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Article

Quantitative Analysis of Distribution and Reliability Based on Maximum Capacity Segmented Subscribers on Distribution Lines

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Abstract: The rapid economic progress and widespread use of sophisticated technology elevate the output value per kWh of electricity consumed, underscoring the paramount importance of maintaining an uninterrupted and dependable power supply to avoid substantial economic losses for consumers and society. Investigating the reliability of urban distribution systems emerges not only as a pivotal factor in enhancing power supply quality but also as a cornerstone of electric power modernization, significantly impacting production, technology, and management within the industry while bolstering its economic and social benefits. This study adopts a multifaceted approach: firstly, establishing a methodology for grid-side storage capacity distribution to mitigate substation load factors and implement peak shaving, thereby minimizing load discrepancies. Secondly, it develops a mathematical model encompassing diverse user distributions, employing analytical techniques to derive reliability indices and optimal segment numbers tailored to different user distributions. The research proposes segment optimization based on user distributions, considering both economic viability and reliability, showcasing an interdisciplinary amalgamation of combinatorial principles and scientific computing methodologies. This approach aims to optimize segment distribution, enhancing the reliability and economic feasibility of urban distribution networks through advanced mathematical and computational techniques.

Keywords: Customer distribution, power supply dependability, overhead single radiation, ideal segmentation

1. Introduction

Electric energy is a very important end-user energy source, and with the development of economy and society, its proportion in energy supply is getting larger and larger [1]. The stable, economic and reasonable supply of electric energy plays a crucial role in the economic development and construction of the whole society. Electric energy is transmitted to thousands of households through distribution networks, which are composed of distribution systems, and the most basic task of distribution systems is to distribute and supply electric energy to end-users as economically and reliably as possible [2]. The distribution system refers to the part of the power generation system that transmits electricity from the transformer node to the end user, and it includes substations of various different voltage levels, distribution transformers, distribution lines, and other electrical equipment that connects various different types of users [3]. Systems on 35 kV are often referred to as Kor-voltage distribution systems, 6-20 kV systems as medium-voltage distribution systems, and 380 V/220V as low-voltage distribution systems [4]. This distinction of distribution levels cannot be defined only by voltage level, but also requires comprehensive consideration of the function of the facility. The end of the whole power system is the distribution system, which connects the power generation system and transmission and transformation system with the user's electricity-using equipment and facilities, etc. It is one of the important links for distributing and supplying electricity to users, and the whole distribution network and its appurtenances, including distribution substations, distribution lines and household connection lines [5, 6]. As the current power supply is mainly in the centralized box-and-shoot mode, it is sensitive to faults. Although this centralized, large grid power supply approach has its insurmountable drawbacks, such as the inability to flexibly track changes in customer load and lead to wasted equipment capacity, remote areas are difficult and costly to provide reliable power supply, large interconnected grid structure is complex, and local failures may spread and lead to large area outages, currently ninety percent of the world's existing power supply is used in this way, complete reconstruction is not It is not realistic to completely rebuild [7, 8]. At present, the development of distributed power generation (Distributed Generation) is relatively rapid, and several projects of grid-connected power generation such as photochemical and wind power have been put into use or are under construction in China, which has played a greater role in alleviating the shortage of power at peak hours of the large power grid, and also made outstanding contributions to energy saving and emission reduction, and environmental protection [9]. Distributed generation system access can improve the safety, reliability and flexibility of the grid, which is the future development direction of China's power system, but it cannot replace the traditional centralized main power supply method for a long time in the future [10]. Therefore, the main object of this paper is to study the structure of the existing distribution grid system. Along with the development and increasing maturity of China's power grid construction, the reliability assessment and application of the distribution grid system have become more and more important. The situation of "emphasizing generation and transmission, regardless of supply" has been greatly improved in China [11]. In recent decade, the reliability of China's power distribution system has been greatly improved, and the reliability management of major power supply enterprises in each province and city has been based on strengthening the control and optimization of power outages and maintenance work [12]. Through the reference of each reliability index, the blind and inefficient outages have been effectively reduced, and the research and application of reliability optimization control has greatly reduced the probability of occurrence of distribution network system accidents. In addition, the transformation of urban and rural power grids by our government in recent years has provided a better material basis for improving the coercibility of the distribution grid system. Nevertheless, there is still a certain gap between the reliability level of China's distribution network and the international level, and we should continue to strengthen the reliability research and management of the distribution network and its equipment. It can be seen that the distribution network system is an important link in the whole power system, and its normal operation plays a role in ensuring the economic development. However, there is a big gap between the level of distribution system reliability assessment research in China and foreign countries, and it is necessary to carry out distribution network reliability assessment research for this problem.

