# Ranking power system contingencies for real-time assessment of voltage stability based on PMU data

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**Voltage stability has been one of the main challenges for power system operators in recent years. The ranking of contingencies is one of the practical factors in assessing voltage stability. Therefore, the importance of maintaining grid stability necessitates the real-time assessment of voltage stability to protect the system from the risk of instability, and contingency ranking provides a list of essential and critical contingencies in terms of their impact on the network for real-time use. In this paper, a new index for classifying contingencies is presented, which is defined based on the voltage deviation and phase angle of the buses and PMU data. The proposed index has been tested on the IEEE 30-bus network. First, using this index, a contingency study was performed in 1000 operating points, and in the second stage, the results of these studies were compared with a random operation point. Comparing the results obtained from the proposed index with other available indices shows its proper performance for ranking and screening possible contingencies in power systems.** 

***keywords:*** *Voltage stability assessment, contingencies, ranking contingencies.*

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## 1. INTRODUCTION

The phenomenon of voltage instability and voltage collapse has caused global blackouts in recent years. The blackouts of New York in 1970, Tokyo in 1987, and the North American shutdown in 2003 are among the most notable ones. The contingencies have prompted researchers to conduct significant research in this area. In addition, the phenomenon of voltage stability has become a significant concern for network operators due to various issues such as a rapid and significant increase in demand in contrast to the slow process of construction of transmission lines and economic issues. Moreover, due to economic factors, most of the capacity of transmission lines is used, and there must be a loading margin to the point of instability; power grid operators require solutions to compromise between the maximum capacity used in transmission lines and the strength of the power grid. Voltage stability is a critical factor that must be considered during the various stages of planning, operation, and control of power systems to prevent voltage collapse and consequent partial or complete shutdown [1].

Methods and strategies for voltage stability analysis are generally divided into static voltage stability and dynamic voltage stability [2, 3]. In recent years, various techniques and methods have been proposed for static and dynamic analysis to evaluate the voltage stability of power systems. In all cases, the researcher aims to estimate the distance to the point of instability and voltage collapse [4–7].

The numerous static and dynamic methods for assessing voltage stability have led researchers to move toward real-time assessment indices. New indices and methods for assessing voltage stability margins are mainly based on the local voltage and current phases in buses or grid lines. They require fast and simple applications that are easy to implement. Their real-time use determines areas close to voltage instability and protects power grids against voltage collapse.

The indices P [8], VSI [9], SDC [10], and L [11] are the indices related to the bus, which evaluate the voltage stability using voltage and load current phasors. Also, VSMI [12], FVSI [13], LMN [14], NVSI [15], and LVSI [16] Indices related to transmission lines that use voltage and current phasors to evaluate voltage stability and critical lines.

The NVSI index is obtained based on the voltage equation of the transmission lines and the voltage characteristic of the active power at the point of voltage breakdown that it infinitely desires [15]. The index identifies the critical lines when the numeric value of the index reaches 1. The LVSI index is derived from a quadratic voltage equation. In this method, the ABCD parameters of the transmission line are used, and the charging capacity of the lines is considered [16]. The LCPI index is based on the exact model of the transmission system and is obtained using the ABCD parameters of the network and is used to predict voltage collapse and possible ranking of critical lines [17]. The FVSI index is obtained based on the simplified model of transmission lines for predicting voltage instability and ranking events with the outage of power system lines [13]. FVSI does not consider the active power of the lines to assess voltage stability, so that it may give incorrect results under certain operating conditions. The LQP index is obtained from the simplified model of transmission lines, which excludes the charging capacity and resistance of the lines [18]. LQP must be less than one to maintain the system voltage stability.

