotel 2
East-Central	Bus 0506	69	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0507	69	Alpha	Bravo	Bravo 2	Charlie	Hotel 2
East-Central	Bus 0508	69	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0509	69	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0511	69	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0512	69	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0513	69	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0514	69	Alpha	Bravo	Bravo 2	Charlie	Echo
East-Central	Bus 0515	69	Alpha	Bravo	Bravo 2	Charlie	Echo
East-Central	Bus 100516	69	Alpha	Bravo	Bravo 2	Charlie	Echo
East-Central	Bus 0517	69	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0518	69	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0519	138	Alpha				
East-Central	Bus 0520	138	Alpha				
East-Central	Bus 0533	161	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0534	138	Alpha	Bravo	Charlie	Bravo 2	Bravo 2
East-Central	Bus 0538	138					
East-Central	Bus 0539	69	Alpha	Bravo	Iota		
East-Central	Bus 0541	69	Alpha	Bravo	Charlie	Echo	Bravo 2
East-Central	Bus 0542	69	Alpha	Juliett	Delta	Bravo	Echo
East-Central	Bus 0543	138	Alpha	Juliett	Delta	Bravo	Echo
East-Central	Bus 0544	138	Alpha	Juliett	Bravo	Bravo	Echo
East-Central	Bus 0545	138	Alpha	Juliett			
East-Central	Bus 0546	138	Alpha	Juliett	Bravo	Bravo	Echo
East-Central	Bus 0549	138					

Region	Bus #	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
East-Central	Bus 0550	138	Alpha	Bravo	Delta	Charlie	Echo
East-Central	Bus 0551	161	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0552	161	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 0554	69	Alpha	Iota	Bravo		
East-Central	Bus 0555	161	Iota	Alpha	Bravo		
East-Central	Bus 0557	69	Iota	Alpha	Bravo		
East-Central	Bus 0558	69	Iota	Alpha	Bravo		
East-Central	Bus 0560	69	Iota	Alpha	Bravo	Bravo 2	Charlie
East-Central	Bus 0561	69	Iota	Alpha	Bravo	Bravo 2	Charlie
East-Central	Bus 0562	161	Iota	Alpha	Bravo		
East-Central	Bus 0563	161	Iota	Alpha	Bravo		
East-Central	Bus 0566	161	Iota	Alpha	Bravo		
East-Central	Bus 0570	69	Iota	Alpha	Bravo		
East-Central	Bus 0571	69	Iota	Alpha	Bravo		
East-Central	Bus 0573	69	Iota	Alpha	Bravo		
East-Central	Bus 0574	69	Iota	Alpha	Bravo		
East-Central	Bus 0575	69	Iota	Alpha	Bravo		
East-Central	Bus 0576	69	Iota	Alpha	Bravo	Bravo 2	Hotel 2
East-Central	Bus 0577	69	Iota	Alpha	Bravo		
East-Central	Bus 0578	69	Iota	Alpha	Bravo		
East-Central	Bus 0579	69	Iota	Alpha	Bravo	Bravo 2	Hotel 2
East-Central	Bus 0580	69	Iota	Alpha	Bravo	Bravo 2	Charlie
East-Central	Bus 0581	69	Iota	Alpha	Bravo		
East-Central	Bus 0722	69	Iota	Alpha	Bravo		
East-Central	Bus 0723	345	Alpha	Bravo	Bravo 2	Charlie	Yankee
East-Central	Bus 0768	138					
East-Central	Bus 0786	69	Alpha	Bravo	Bravo 2	Charlie	Hotel 2
East-Central	Bus 0798	69	Iota	Alpha	Bravo		
East-Central	Bus 0804	69	Alpha	Bravo	Iota		
East-Central	Bus 1029	69	Alpha	Bravo			
East-Central	Bus 1155	161	Alpha	Bravo			
East-Central	Bus 1216	161	Alpha	Bravo	Charlie	Bravo 2	Echo
East-Central	Bus 1278	69	Alpha	Bravo	Bravo 2	Charlie	Echo

North-Eastern Region

The North-Eastern Region data is seen in Tables A.16-17 with the selected buses used in Table 12 highlighted in yellow.