2. Related Work

Reliability assessment and application technology of distribution network systems is an important branch of research coincidental application area of reliability technology. Reliability technology research is a probability-based risk analysis method that plays an active role in the reliable operation of the whole system or the components and equipment in this system. Many domestic and foreign researches and applications in recent decades have shown that this technology is effective in reducing the downtime and the number of downtimes of the distribution network system, i.e., it is effective in increasing the index of power supply effectiveness of the distribution network and has achieved good economic benefits. Since the distribution network system directly connects the power generation and transmission networks to the customer's terminal facilities, it is an important link in the power network for distributing and providing electricity to customers. About 80% of the customers' outages are caused by faults in the distribution system [13]. Therefore, improving the reliability of the distribution system is one of the most important means to ensure the reliable power supply of the power system, and has attracted more and more attention. In Europe and the United States, with the development of the power industry since the 1960s, reliability engineering theory has been gradually applied to the power industry, and the assessment of power system reliability has gradually entered the practical stage from theoretical research [14]. In 1964, Desineo and Stine first introduced Markov process model into power system reliability assessment research and development, and then Billinton and Stanton solved the linear algebraic equation composed of transfer rate matrix in Markov process model to derive the mean time to failure and repair time of the system under long-term probability distribution [15–17]. In the following decades, through the unremitting efforts of many researchers, a large number of research results have been achieved in the theoretical basic research of reliability assessment, and gradually began to combine theory and practice should be cornered to the engineering practice of power system reliability assessment. Western developed countries have different measures and methods to improve the reliability of their distribution grids. In Canada, the reliability level of power supply is linked to the reliability level of customers, and different reliability standards are set for customer lines of different importance [16]. Japan mainly focuses on the level management of network structure and switching capability, which improves the level of automation of the whole distribution network and ensures the rapid transfer of load after a fault to reduce the outage time, and achieves very good operation results [17]. In the United Kingdom and the United States, detailed reliability guidelines have been developed, giving specific reliability assessment methods, equipment reliability data, basic theory of reliability and economic relationship analysis of distribution network reliability assessment based on non-time-series Monte Carlo simulation algorithm, outage loss data, etc., for reference of each power supply company, and the guidelines have been revised year by year [18]. In conclusion, the distribution network reliability study in western developed countries has achieved good social and economic benefits. The domestic research on power system reliability assessment started late, and the research on distribution network reliability started only in about 1980s, which is slightly later than the reliability research on power generation and transmission system [20]. Due to the lack of statistical data and the lag of analysis methods, the initial research on the reliability of distribution network system basically stayed in the collation of relevant data and the translation of foreign materials. At the same time, the national authorities have issued a series of standards and regulations to improve the smooth operation and reliability of power systems [21]. For example, in the early 1990s, China had its own intellectual property rights of distribution network reliability assessment software (e.g., DSRE-TH1 and its upgraded version DSRE-TH2 developed by Tsinghua University) for urban network and agricultural network renovation [22, 23]. Over the past decades, China's power system reliability management has been carried out in an organized and planned manner, which has not only well adapted to every change and reform in the development of China's electric power industry, but also strengthened and improved its own management system and capability during the reform, and guided the electric power enterprises to scientifically apply the various assessment indicators in the power reliability management in the safety production management It also guides the electric power enterprises to scientifically use various evaluation indicators in electric power reliability management for the analysis and evaluation of electric power system reliability [24]. Through the continuous research of researchers and the technical and management measures of power management departments, the level of power supply reliability in China has made great progress in the past 20 years, but the gap with developed countries is still obvious. However, the gap with developed countries is still obvious. Domestic research is more focused on algorithms and model building, and there is a lack of independent development of software for practical reliability calculation and analysis, which leads to a low application rate of reliability theory research and development [25]. Therefore, in order to ensure the reliability of the operation of the distribution system, it is necessary to adopt a reasonable method to evaluate the reliability of the distribution system, whether for the improvement of the operation efficiency of the distribution system, or for the healthy development of China's electricity, or for the further development of China's market economy in which aspect, it is imperative to evaluate the reliability of the distribution system.