In large power systems, investigating all possible contingencies to assess security and stability is time-consuming and difficult. Also, not all contingencies in the network have a severe impact. Therefore, not all of them need to be analyzed. Thus, ranking contingencies appears essential to assess the security and stability of the power systems. It is possible to classify the contingencies using the mentioned voltage stability assessment indices. In [19–21], using FVSI and L indices, the ranking contingencies are discussed in which the contingency is the line outage. [22] Evaluated voltage stability and ranking contingencies with the help of P-V and P-Q curves.

With the introduction of artificial intelligence, the ranking of possible contingencies based on fuzzy logic in [23–25] and based on neural networks in [26–28] has been done. In [29], authors have ranked the various network contingencies by calculating two active performance indices (PIP) and reactive power performance index (PIV). By calculating two active performance indices (PIP) and reactive power performance index (PIV), authors in [29] have ranked the various network contingencies. In [30], the magnitude of voltage measurement deviations and the apparent flowing power in the lines of nominal values are summed. A combination of them is normalized and considered an indicator, in which the transient safety assessment responds to this question. It is defined whether system fluctuations that occur after a fault disrupt the synchronization of system generators. For this purpose, an index called the transient security index is defined. A method based on a performance index (PI) has been introduced in [31] for ranking line outage contingencies. The method's independent contingency tanking is based on multiple network variables, such as voltage, real and reactive power, and some combinations. In [32], the authors introduced a framework and a method that performs contingency screening and stability assessment online. The method employs a machine equivalent method intending to improve the state-of-the-art techniques. The authors in [33] have studied a Cellular Jordan Recurrent Network (CJRNs) for contingency ranking. The method is based on non-linear voltage prediction, and the voltages are utilized to calculate the performance indices. These indices are consequently used to attain proximity to voltage collapse severity of the contingencies In [34], the authors propose a transient stability contingency ranking method that considers the uncertainties of active distribution networks using distributed energy resources. Authors in [35] propose two methods for contingency ranking. The first method is based on voltage stability index, and the second method is based on dynamic voltage stability. In [36], a novel approach to contingency analysis is presented, which employs static voltage analysis based on the modal analysis.

Thus the importance of ranking network contingencies in assessing the safety and stability of voltage and helping the operator perform appropriate control and correction measures is apparent, and the need for an index that correctly shows the importance of contingencies with high accuracy seems necessary. In load flow studies, the magnitude and phase angle of the bus voltage are defined as state variables; Therefore, by having them, other network parameters can be easily found through network equations. On the other hand, when conducting a contingency study in the network, each element's outage causes fluctuations in the network parameters. Of course, these fluctuations will be more visible in the network state variables than any other variable. Therefore, using these two variables can provide the operator with a correct assessment of network security. One of the parameters always considered in evaluating the network security is the magnitude of the bus's voltage. When a notable contingency occurs in the network, the voltage of some busbars exceeds the suitable values. The higher the voltage deviation, the more critical the contingency and the higher the priority in the list of contingencies [37]. When a contingency occurs, the voltage across the bus changes. One of the parameters that have a significant relationship with the network power in the network is the phase angle of the buses. In some studies, this relationship is such that the injected power to the bus is defined only as a function of the bus's phase angle. This relationship between power and phase angle led to the use of phase angles of bus voltages to measure the static network security instead of flowing power in lines.

The use of PMUs facilitates access to voltage phase angles. Therefore, in this paper, two indices are presented for proper ranking of network contingencies based on the state variables of load flow studies, i.e., voltage magnitude and voltage phase angle. Since the outage of the elements has the most significant effect on the load distribution scenario variables at the time of the contingency study, the use of voltage and phase angle in the proposed index provides an accurate assessment of the network's stability. The point that distinguishes the proposed index from the existing ones is the low input parameters and the use of parameters provided directly by the PMUs, making this index easy to use in real-time calculations. The purpose of this paper is to provide a new index based on PMU information. This information includes the voltage and phase angle of the power grid buses. Since the magnitude of the voltage and the phase angle of the bus are state variables in load flow studies, this index can provide a comprehensive assessment of the state of the network and help the operator to perform corrective actions. One of the advantages of the proposed index is its sensitivity to high voltage differences between network buses.