TABLES A.16-17

Ranked Generators Based on Their Voltage Sensitivity in North-Eastern Region

Region	Bus	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
North-Eastern	Bus 0019	138	Bravo 2	Bravo	Charlie	Echo	Delta
North-Eastern	Bus 0021	345	Bravo	Bravo 2	Charlie	Echo	Delta
North-Eastern	Bus 0022	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0030	138	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0031	138	Delta	Bravo	Bravo 2	Bravo 2	Echo
North-Eastern	Bus 0033	69	Delta	Bravo	Bravo 2	Charlie	Echo
North-Eastern	Bus 0037	69	Bravo	Bravo 2	Delta	Charlie	Echo
North-Eastern	Bus 0038	138	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0049	69	Bravo	Bravo 2	Delta	Charlie	Echo
North-Eastern	Bus 0050	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0055	69	Bravo 2	Bravo	Charlie	Delta	Echo
North-Eastern	Bus 0060	138	Juliett	Juliett 2	Kilo	Echo	India
North-Eastern	Bus 0063	69	Juliett	Delta	Echo	Charlie	Juliett 2
North-Eastern	Bus 0064	69	Juliett	Delta	Echo	Charlie	Juliett 2
North-Eastern	Bus 0065	69	Juliett	Delta	Juliett 2	Echo	Charlie
North-Eastern	Bus 0068	69	Delta	Alpha	Bravo	Juliett	Echo
North-Eastern	Bus 0089	138	Alpha	Delta	Bravo	Charlie	Echo
North-Eastern	Bus 0091	69	Juliett	Delta	Echo	Juliett 2	Charlie
North-Eastern	Bus 0098	69	Juliett	Delta	Echo	Juliett 2	Charlie
North-Eastern	Bus 0257	69	Delta	Bravo	Charlie	Bravo 2	Echo
North-Eastern	Bus 0288	138	Delta	Bravo	Charlie	Echo	Bravo 2
North-Eastern	Bus 0302	69	Delta	Bravo	Charlie	Bravo 2	Echo
North-Eastern	Bus 0307	138	Juliett 2	Juliett	Kilo	India	Echo
North-Eastern	Bus 0309	138	Juliett	Juliett 2	Kilo	Kilo	Echo
North-Eastern	Bus 0312	138	Juliett 2	Juliett	Kilo	Echo	India
North-Eastern	Bus 0316	69	Juliett	Delta	Echo	Charlie	Charlie
North-Eastern	Bus 0317	69	Juliett	Delta	Echo	Charlie	Charlie
North-Eastern	Bus 0320	69	Juliett	Delta	Echo	Charlie	Charlie
North-Eastern	Bus 0321	69	Juliett	Delta	Echo	Juliett 2	Charlie
North-Eastern	Bus 0323	69	Juliett	Delta	Echo	Juliett 2	Charlie
North-Eastern	Bus 0324	69	Juliett	Delta	Echo	Echo	Charlie
North-Eastern	Bus 0326	69	Juliett	Delta	Echo	Juliett 2	Charlie
North-Eastern	Bus 0327	69	Juliett	Delta	Echo	Charlie	Juliett 2
North-Eastern	Bus 0329	69	Juliett	Delta	Echo	Charlie	Juliett 2
North-Eastern	Bus 0330	69	Bravo	Bravo 2	Delta	Charlie	Echo
North-Eastern	Bus 0331	69	Delta	Juliett	Echo	Bravo	Charlie
North-Eastern	Bus 0332	69	Juliett	Delta	Echo	Charlie	Juliett 2
North-Eastern	Bus 0334	138	Juliett	Juliett 2	Delta	Echo	Charlie
North-Eastern	Bus 0340	138	Juliett	Juliett 2	Echo	Charlie	Delta
North-Eastern	Bus 0344	138	Delta	Juliett	Echo	Charlie	Bravo
North-Eastern	Bus 0348	138	Delta	Bravo	Charlie	Echo	Foxtrot
North-Eastern	Bus 0349	138	Delta	Bravo	Charlie	Echo	Juliett
North-Eastern	Bus 0352	138	Delta	Bravo	Charlie	Echo	Bravo 2
North-Eastern	Bus 0353	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0354	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0357	138	Delta	Bravo	Charlie	Bravo 2	Echo
North-Eastern	Bus 0358	138	Delta	Bravo	Charlie	Bravo 2	Echo
North-Eastern	Bus 0360	138	Delta	Bravo	Bravo 2	Charlie	Echo
North-Eastern	Bus 0361	138	Delta	Bravo	Bravo 2	Charlie	Echo
North-Eastern	Bus 0362	138	Delta	Bravo	Bravo 2	Charlie	Echo
North-Eastern	Bus 0363	138	Delta	Bravo	Bravo 2	Charlie	Echo
North-Eastern	Bus 0364	69	Delta	Bravo	Bravo 2	Charlie	Echo