3. Grid-side energy storage capacity configuration method

In this paper, grid-side energy storage is mainly considered to reduce the substation load factor, peak shaving and valley filling in order to reduce the peak-to-valley ratio of the grid load, and the storage capacity allocation methods for substation load reduction and peak shaving are proposed.

3.1. Energy storage capacity configuration method for substation load shedding

Due to the early construction of substations and the low technical standards of equipment selection, most substations have the following problems:

1. The load factor of the substation is high. If the maximum load factor of a substation exceeds 90%, the safe operation of the substation will be seriously threatened.
2. Large peak-to-valley load difference. Some substations have a large peak-to-valley load difference, resulting in a low utilization rate of their equipment as a whole.

3.2. Energy storage capacity allocation methods for peak-shaving and valley-filling

The problem of peak shaving and valley filling is one of the fundamental problems of grid operation. Most thermal power units have insufficient regulation capacity. Hydropower units have flexible operation, rapid start and stop, and a regulation range close to 100%, but the choice of their construction site is entirely dependent on geographical conditions. Energy storage, with its fast response time and the fact that its construction is not restricted by geographical conditions, can meet the large-scale peak and valley reduction needs of the grid. The power of energy storage for peak shaving should be taken as the maximum power limit for grid peaking. The power of energy storage is selected as follows

$$P_{BESS} = \max\left(|\Delta P_1|, |\Delta P_1|, ..., |\Delta P_N|\right) \tag{1}$$

Where: P_{BESS} is the power selection value; $|\Delta P_i| (i = 1, 2, ..., N)$ is the power demand value calculated at each moment. Based on the above determined values of energy storage power, the capacity of energy storage is selected as shown in equation (2) - equation (4).

$$E_{BESS} = \max\left(N_1, N_2\right) \tag{2}$$

$$N_1 = \max\left(|\Delta P_1 \Delta T|, |\Delta P_1 \Delta T + \Delta P_2 \Delta T|, ..., |\Delta P_1 \Delta T + \Delta P_2 \Delta T + ... + \Delta P_N \Delta T|\right) \tag{3}$$

$$N_2 = \max\left(\left|\sum_{i=1}^{m_1} \Delta P_i \Delta T\right|, \left|\sum_{i=m_2}^{m_3} \Delta P_i \Delta T\right|, ..., \left|\sum_{i=m_j}^{m_n} \Delta P_i \Delta T\right|\right) \tag{4}$$

Equation (2) - Equation (4): E_{BESS} is the capacity selection value of the energy storage system; ΔT is the data sampling interval; $1 \sim m_1, m_1 \sim m_2, ..., m_j \sim m_n$ is the time period when the energy storage is in the charge/discharge state.

4. Mathematical model of the user distribution

It was frequently believed in earlier research that the users on the lines were dispersed equally. However, the distribution of users on the actual grid is frequently unequal, which also causes some discrepancy between the theoretical analysis's findings and the actual scenario. As a result, the following equation is used to define the degree of user distribution uniformity:

$$a_k = \frac{NC_k}{C} \tag{5}$$

Obviously, when $a_k = 1$ indicates that the segment k is average, when $a_k > 1$ indicates that the users in segment k is greater than average, and when $a_k < 1$ indicates that the segment k is below average.(See Figure 1)

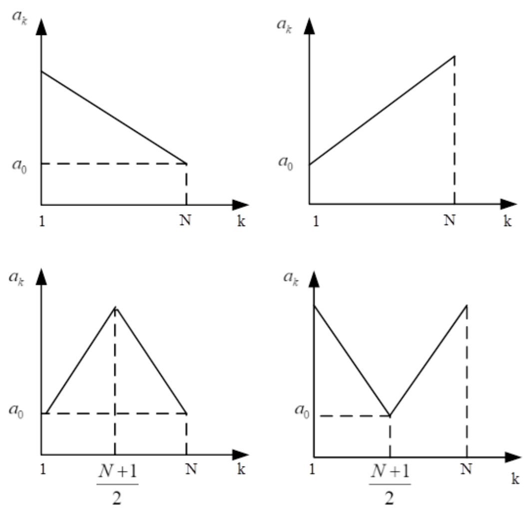


Figure 1. Uniformity of user distribution

4.1. Head-heavy

It is a distribution method with more users at the head end, which is evident from the definition of the degree of uniform distribution of users, i.e.

$$N = \sum_{k=1}^{N} a_k \tag{6}$$

Substituting Eq. (6) into (7) gives thus

$$\beta = \frac{2(1-a_0)}{N-1} \tag{7}$$

Substitute into equation (6) to find the expression for the distribution of head-heavy users

$$a_k = \frac{2(1-a_0)}{N-1}(N-k) + a_0(k \in [1, N]) \tag{8}$$

Where: a_k is the average outage time for fault operation state k; a_0 is the value.