This paper's structure is as follows: In Section 2, some of the available indices for ranking contingencies are examined. Then, in Section 3, the scenarios of the proposed index are introduced. In Section 4, simulation results are analyzed, and finally, Section 5 concludes and discusses the meaning of the results.

## 2. EXISTING INDICES

It is not possible to do study all contingencies. Usually, priority contingencies are identified offline, and assessments are performed only on these contingencies. Hence the indices are usually defined. In this section, the PIP and PIV indices are briefly introduced for comparison.

### A. Active Power Performance Index (PIP)

This index represents the amount of excess power from transmission lines. It shows the overload at the point of operation of the system

$$PIP = M_P \sum_{i=1}^{l} \left( \frac{P_i}{P_{i\,\max}} \right)^n \tag{1}$$

Wherein,
$P_i$: Active power in line i;
$P_{i\max}$: Maximum active Power on line i;
n: the order;
L: weighting coefficient;
and $M_p$: The number of transmission lines of the system.
If in equation (1), n is a large number and several transmission lines exceed their load limit, $PIP$ is a large number, and vice versa, if the power in the lines is within their allowable range, $PIP$ will be a small number [29].

### B. Reactive power performance index (PIV)

One of the parameters to evaluate the stability and security of the network is the PIV index. This index determines the extent and severity of the voltage of the bus exceeding the allowable range. In addition, this index demonstrates the effect of different network elements on the system voltage profile. The PIV index determines the importance of different network contingencies and their impact on network stability, as in equation (2).

$$PIV = M_v \sum_{i}^{N_{pq}} \left( \frac{2\left(V_i - V_{inom}\right)}{V_{i\max} - V_{i\min}} \right)^2 \tag{2}$$

Wherein,
$V_i$ is bus voltage,
$V_{i\max}$ is maximum bus voltage,
$V_{i\min}$ is minimum bus voltage,
$V_{inom}$ average of $V_{i\max}$ and, $V_{i\min}$
$N_{pq}$ is the number of network loads and $M_v$ is the weighting coefficient. This index shows a small number when the voltages are within the allowable range [29].

## 3. PROPOSED INDEX

In order to study a network contingency, network elements must be removed. As the elements undergo outage, fluctuations in network values occur. These fluctuations affect the voltage and phase angle of the buses as load distribution scenario variables. Therefore, an index that uses the bus's voltage and phase angle are useful for categorizing contingencies and evaluating voltage stability. The following are the voltage deviation and angle deviation indices.

### A. Voltage deviation index

In measuring the voltage stability of power systems, the buses' voltage measurement is a useful variable. When a contingency occurs in the power system, the magnitude of the bus voltage changes. The higher the bus voltage change, the more significant the impact of the contingency, and it has a higher priority when ranking contingencies. Various methods have been proposed to investigate the effect of voltage variation of buses. This paper investigates the effects of contingencies, the changes in the voltage of buses, and changes in the average value of the bus voltages. To calculate the average voltage value, first, the studied network bus's voltage is sorted from minimum to maximum, and the upper and lower quartiles are removed from the data. The average of the remaining data is then extracted. This step is to prevent the effects of buses with high voltage differences, affecting the average value and deviation from the average voltage of other buses. Also, when any contingencies occur in the network, the network buses with maximum and minimum voltage may have a significant difference. As a result, the network voltage might become unstable. The parameter $\alpha$ has been used to consider the effect of these buses' voltage on the proposed index. $\alpha$ increases the sensitivity of the indicator to substantial voltage differences in the network $\alpha = 1 - (Vi\max - Vi\min)$.

