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Retraction

Retracted: Construction of Grid Reliability Assessment Model Based on Sensitivity Analysis

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] L. Zhang, Y. Wu, H. Li, and Y. Liu, "Construction of Grid Reliability Assessment Model Based on Sensitivity Analysis," *Mobile Information Systems*, vol. 2022, Article ID 2231704, 7 pages, 2022.

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Research Article

Construction of Grid Reliability Assessment Model Based on Sensitivity Analysis

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The traditional reliability of power supply only focuses on the continuity of power supply and does not include the impact of power quality on customers in the assessment. In this paper, we use "the ability of the grid to provide continuously available power to customers" as the criterion to reflect more realistically the level of reliability perceived by customers. This reliability assessment, which is closer to the customer's perspective, can also be used as a basis for quality-based pricing in the electricity market that is acceptable to both the supplier and the consumer, and the difference between the reliability of electricity consumption and the reliability of electricity supply statistics can also be used by power supply companies to evaluate their own power supply quality and service level. This paper uses the AC algorithm to calculate the reliability indexes of the power system in combination and proposes to use the component sensitivity analysis to rank the system components to obtain the key component information for the combination of the power system reliability indexes.

1. Introduction

With the new round of power system reform, the competitive power market is gradually established and improved, and power users have more opportunities to freely choose and change power suppliers according to their demand preferences [1, 2]. In order to improve market competitiveness, power supply companies will change their business philosophy and pay more attention to customers' experience and satisfaction with power supply services and put more attention to the management and improvement of distribution network reliability and power supply quality [3, 4].

In recent years, power supply enterprises have carried out a lot of power supply reliability management work, but in practice, there is still a situation that the power supply reliability work on the grid side has been very effective, but the reliability level experienced by users is not ideal [5, 6]. This is because the traditional power supply reliability assessment and analysis method only considers the impact of a power outage on customers, but with the improvement of customers' equipment requirements on power quality, the power quality problems in the distribution network can also lead to the inability of customers to use electricity normally or even the interruption of electricity [7, 8], which seriously affects the normal development of customers' production and life, and the number of complaints from customers to power supply enterprises is increasing year by year [9, 10]. This situation leads to a large gap between the statistical results of power supply reliability of power supply enterprises and the actual reliability level experienced by customers, which not only reduces the service level of power supply enterprises and customer satisfaction but also has a direct impact on the power sales efficiency of the power grid, so we should pay attention to this situation [11, 12].

On the other hand, with the continuous promotion of smart meter installation in recent years, power supply enterprises are expected to obtain more and more customer electricity consumption data and information, and how to sort out and apply the massive customer-side electricity data has become a new problem for power supply enterprises [13, 14]. Among them, it is a feasible and effective way to analyze the correlation between the electric energy data and

Table 1: Common indicators of IEEE 1366-2012 and DL/T 836-2016.

Indicator type	Indicator name	Nonidentical part
System user index	Average supply reliability (ASAD)	IEEE1366-2012: Only continuous outages (outage time greater than 5 min) are considered DLT836-2016 (1) Considering both continuous outage (outage time greater than 3 min) and short-time outage (2) Further refined into 4 indicators according to whether to take into account external influence, system power shortage limitation, and short-time power outage
	System average outage duration (SAID) System average outage frequency (SAIED)	IEEE1366-2012: Only continuous outages are considered DLT836-2016 (1) Considering both continuous outage and short-time outage (2) Further refined into 6 indicators according to whether to take into account external influence, system power shortage limitation, and short-time outage, as well as separate statistics for prearranged outage and fault outage
Outage user index	Average outage customer outage time (CAIDD) Average time per outage (CTADI) Average outage frequency for customers with power outages (CAIFD)	IEEE1366-2012: Only continuous outages are considered DLT836-2016 (1) Considering both continuous outage and short-term outage (2) Further refined into 2 indicators according to whether short-time outages are taken into account
Long-time outage index	Ratio of customers with a prolonged power outage ($CELID_{-t}$) Ratio of single long-time outage customers ($CELID_{-s}$)	
Repeat outage indicators	Ratio of customers with multiple outages ($CEMSMI_n$) Ratio of customers with multiple persistent outages ($CEMI_n$)	
Load-based metrics	Average system equivalent downtime (ASIDI) Average system equivalent outage frequency (ASIFI)	
Short-term outage indicators	System average short-time outage frequency (MAIFI)	DLT836-2016: 2 additional indicators based on separate statistics for prearranged outages and fault outages