4.2. Head-light distribution

There are more users in the tail and fewer users at the head of the distribution. The expression can be produced as by applying the same thought process as described previously.

$$a_k = \frac{2(1-a_0)}{N-1}(k-1) + a_0(k \in [1, N]) \tag{9}$$

5. Quantitative Analysis

5.1. Assumptions

The following presumptions and simplifications are used to aid computations and discussions.

1. Only single point faults are taken into account; multiple problems and the consequences of scheduled outages are not.
2. No consideration is given to the influence of the higher level grid and the influence of disconnector faults on either side of the switch in the immediate vicinity of the switch.
3. Fuse faults are not taken into account, and since the fuse above the distribution substation will open reliably in the event of a fault, thus limiting the fault to the customer's access point, distribution substation faults are also not considered for the time being for simplicity.
4. Define the number of users per segment as $C_k(k \in [1, N])$, and $\sum_{k=1}^{N} C_k = C$.
5. Set overhead line fault outage rate at λ_0 (times/km-Year), overhead line fault outage time at r_0 (h/time), switch fault outage rate at λ_s (times/unit-Year), switch fault outage time at r_s (h/time), average fault isolation transfer time at t_r (h/time).

5.2. Theoretical derivation

A schematic diagram of the N segmented single radiation is shown in Figure 2. The specific

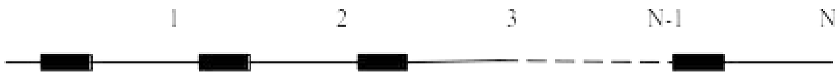


Figure 2. Overhead line with N-segmented single radiation

derivation process can be found in [26], which gives the customer fault outage time in the segment $k(1 \leq k \leq N)$. Therefore, the average system fault outage time for the whole feeder can be obtained as

$$SAIDI-F = \frac{\sum\limits_{k=1}^{N} C_k u_k}{C} = \frac{L\lambda_0}{CN}\left[\sum_{k=1}^{N} C_k k r_0 + \sum_{k=1}^{N} C_k (N-k) t_r\right] + \frac{\lambda_s}{C}\left[\sum_{k=1}^{N} C_k k r_s + \sum_{k=1}^{N} C_k (N-k) t_r\right] \tag{10}$$

Substituting equation (9) into equation (12), we get

$$SAIDI-F = \sum_{k=1}^{N} \frac{a_k k}{N}\left[\frac{L\lambda_0 (r_0 - t_r)}{N}\right] + (L\lambda_0 + N\lambda_s) t_r \tag{11}$$

If the users are uniformly distributed, equation (12) can be written as

$$SAIDI-F = \frac{N+1}{2}\left[\frac{L\lambda_0 (r_0 - t_r)}{N} + \lambda_s (r_s - t_r)\right] + (L\lambda_0 + N\lambda_s) t_r \tag{12}$$

If head-heavy, substituting equation (9) into equation (12) gives

$$SAIDI-F = \frac{(N+1)(a_0+2)}{6}\left[\frac{L\lambda_0 (r_0 - t_r)}{N} + \lambda_s (r_s - t_r)\right] + (L\lambda_0 + N\lambda_s) t_r \tag{13}$$

If head-light, substituting equation (10) into equation (14) gives

$$SAIDI-F = \frac{(N+1)(4-a_0)}{6}\left[\frac{L\lambda_0 (r_0 - t_r)}{N} + \lambda_s (r_s - t_r)\right] + (L\lambda_0 + N\lambda_s) t_r \tag{14}$$

If spindle-shaped, substituting equation (11) into equation (12) gives

$$SAIDI - F = \frac{N+1}{2}\left[\frac{L\lambda_0(r_0 - t_r)}{N} + \lambda_s(r_s - t_r)\right] + (L\lambda_0 + N\lambda_s)t_r \tag{15}$$

If the user distribution is hourglass-shaped, substituting equation (9) into equation (12) gives

$$SAIDI - F = \frac{N+1}{2}\left[\frac{L\lambda_0(r_0 - t_r)}{N} + \lambda_s(r_s - t_r)\right] + (L\lambda_0 + N\lambda_s)t_r \tag{16}$$