Region	Bus	Nom. kV	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
North-Eastern	Bus 0365	138	Delta	Bravo	Bravo 2	Charlie	Echo
North-Eastern	Bus 0366	69	Delta	Bravo	Charlie	Echo	Bravo 2
North-Eastern	Bus 0368	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0370	69	Delta	Bravo	Bravo 2	Charlie	Echo
North-Eastern	Bus 0371	69	Bravo	Delta	Bravo 2	Charlie	Echo
North-Eastern	Bus 0372	69	Bravo	Delta	Bravo 2	Charlie	Echo
North-Eastern	Bus 0373	69	Delta	Bravo	Bravo 2	Charlie	Echo
North-Eastern	Bus 0374	69	Bravo	Bravo 2	Delta	Charlie	Echo
North-Eastern	Bus 0375	69	Bravo	Bravo 2	Delta	Charlie	Echo
North-Eastern	Bus 0376	138	Bravo	Bravo 2	Delta	Charlie	Echo
North-Eastern	Bus 0377	69	Bravo	Bravo 2	Delta	Charlie	Echo
North-Eastern	Bus 0381	69	Bravo	Bravo 2	Delta	Charlie	Echo
North-Eastern	Bus 0386	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0387	69	Bravo	Bravo 2	Delta	Charlie	Echo
North-Eastern	Bus 0388	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0389	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0390	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0392	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0393	69	Bravo 2	Bravo	Charlie	Delta	Echo
North-Eastern	Bus 0395	69	Bravo 2	Bravo	Charlie	Delta	Echo
North-Eastern	Bus 0396	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0397	69	Bravo 2	Bravo	Charlie	Delta	Echo
North-Eastern	Bus 0482	138	Juliett	Juliett 2	Kilo	India	India
North-Eastern	Bus 0587	138	Bravo	Delta	Bravo 2	Charlie	Echo
North-Eastern	Bus 0667	138	Delta	Bravo	Charlie	Echo	Foxtrot
North-Eastern	Bus 0686	69	Bravo 2	Bravo	Charlie	Delta	Echo
North-Eastern	Bus 0687	69	Bravo 2	Bravo	Charlie	Delta	Echo
North-Eastern	Bus 0702	138	Delta	Juliett	Echo	Charlie	Bravo
North-Eastern	Bus 0715	69	Juliett	Delta	Echo	Juliett 2	Charlie
North-Eastern	Bus 0717	69	Juliett	Delta	Echo	Charlie	Juliett 2
North-Eastern	Bus 0718	138	Delta	Juliett	Echo	Charlie	Bravo
North-Eastern	Bus 0746	138	Juliett 2	Juliett	Kilo	India	Echo
North-Eastern	Bus 0752	138	Delta	Juliett	Echo	Charlie	Bravo
North-Eastern	Bus 0766	69	Juliett	Delta	Echo	Juliett 2	Charlie
North-Eastern	Bus 0783	69	Bravo	Bravo 2	Delta	Charlie	Echo
North-Eastern	Bus 0785	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0787	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0792	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0793	69	Delta	Bravo	Charlie	Echo	Bravo 2
North-Eastern	Bus 0796	69	Juliett	Delta	Echo	Juliett 2	Charlie
North-Eastern	Bus 0799	69	Bravo 2	Bravo	Charlie	Delta	Echo
North-Eastern	Bus 0800	138	Juliett	Delta	Juliett 2	Echo	Charlie
North-Eastern	Bus 0810	138	Delta	Bravo	Charlie	Bravo 2	Echo
North-Eastern	Bus 0843	138	Juliett	Juliett 2	Echo	Charlie	Delta
North-Eastern	Bus 0893	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0894	69	Bravo 2	Bravo	Delta	Charlie	Echo
North-Eastern	Bus 0899	69	Delta	Bravo	Bravo 2	Charlie	Echo
North-Eastern	Bus 0931	138	Delta	Echo	Juliett	Charlie	Bravo
North-Eastern	Bus 1173	138	Bravo 2	Bravo	Charlie	Echo	Delta
North-Eastern	Bus 1198	69	Bravo	Delta	Bravo 2	Charlie	Echo

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