The amount of bus voltage deviation can be calculated according to equation (3):

$$VDI = \sum_{i=1}^{n} \frac{(Vi - Vav)^2}{\alpha} \tag{3}$$

where we have:
$V_i$: Bus voltage;
$V_{av}$: The average voltage of mains bus in base load scenario without considering high and low quarters;
$V_{i\max}$: Maximum bus voltage;
$V_{i\min}$: Minimum bus voltage;
$\alpha$: Index sensitivity factor to min and max voltages inside the network; and
$n$: The number of network buses understudy

### B. Angle Deviation Index

The phase angle of the buses is related to the power flowing in the grid lines. In load flow studies, the injection power of the buses is a function of the phase angle. Due to this relationship, the buses' phase angle can be used as a criterion to evaluate the voltage stability instead of the power flowing through the lines. To define and calculate the angle deviation index, first, the degree of phase angle deviation when the contingency occurs is defined according to equation (4):

$$ADI = \begin{cases} \sum\limits_{i=1}^{n} \left(1 - \frac{|\theta_i|}{\frac{\pi}{16}}\right)^2 & if : |\delta_i| > (\pi/16) \\ 0 & Otherwise \end{cases} \tag{4}$$

### C. Voltage deviation-angle index

In order to rank the contingencies using the voltage deviation index, the contingency's effect on the bus voltage has been examined. This variable seems to be a suitable criterion for examining the contingencies' effect on mains voltage stability. However, it should be noted that some contingencies affect the power flowing through the lines; Thus, the voltage stability deviation index cannot be a comprehensive measure of voltage stability. In order to solve this problem, the voltage deviation index is combined with the phase angle deviation index with the help of weight coefficients, and the voltage-angle deviation index is defined. Weight coefficients are obtained according to equations (5) and (6). In these equations $M$ is the number of network contingencies.

$$A = \sum_{J=1}^{M} VDI_J \tag{5}$$

$$B = \sum_{J=1}^{M} ADI_J \tag{6}$$

Therefore, the definition of voltage-angle deviation index is as follows:

$$VAI = \frac{(A \times ADI + B \times VDI)}{(A + B)} \tag{7}$$

## 4. PROBLEM DEFINITION

In this paper, the purpose of providing the proposed indices is to prioritize network contingencies properly and to be used by the operators to perform appropriate control measures when operating power systems. Therefore, these indices should prioritize and rank contingencies so that their importance and impact on the network are well defined. In order to check the performance of the indices, the line outage contingency is studied. The higher the values of the indices for the contingency, the higher its importance and the higher its priority in the ranking. Hence, the contingency will have a significant impact on the stability and security of the system.

More attention should be paid to system stability during operation and operation points of the system, including line outage studies. For this purpose, in this paper, for each contingency, the indices are examined on an IEEE 30-bus network at a large number of 1000 operating points, and the contingencies are ranked based on their results. The implementation scenarios for ranking contingencies are shown in the flowchart in Figure 1. For the 1000 operation points studied, each line is in outage in order, and the index corresponding to each of the contingencies in each different operation point is calculated. Lastly, the average of all the indices that each contingency has is considered as the final index.

## 5. SIMULATION RESULTS

In this section, the proposed indices are tested on the IEEE 30-bus network, and the results are compared with the Active Power Performance Index (PIP) and the Reactive Power Performance Index (PIV).

First, the index value for each event is calculated using 1000 operation points. This scenario is demonstrated as "Cumulative" in the figures. Then, to ensure the accuracy of these results, it is compared with the scenario named "Test," which results from ranking indices using a random operating point.

In this paper, contingency is defined as the line outage, and in the 30-bus network, we have 41 transmission lines, and therefore 41 contingencies are considered.

### A. Active power performance index

This indicator shows the intensity of the extra power flowing through the lines. During contingencies, the active power in the lines changes and may exceed the maximum power permitted to pass. This index determines the effect of this increase in power and its intensity. The method presented in the flowchart of Figure 1 is used to rank the contingencies using this index. The value of the index for each event is obtained at 1000 random operation points, and the final index of each event is the average of the total indices of that event at 1000 operating points. In order to evaluate the accuracy of the study method to determine the significance of the contingencies, the results obtained using 1000 operating points as Cumulative were compared with the Test scenario results obtained for a random operation point. Figure 2 shows the results.