the real reliability level experienced by customers by mining the electric energy data of customers and then establish a method to obtain the reliability of customers through electric energy data sheets, so as to guide the reliability management and improvement work on the customer side [15, 16].

The contributions of this paper are as follows:

This paper plans to carry out the power grid reliability evaluation analysis based on sensitivity analysis; deeply analyze the correlation between voltage quality, voltage transient drop, and power reliability based on power grid data; transfer the reliability analysis and evaluation work from the power grid side to the user side; and study the real reliability level of customer experience.

The research work of this paper can help power supply enterprises understand the reliability level of customers, improve the degree of fine management, promote the research of power supply quality improvement strategies and methods, and improve the customer satisfaction and market competitiveness of power supply enterprises under the background of the open power market.

Based on the sensitivity of the system to component probability, some of the 76 components are selected for reliability combination calculation. The results show that the load rejection method is an approximate load rejection method, and the order of the load rejection domain is level 3.

2. Grid Reliability Evaluation

The standard "IEEE Std 1366-2012 Distribution Reliability Index Guidelines" and the national standard "DL/T 836-2016 Power Supply System Customer Power Supply Reliability Evaluation Regulations" are both widely adopted standards for power supply reliability evaluation of distribution networks [17–20]. The reliability indicators in IEEE1366-2012 are divided into three major categories: continuous outage indicators, load-based indicators, and other indicators; the indicators in DL/T 836–2016 are divided into two major categories: main indicators and reference indicators. To compare the two standards, this paper refines the indicator types according to the content of the indicator evaluation, then the common indicators of the two standards are shown in Table 1, and the different indicators are shown in Table 2.

In addition, the standard IEEE 1366-2012 does not distinguish between the voltage levels of users; DL/T 836-

Table 2: Different indicators of IEEE 1366-2012 and DL/T 836-2016.

Indicator type	Indicator name	Source of indicator
Short-term outage indicators	Average frequency of short-term outage events (MAIFIE)	IEEE1366-2012
	Average number of customers with outages (MIC)	
Index of power outage users	Average number of prescheduled outages (MIC_{-s})	
	Average number of customers with fault outages (MIC_{-F})	
	Average outage shortage of electricity to customers (AENS)	
Power shortage index	Average outage shortage of power $(AENT_{-S})$ for prescheduled outages	
	Average outage shortage of power $(AENT_{-F})$	DL/T836-2016
Average duration of power failure	Prescheduled outage mean duration (MID_{-S})	
	Mean duration of fault outages (MID_{-F})	
Indicators considering external impact	External impact outage rate (IRE)	
Facility-based indicators	Facility outage rate (FEOI)	
	Mean duration of facility outages (MDEOI)	
	Line fault outage rate (FLFI)	
	Fault outage rate on overhead lines (FOLFI)	
	Cable line fault outage rate (FCFI)	
	Distribution transformer fault outage rate (FTFI)	
	Outgoing circuit breaker fault outage rate (FCBFI)	
	Other switch fault outage rate (FOSFI)	

2016 divides users into high-, medium-, and low-voltage users and lists the indicators applicable to users of different voltage levels. Among them, the indicators of shortage of power supply in DL/T 836-2016 are not followed for low-voltage users. However, with the popularization of smart meters, it has become possible to obtain the data related to power outages of low-voltage users, and it is achievable to apply this index to low-voltage users.