Comparing equations (13) to (17), it can be seen that the average system fault outage time is smaller than the case of uniform user distribution when the user distribution is top-heavy, larger than the case of uniform user distribution when the user distribution is top-heavy, and the average system fault outage time when the user distribution is spindle or hourglass shaped. The method does not require network equivalence, the principle is simple and straightforward, the calculation accuracy is high, and it is easy to implement on a computer. It takes into account the difference in the impact of fault outages and planned outages on reliability. When the reliability of a load point needs to be calculated, it is not necessary to analyze all component outages, and the search process does not require the formation of a network adjacency matrix or special chain table relationships, but directly uses the most basic node data table and branch data table to search the network, which is easy to interface with field data. The search algorithm uses recursive algorithms, which can greatly reduce the programming effort, improve the efficiency of over-order execution, and calculate the impact of distribution network automation on reliability.

6. The distribution of users

6.1. Optimal segmentation with integrated consideration of reliability and economy

Cost discounting is used to determine the best segmentation approach for a distribution network since, in addition to the reliability enhancement effect, the implementation cost must also be taken into account. The sum of the segmentation switching cost and the outage loss cost is referred to as the total cost. Can write the total cost function as

$$C_y = C_1 + C_2 = c_b(N-1) + c_pCP \times SAIDI - F \tag{17}$$

Where: C_y is the total cost; C_1 and C_2 are the equipment cost and reliability cost respectively; c_b is the switching unit cost converted to the equivalent annual value. The cost of switching segments increases proportionally with the number of segments, while the cost of outage losses varies roughly as a quadratic curve with the number of segments (See Figure 3). When the users are uniformly distributed, it follows from equations (13) and (22) that

$$N_{best} = \left\lfloor \sqrt{\frac{c_pCP\lambda_s(r_s - t_r)}{c_pCP\lambda_s(r_s + t_r) + 2c_b}} \right\rfloor \tag{18}$$

6.2. Examples and analysis

(1) Example 1

Example 1 uses a typical distribution system, the network in RBTS. The line and load conditions in the system are shown in Tables 1 and 2. F1 and F2 are contacted lines and F3 and F4 lines are non-contacted lines. According to the alternative optimal installation location of switches proposed in this paper, the switchgear in the non-contacted section needs to be installed at the power end of the line section, while certain segmental switch locations are located at the non-power end of the non-contacted section.

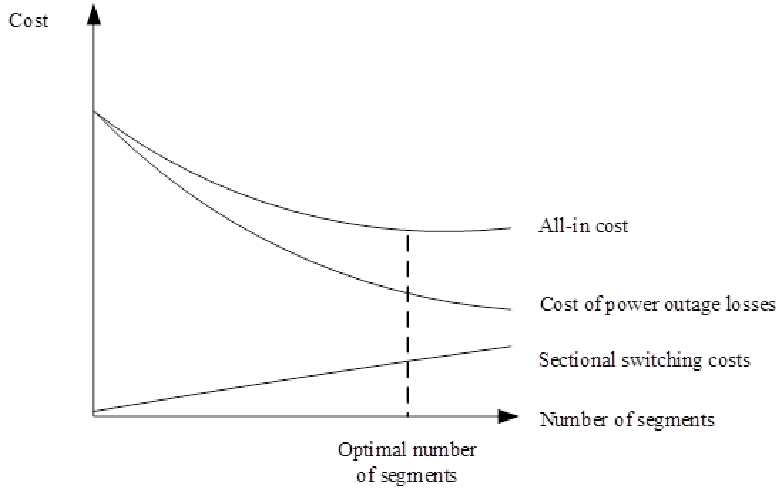


Figure 3. Relationship segments

Feeder type	Line length (km)	Line section
1	0.7	2,6,10,14,17,21,25,28,30,34,41,47
2	0.76	1,4,7,9,12,16,19,22,24,27,29,32,61
3	0.9	3,5,8,11,13,15,18,20,23,26,31,33,47
4	1.0	38,44
5	1.7	37,39,42,49,54,62
6	2.6	36,40,52,57,60
7	2.9	35,46,50,56,59,64
8	3.3	45,51,53,58,63,
9	3.6	48