Assuming that contingencies with a priority of 1 to 20 are essential contingencies that should be included in the final list of the network, we have for both Cumulative and Test.

1 Cumulative scenario: 1, 2, 4, 5, 7, 8, 9, 10, 15, 17, 18, 19, 21, 22, 25, 27, 30, 36, 37 and 38.

2. Test scenario: 1, 2, 4, 5, 7, 8, 9, 11, 15, 17, 18, 19, 21, 22, 25, 27, 36, 37, 38 and 41.

Evaluating the results demonstrates that only two errors have occurred out of 20 contingencies. This represents a 90% success rate in identifying priority contingencies. Moreover, it shows that the reactive power performance index has good accuracy in ranking possible contingencies.

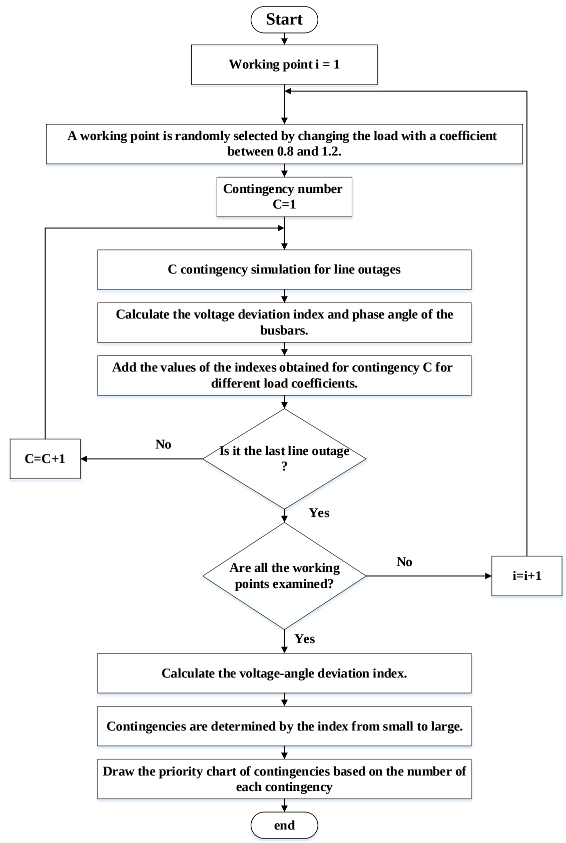


**Fig. 1.** Network contingencies selection flowchart

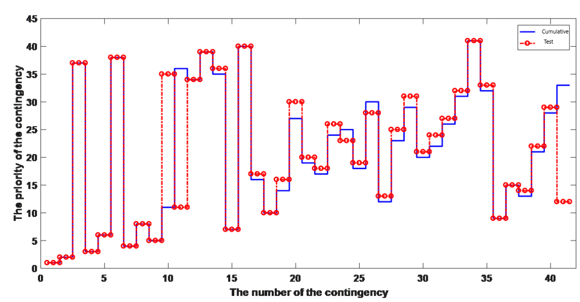


**Fig. 2.** Result of ranking contingencies for the active power performance index

### B. Reactive power performance index

This index tries to show the amount of voltage deviation of different network buses and performs contingency ranking. $V_{\max}$ and $V_{\min}$ are used to rank contingencies and play a vital role in this method. The amount of voltage deviation of the basses is calculated from the average of the $V_{\max}$ and $V_{\min}$ voltages. Contingency ranking is based on the flowchart in Figure 1.