In summary, the current power supply reliability evaluation standards are very comprehensive and detailed in terms of power supply continuity. However, in terms of power availability, there is no quantitative assessment of the impact of power quality on customers.

3. Grid Reliability Assessment Model

In the power system reliability analysis, we can calculate the reliability indexes of the system and each node, such as L_{OLP} (loss-of-load probability), L_{OLE} (loss-of-load expectation), F_{LOL} (loss-of-load frequency), D_{LOL} (loss-of-load duration), $E_{DN\ S}$ (expected demand not supplied), E_{ENS} (expected energy not supplied), and so on. The definitions are as follows.

If each branch of a circuit set F_i fails, the system will experience a power shortage, and the branch set F_i is said to be a failure event of the system. The set of all failure events of the system is denoted as F. Once the set of failure events F is found, the reliability index of the network can be calculated by the following equation:

$$L_{OLP} = \sum_{F_i \in F} P_{rob}(F_i), \tag{1}$$

where L_{OLP} is the magnitude of the probability of loss of load.

$$L_{OLE} = 8760 \times p\left\{ \bigcup_{F_i \in F} F_i \right\}, \tag{2}$$

where L_{OLE} is the average number of hours of power shortage per year, *h*/year.

$$F_{LOL} = \sum_{F_i \in F} f_{re}(F_i), \tag{3}$$

where F_{LOL} is the average number of power outages per year, times/year, and f_{re} is the frequency of event F_i.

$$D_{LOL} = \frac{L_{OLE}}{F_{LOL}}, \tag{4}$$

where D_{LOL} is the average duration of each outage, *h*/time.

$$E_{DNS} = \sum_{F_i \in F} P_{rob}(F_i) \times D_{NS}(F_i), \tag{5}$$

where E_{DNS} is the average annual power deficit, MW/year. $D_{NS}(F_i)$ is the load shedding for event F_i, which can be calculated by the load shedding strategy. $P_{rob}(F_i)$ is the probability of event F_i.

$$E_{ENS} = 8760 \times \sum_{F_i \in F} P_{rob}(F_i) \times D_{NS}(F_i), \tag{6}$$

where E_{ENS} represents the average number of kilowatt-hours per year, MWh/year.

(1) The sensitivity of the system outage time expectation to the probability of component failure is

$$(S_L)_{Q_i} = \frac{\partial L_{OLE}}{\partial Q_i}. \tag{7}$$

The essence of equation (7) is the partial differentiation of the system's outage time L_{OLE} to the probability of failure of a component. This sensitivity reflects the extent to which the failure of a component affects the system's outage time index L_{OLE}, but it does not reflect the effect of component failure on system power shortage. In the operation of the power system, this sensitivity index can be considered to identify the components with the largest indexes, so as to enhance maintenance and reduce the system outage time.

Table 3: Comparison of sensitivity indicator calculation results.

Network name	Total number of nodes/piece	Total number of lines/piece	Total number of generators/set	Total number of transformers/set	Sensitivity calculation time/S
IEEE-RTS24	23	30	33	4	1
City grid 1	56	97	56	0	27
City grid 2	142	141	78	68	90

(2) The sensitivity of system power shortage expectation to component failure probability is

$$(S_E)_{Q_i} = \frac{\partial E_{ENS}}{\partial Q_i}. \tag{8}$$

The essence of equation (8) is the partial differentiation of the system undercharge expectation E_{ENS} to the component probability. This sensitivity reflects the degree of impact of component failure on the system shortage, and it is an important indicator in the sensitivity analysis. The sensitivity index can be considered to identify the component with the largest index and enhance maintenance to maintain a high transmission capacity.