Table 1. Line types and lengths

Based on the alternative optimized installation locations for the switches proposed in this paper, the switches at line sections 31, 37 non-powered end, 40 non-powered end, 44 non-powered end and 46 non-powered end in Table 2 can be removed. The reliability of the system after the removal of these five switches is compared with that without the removal; and the switches on lines F2, F3 and F4 are optimally configured. The results are shown in Table 3, assuming a fault rate λ of 0.05 faults/(year-km) and t_1 of 4 h: As can be seen from Table 3: According to the selection of alternative optimal installation locations for the switches proposed in this paper, the reliability of the RBTS-BUS6 system did not decrease when the switches at line sections 31, 37 non-powered end, 40 non-powered end, 44 non-powered end and 46 non-powered end were removed, but remained the same as before; the system SAIDI was 2.76h and the ENS was 27,800 kWh/year. However, when considering the failure of the switches, the system SAIDI obtained in this paper is increased and the ENS is reduced because the number of segment switches is reduced.

According to the definition of the switch beneficiary load and isolated line length can be seen, the system F4 feeder for the radiation type of line, line section 37, 40, 44, 46 on the load and no load, in its non-power end of the installation of segment switches, the beneficiary load and isolated line length are 0, so there is no need to install segment switches.

(2) Calculation Example 2

This paper uses actual feeders for calculations. The length of the line and the load data are shown in Table 4. a fault rate λ of 0.05 faults/(year-km) and t_1 of 4 h are assumed. the ENS is used as a reliability indicator for the line segmentation.

Total	Node	Type	Average load size (MW)	Quantity
5	1-3,10,11	Resident	0.536	211
4	12,17-19	Resident	0.46	201
1	23	Resident	0.297	148
4	25,28,31,36	Resident	0.279	80
4	27,29,33,36	Resident	0.2832	75
1	8	Small user	2	2
1	9	Small user	1.16	2
6	4,5,13,14,20,21	Government/Industry	0.567	2
5	6,7,15,16,22	Business	0.455	11
2	32,37	Agriculture	0.5026	2
2	30,34	Agriculture	0.6518	2
1	35	Agriculture	0.687	2
2	24,40	Agriculture	0.7966	2
2	26,38	Agriculture	0.7376	2

Table 2. Line Load Conditions

Method	Number of switches	SAIDI(h)	ENS (10000 kWh/year)
Literature [1]	14	2.76	2.78
This document (considering only alternative installation locations)	9	2.76	2.78
This paper	6	2.71	2.73

Table 3. Comparison Results of Switch Optimization

The alternative installation locations for the switches without and with contact lines are shown in Figure 4 and Figure 5. The results of the forward and backward quadratic optimization algorithms in this paper are the same and the results of the switch configurations without and with contact lines are shown in Figure 6 and Figure 7 respectively.

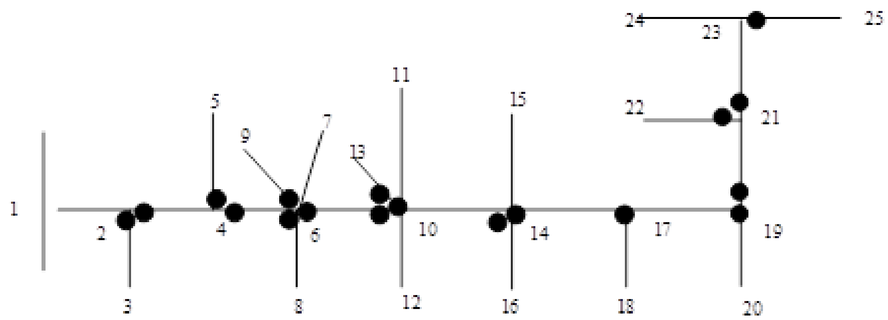


Figure 4. Diagram showing the distribution of alternative installation locations for switches without contact lines

A comparison of the calculation results of the method in this paper with those in the literature [27] and literature [28] is shown in Table 5. When the line is a non-contact line, its maximum effective number of segments is 3, requiring the installation of 2 segment switches, located at the front end of 6-10 and 14-17, with an ENS of 204,800 kWh/year; the method in literature [27] also requires the installation of 2 switches, located at the front end of 6-10 and 17-19, with an ENS of 205,000 kWh/year. The method in this paper reduces the system energy deficit (ENS) by 1% compared to the method in the literature [27] with the same capital investment. The maximum effective number of segments with contact lines is 5, requiring the installation of 4 segment switches, located at 4-6 rear end, 6-10 rear end, 10-14 front end and 17-19 rear end, for an ENS of 113,500 kWh/year; the method in the literature [28] also requires the installation of 4 switches, located at, 6-10 rear end, 10-14 front