Figure 3 shows the results of the contingency ranking. By examining Figure 3, the priority of the first 20 contingencies that

are assumed to have priority for the operator in each of the two scenarios Cumulative and Test are as follows:
1. Cumulative scenario: 1, 2, 4, 7, 8, 9, 10, 11, 17, 18, 19, 21, 22, 23, 30, 31, 32, 36, 37 and 38
2. Test scenario: 1, 2, 4, 5, 7, 8, 9, 10, 11, 17, 18, 19, 21, 22, 23, 30, 32, 36, 37 and 38
It is observed that in this sample network, the number of differences between the Cumulative and Test studies is 2. These results mean using the reactive power index, and there is a 10% difference between the list of predicted contingencies and the list of contingencies in the Test study. This amount of difference can also be said to be almost acceptable. According to these results, the error rate seems to be lower in larger networks; As in real networks, the number of buses is higher.

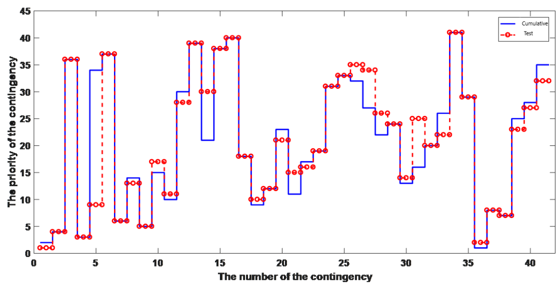


**Fig. 3.** Result of contingencies ranking for the reactive power performance index

### C. Voltage Deviation Index Results

The voltage deviation index shows the amount of deviation of the mains bus voltage from the permissible state. One of the main differences between this index and the reactive power performance index is that in this index, the effect of minimum and maximum voltages on the $\alpha$ sensitivity factor has been seen, and by removing the upper and lower quarters, the voltage of the used buses is tried to be closer to the average.
To be able to calculate the voltage deviation index, the flowchart in Figure 1 is used. Similar to the previous sections, the ranking is done for Cumulative and Test scenarios.
In this case we have for Cumulative and Test scenarios:
1. Cumulative scenario: 4, 9, 10, 11, 12, 17, 18, 19, 20, 21, 22, 23, 29, 30, 31, 32, 33, 36, 37 and 38.
2. Test scenario: 1, 4, 8, 10, 12, 11, 17, 18, 19, 20, 21, 22, 23, 30, 32, 33, 36, 37 and 38.
Examination of the results demonstrates differences between Cumulative and Test scenarios, representing a difference of 10% according to the number of selected contingencies. This shows that the prediction of contingencies is made with reasonable accuracy. It should be noted that the simulation on larger networks showed better performance of the voltage deviation index and a lower error rate, so in a real network with more buses, the rate of error would be lower.

### D. Angle Deviation Index Results

The method presented in Figure 1 is used to rank the contingencies based on the angle deviation index. In this paper, the purpose of the Cumulative scenario is the results of the contingencies study on 1000 operation points, and the purpose of the Test scenario is to perform the contingency study on a random operation point. Figure 5 shows the results of the angle deviation index for prioritizing contingencies. A comparison of the