(3) The sensitivity of the system power shortage expectation to the transmission capacity of the components is

$$(S_E)_{C_i} = \frac{\partial E_{ENS}}{\partial C_i}. \tag{9}$$

The essence of equation (9) is the partial differentiation of the system power deficit expectation E_{ENS} on the probability of component failure. This sensitivity reflects the degree to which the through the capacity of the component affects the power shortage, and it is an important indicator in a sensitivity analysis. The analysis of this indicator can be used to study the start-up and shutdown methods or grid enhancements to maintain adequate backup margins.

Using equation (9) as an example, the following formula can be derived to calculate the sensitivity of system power shortage expectation to component failure probability:

$$\begin{aligned}(S_E)_{Q^i} &= \frac{\partial E_{ENS}}{\partial Q_i}\\ &= 8760 \times \sum_{F_j \in F} \partial P_{rob} \frac{(F_j)}{\partial Q_i} \times D_{NS}(F_i).\end{aligned} \tag{10}$$

If $E_i \notin F_j$, then $\partial P_{rob}(F_j)/\partial Q_i = 0$. If $E_i \notin F_j$, then

$$\frac{\partial P_{rob}(F_j)}{\partial Q_i} = \prod_{E_i \in F_j} P_{rob}(E_l) \cdot \prod_{E_i \in (E - F_j)} (1 - P_{rob}(E_l)). \tag{11}$$

Equations (10) and (11) are the formulas for calculating the sensitivity of component E_i.

When calculating the sensitivity, the failure event F_i can be determined by the grid flow method and the DC method, which can quickly calculate the sensitivity index of each component of the system. The calculation times for several typical grid sensitivity indicators are shown in Table 3.

The basic idea of the sensitivity-based reliability calculation model is to find out the set of components with a high impact on the system reliability index through the sensitivity calculation and to calculate the reliability index of the power system by combining the components in the set.

In this paper, the components with high sensitivity indexes are sorted to select the set of components with high sensitivity indexes, and the reliability indexes of the power system are calculated by using the AC current algorithm. The procedure of the algorithm is as follows.

The advantage of this algorithm is that it selects the components that have the most influence on the system to calculate the reliability index of the system and does not consider those components that have less influence on the system, thus greatly improving the calculation speed of the reliability of the power system. The block diagram of the algorithm is shown in Figure 1.

4. Experimental Setup

In this paper, the sensitivity and reliability of the IEEE-RTS24 system are calculated and analyzed. The system has 32 generators, 29 transmission lines, and 5 transformers. Using existing ant colony algorithms for route planning leads to another bad result: uneven load on the tourist attractions [21]. A tourist crowd that all follows the optimal path will inevitably lead to a sudden increase in the number of people at one or some attractions, while the number of people at some attractions is low [22]. Therefore, dynamic planning needs to be added to the ant colony algorithm. The path calculation method between two attractions is improved so that the improved ant colony algorithm has dynamic planning capability, which can well achieve load balancing of tourist attractions [23, 24]. Assuming that there are 10 attractions in a scenic area, the 10 attractions are used as an example to illustrate the ability of the algorithm in dynamic tourism route planning. The sensitivity indexes of the IEEE-RTS24 system are ranked in the top part as shown in Table 4. It can be seen that the sensitivity of the generators in this system is relatively large and is a major concern for reliability improvement.

It can be seen from Table 4 that in the IEEE-RTS24 system, the sensitivity of the generator is far greater than that of the line. Therefore, the fault impact of the generator accounts for the main proportion of the reliability index of the IEEE-RTS24 system. Among them, the sensitivity of the No. 1 generator on bus B_{18} and the No. 1 generator on bus B_{21} is far greater than that of other components, Therefore, these two generators have become the weakest link of the

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(1) Initial calculation parameters.
(2) Calculate the sensitivity of each indicator to the component by the net flow method.
(3) Rank the sensitivity indicators of the components.
(4) Select the components that have a greater impact on the sensitivity of the indicators and form the set $F$. This determines the
    number of components in the set $F$ according to the accuracy of the reliability indicators.
(5) Enumerate the events in the set $F$.
(6) If there are no events, the program ends.
(7) Determine if the system is unlisted.
(8) If unlisted, go to step (11).
(9) Calculate the tide of each block network.
(10) Determine if the system is in a fault state. If the system is in a fault state, go to step (11); otherwise, go to step (5).
(11) Perform the system behavior analysis and calculate the reliability index.
(12) Go to step (1).
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ALGORITHM 1: AC current algorithm.