Starting point	End	Line length (km)	Load (kw)
1	2	0.404	
2	3	0.121	193
2	4	0.525	
4	5	0.481	202
4	6	0.611	
6	7	0.001	135
6	8	0.221	640
6	9	0.000	362
6	10	0.264	
10	11	0.000	202
10	12	0.937	640
10	13	0.816	362
10	14	0.584	
14	15	0.000	659
14	16	0.196	202
14	17	0.000	
17	18	0.201	384
17	19	0.201	
19	20	0.205	640
19	21	0.141	
21	22	0.605	256
21	23	0.401	
23	24	0.000	256
23	25	0.401	244

Segment mode	Method	Sectional switch position	ENS (10000 kWh/year)
No contact	Method in this article	6-10 power supply terminal, 14-17 power supply terminal	20.48
	Literature [27] Methods	6-10 power supply terminal, 17-19 power supply terminal	20.50
Connected	Method in this article	4-6 standby power supply terminal, 6-10 standby power supply terminaler supply terminal	11.35
	Literature [28] Methods	6-10 main power supply terminal, supply terminal, 19-21 main power supply terminal	11.40

end, 14-17 rear end and 19-21 rear end, with an ENS of 11.4 million kWh/year. The method in this paper reduces the system energy deficit (ENS) by 4.38% for the same investment compared to the method in the literature. This shows that, compared to various other methods, obtaining the same number of sectional switches but different installation locations; the method in this paper results in higher reliability.

6.3. Grid line optimization

The two scenarios of wind power breeze off-grid under rainy conditions and wind power strong wind off-grid under sunny conditions are studied for the grid user distribution network. Figure 8 reflects the wind power breeze off-grid in the grid user distribution network under cloudy and rainy conditions.

As can be seen from the above figure, for the load disturbance of sine wave plus square wave plus white noise, the scheme in this paper basically converges in about 1500s. The controller convergence time of 2000s appears to be smaller, and the convergence can basically track the sudden load disturbance well after convergence, with fast convergence and high stability. 67000S later at night, the grid user distribution network stops working, and the scheme in this paper timely adjusts the output of small hydropower and gas turbine, which quickly compensates the lack of output due to the withdrawal of grid user distribution network and wind power failure. The only shortcoming is that during the process from 70,000s to 73,000s, the AGC fluctuates frequently, causing some difficulties for the

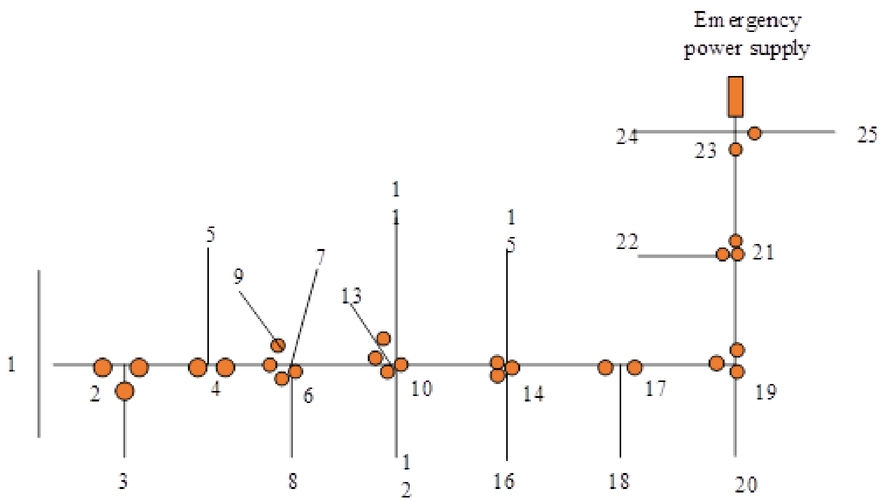


Figure 5. Schematic Diagram of Alternative Installation Locations of Interconnection Line Switches