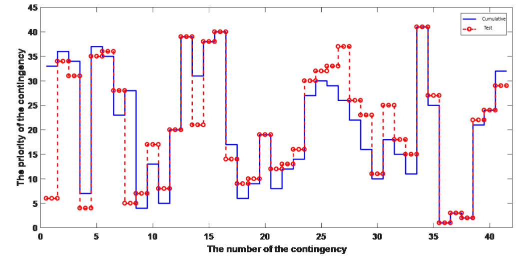


**Fig. 4.** Results of contingencies ranking for voltage deviation index

two diagrams in Figure 5 shows that the general shape of both is almost the same. Contingencies with a priority of 1 to 20 that should be provided to the operator for real-time assessment and Cumulative and Test scenarios are as follows:
1. Cumulative scenario: 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 14, 15, 18, 25, 27, 35, 36, 37, 38 and 41.
2. Test scenario: 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 14, 15, 18, 25, 27, 35, 36, 37, 38 and 41.
According to the results, it can be seen that the angle deviation index has 100% accuracy in the similarity of incident ranking with Cumulative scenario and Test scenario, which has a higher success rate than the voltage deviation index in priority contingency ranking.
It is found by comparing the Cumulative results of the voltage deviation and phase angle deviation indices that there are 12 differences in the 30-bus network, equivalent to 60% of the difference. This significant difference is in the inherent difference between the two indices; Because the phase angle has little to do with the bus voltage. That is why in the next section, the combination of these two characteristics is used to evaluate the security and stability of the network.

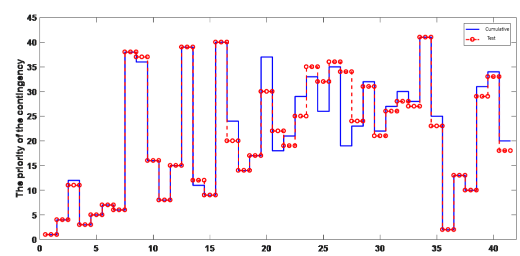


**Fig. 5.** Result of contingencies ranking for the angle deviation index

### E. Voltage-Angle Deviation Index Results

According to the previous sections, it was found that the voltage deviation and phase angle deviation indices of each point of view rank the contingencies and are 60% different in the ranking. In this section, a combination of the two indices uses both indices' impact in ranking contingencies. Like the sections before, the method shown in Figure 1 is used to rank contingencies. The 30-bus network has 41 lines and, therefore, 41 contingencies. In this network, the outage of lines 13, 16, and 34 lead to the disconnection of bus 11, 13, and 26 from the network. Therefore, the three contingencies 13, 16, and 34 are of the highest importance, which has not been considered. Figure 6 shows the results of the event ranking for the two scenarios, Cumulative and the Test

**Table 1.** Percentage of success rates of indices in ranking 30 bus network contingencies

| Result of contingencies ranking for voltage-angle deviation index | Angle deviation | Voltage deviation | PIV [23] | PIP [23] | Index Network |
|---|---|---|---|---|---|
| 95% | 100% | 90% | 90% | 85% | 30 Bus |

using the voltage-angle deviation index. The contingencies with a priority below 20 for both scenarios are as follows:
1. Cumulative scenario: 1, 2, 3, 4, 5, 6, 7, 11, 12, 14, 15, 19, 20, 21, 23, 27, 32, 33, 36, 37 and 38.
2. Test scenario: 1, 2, 3, 4, 5, 6, 7, 11, 12, 14, 15, 17, 19, 20, 21, 23, 32, 33, 36, 37 and 38.

The voltage-angle deviation index has one difference between the Cumulative and the Test, which indicates a 95% accuracy. It is observed by comparing the results of the Cumulative scenario for the voltage-angle deviation and phase angle deviation indices that these two indices have a 20% difference in the ranking contingencies. Also, this index has a 45% difference from the voltage deviation index.

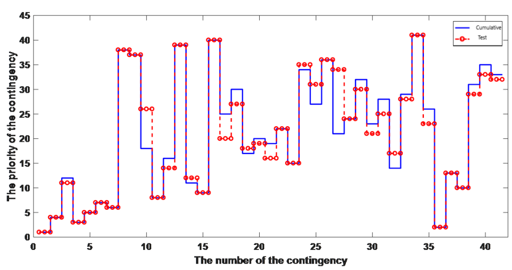


**Fig. 6.** Result of contingencies ranking for voltage-angle deviation index

### F. Analysis of results

Examining the results obtained for the proposed indices and the PIP and PIV indices in Table 1 demonstrates that each of the indices has a suitable accuracy for comparing the ranking of contingencies in the Cumulative scenario and the test scenario. It is important to note to what extent each of these indices is a good measure for ranking and monitoring contingencies. Therefore, a criterion should be considered for selecting the index.