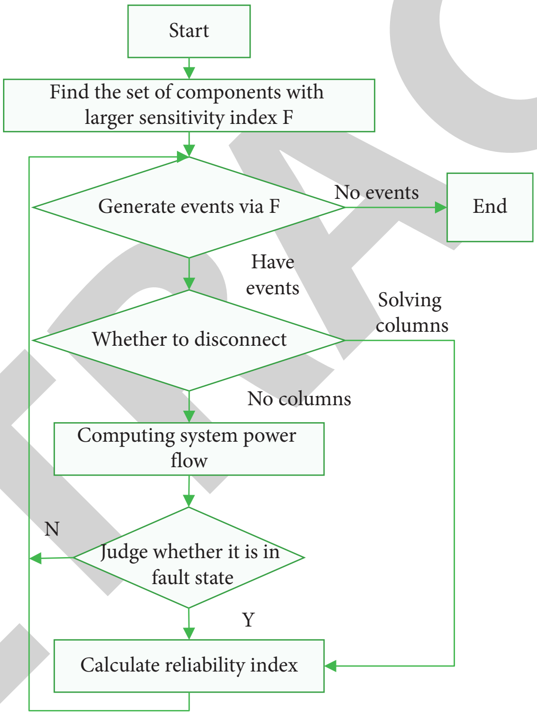

FIGURE 1: The flow chart of reliability calculation.

TABLE 4: Sensitivity data of IEEE-RTS24 system.

Component name	L_{OLE} sensitivity to component probabilities	E_{ENS} sensitivity to component probabilities	E_{ENS} sensitivity to component capacity
Machine B_{18} 1	1.196571×10^{2}	1.165213×10^{2}	2.554781×10^{1}
Machine B_{21} 1	1.189876×10^{2}	1.078449×10^{2}	2.372687×10^{1}
Machine B_{23} 3	5.220312×10^{1}	4.543264×10^{1}	1.200261×10^{1}
Machine B_{13} 3	3.054123×10^{1}	2.792319×10^{1}	1.343261×10^{1}
Machine B_{13} 2	3.054123×10^{1}	2.697864×10^{1}	1.288971×10^{1}
Machine B_{13} 1	3.054123×10^{1}	2.789862×10^{1}	1.335493×10^{1}
Line 11	7.089549×10^{-1}	9.689726×10^{-4}	4.406277×10^{-4}
Machine B_{1} 2	8.553621×10^{-2}	2.115883×10^{-1}	9.495255×10^{-1}
Machine B_{1} 1	8.555363×10^{-2}	2.423978	1.095234×10^{1}

Table 5: Reliability calculation results of IEEE-RTS24 system.

Calculation method	Loss of load probability, L_{OLP}	Power shortage expectation, E_{ENS}	Calculation time (s)
Select the top 5 components in order of sensitivity	0.01998	246.8	—
Select the top 10 components in order of sensitivity	0.03622	432.7	3
Select the top 15 components in order of sensitivity	0.05889	743.3	15
Select the top 20 components in order of sensitivity	0.07622	951.2	58
Select the top 25 components in order of sensitivity	0.08299	1,055	171
Select the top 30 components in order of sensitivity	0.09048	1,139	378
Select the top 35 components in order of sensitivity	0.09337	1,197	590
Calculation results of R_Billinton	0.08521	1,053	1,099

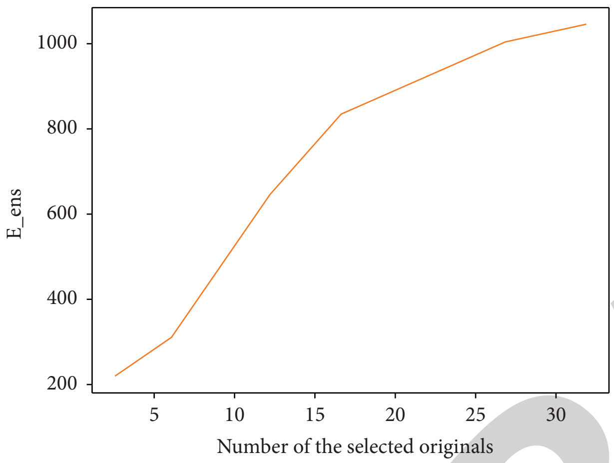

Figure 2: Variation curve of E_{ENS}.

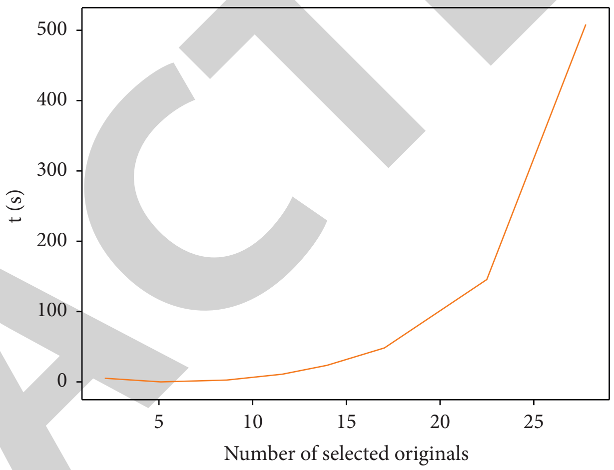

Figure 3: Calculation time variation curve.

IEEE-RTS24 system. Therefore, to improve the reliability of IEEE-RTS24 system, we can consider strengthening the maintenance of the No. 1 generator on bus B_{18} and the No. 1 generator on bus B_{21} to improve the operation reliability of these two generators, so as to improve the operation reliability of the whole system.

Based on the sensitivity of system L_{OLE} to component probability (of course, other sensitivity indicators can be used, as they are of the same order and therefore have little impact on the calculation of the system index), some of the 76 components (32 generators, 29 transmission lines, and 5 transformers) were selected for the reliability combination calculation, and the results are shown in Table 5. The calculation is based on the following conditions: the generators are considered to be 4th order, the lines are considered to be 2nd order, the load shedding method is the near load shedding method, the degree of the load shedding domain is 3 levels, and the Newton–Raphson method is used for the AC current algorithm [21, 22].

The results of Table 5 are shown in Figures 2 and 3. From the trend, the more the components are selected in the reliability calculation, the longer the calculation time is, but the system index E_{ENS} does not change much under certain conditions, so a certain number of components can be selected through the sensitivity calculation to calculate the system reliability to the required accuracy.

Taking the IEEE-RTS24 system as an example, comparing the calculation results in Table 5 with those in Figure 3, we can see that the calculation time of the sensitivity indicator is less than a few percent of the calculation time of the reliability indicator. Therefore, this algorithm can alleviate the problem of "computational disaster" in grid reliability calculation [23–25].

5. Conclusion

In order to further explore the engineering application methods of large-scale power networks, this paper proposes the algorithm of network reliability assessment based on sensitivity analysis while introducing the component sensitivity index. The basic idea is to obtain the information of key components with high importance through the sensitivity analysis of system reliability to component reliability parameters and then to combine the system reliability indicators. The computational analysis of the IEEE-RTS24 system shows that the model and algorithm are not only reliable but also have an order of magnitude improvement in computational speed, which demonstrates the effectiveness of the algorithm and shows potential engineering applications, providing a powerful computational analysis tool for grid operation and planning decisions.

Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declared that they have no conflicts of interest regarding this work.

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