Two criteria for selecting the appropriate index can help the network operator. The first is the reproducibility of the results for ranking the contingencies, and the second is the scientific and logical definition of the index used [26]. According to the flowchart of Figure 1, the values of the indices have been tested for 1000 different operation points and tested with a random operating point. The results of Table 1 show the success of the indices in ranking the contingencies and repeatability of their results.

It is important to note that to what extent indices demonstrate the importance of contingencies and the extent to which they are appropriate for prioritizing contingencies. In order to examine this issue, the extent of the difference in prioritization of contingencies for different indices is shown in Table 2.

Examination of Table 2 demonstrates that the indices have a significant difference in the ranking of contingencies, and the extent and reasons for these differences depend on the definition

**Table 2.** Percentage of differences in indices in the ranking contingencies of 30 bus network

| Angle deviation | Voltage deviation | PIV | PIP | |
|---|---|---|---|---|
| | | | 20 | PIV |
| | | 15 | 40 | Voltage deviation |
| | 60 | 50 | 30 | Angle deviation |
| 25 | 40 | 35 | 45 | Voltage-angle deviation |

of the index. These results show the significance of choosing the right index in ranking contingencies. Assume that a suitable index has not been selected; therefore, inconsequential contingencies in the real-time assessment will waste operators' time. Important contingencies overlooked by the index will pose a risk to the network's stability and security.

Since the voltage-angle deviation index uses the two variables of the network scenario, namely the voltage magnitude and the angle of the voltage phasor, in its definition, it can provide the operator with a correct picture of network security and stability. Nowadays, due to the increase in the use of phasor measuring systems (PMUs), it is easier to access the phasor information, which includes voltage measurement and phase angle. Therefore, it is crucial to consider faster methods for real-time assessment of the security and stability of network voltage. Hence, the proposed index can play a useful role in the real-time assessment of network voltage security and stability and provide appropriate information on real-time ranking contingencies to the network operators.

## 6. CONCLUSION

Since the ranking network contingencies is of utmost significance for evaluating systems' security and stability, an index that correctly shows the rank of contingencies is crucial in power system operation. In this paper, the voltage-angle deviation index is presented to rank possible power network contingencies. Due to the effect of contingencies on voltage and phase angle, this index is obtained by combining the voltage deviation index and the angle deviation index. Two "cumulative" and "testing" scenarios were performed on the IEEE 30-bus network to test and evaluate the proposed method. The results presented the reproducibility of the proposed method and 95% accuracy in the similarity of contingency ranking for the two scenarios. The results of the proposed index were compared with PIP and PIV indices, and the success rate of them was 10% and 5% higher, respectively, in ranking IEEE 30 bus test network contingencies. The percentage of deviation of different indices in ranking different contingencies suggests that the Voltage-Angle Deviation index has the lowest difference (25%) with the angle deviation index and the highest difference (45%) with PIP. The differences between indices in ranking contingencies show the importance of choosing the appropriate index in ranking contingencies.

In ranking contingencies, any contingency with a more considerable index value has a higher priority. Therefore, the difference in the ranking of contingencies for various indices demonstrates that the index should be carefully selected. Since the proposed index uses the state variables of the load flow studies in its definition, this index can have a correct assessment in ranking contingencies. Similarly, since network phasors are available using PMU information, this index can be used for online network evaluations.

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**Abbreviations**

1-Phasor Measurement Units (PMU)
2-Voltage Stability Index (VSI)
3-S (Apparent Power) Difference Criterion (SDC)
4-Voltage Stability Margin Index (VSMI)
5-Fast Voltage Stability Index (FVSI)
6-Line Stability Index ($L_{\min}$)
7-New Voltage Stability Index(NVSI)
8-Line Voltage Stability Index (LVSI)
9-Active Power Performance Index (PIP)
10-Reactive Power Performance Index (PIV)