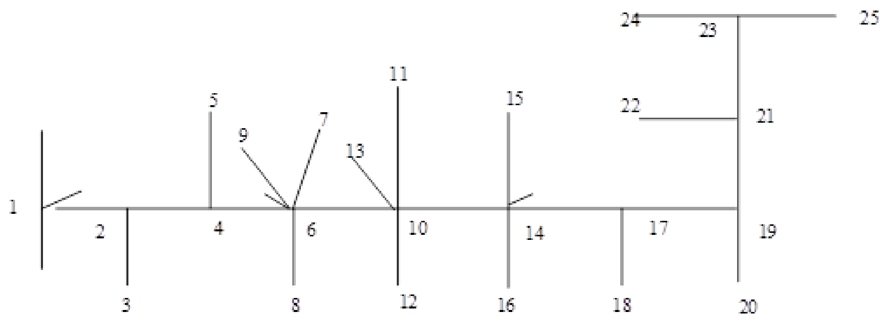


Figure 6. Schematic diagram of the results without contact lines

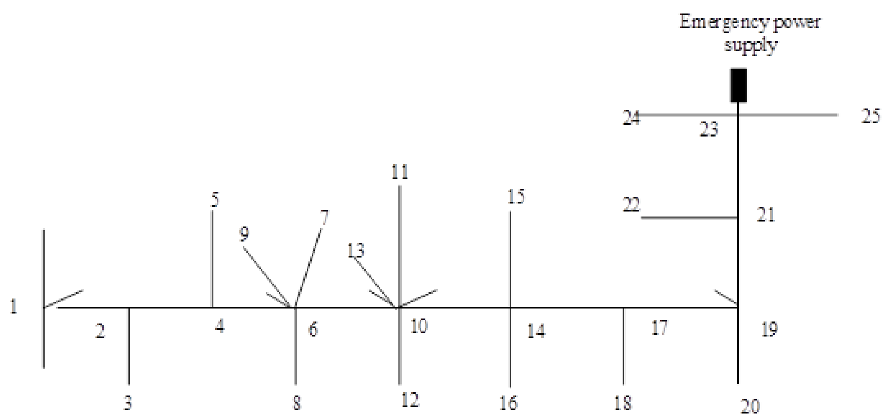


Figure 7. 7 Schematic Diagram of Results with Connecting Lines

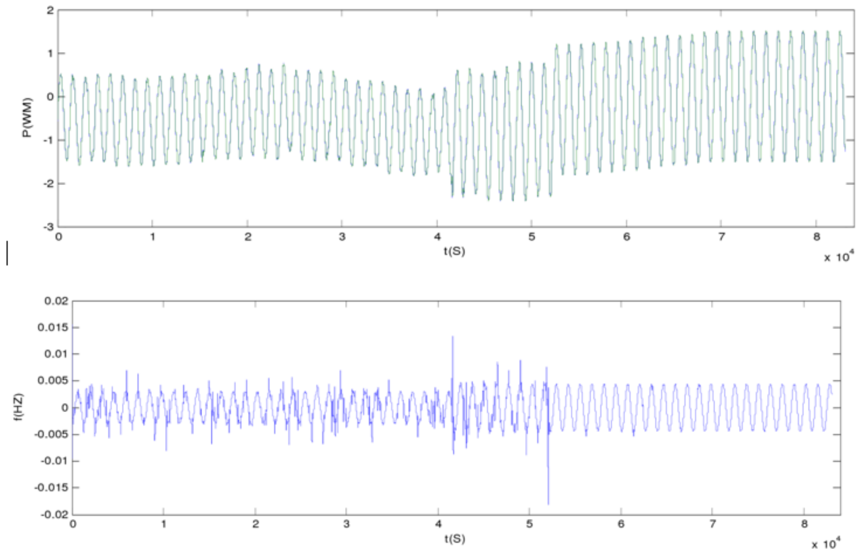
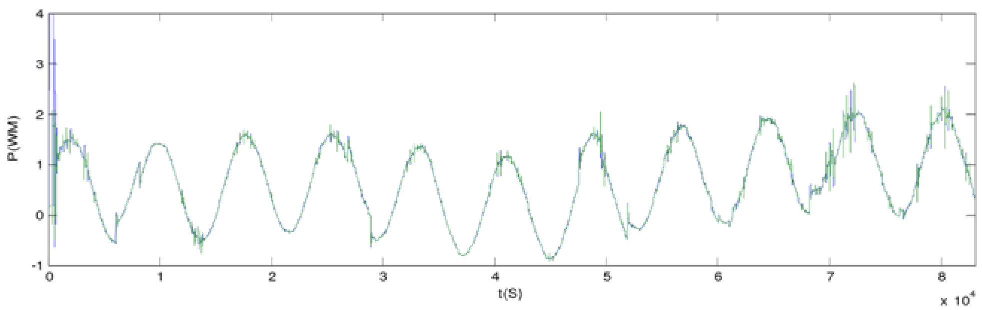
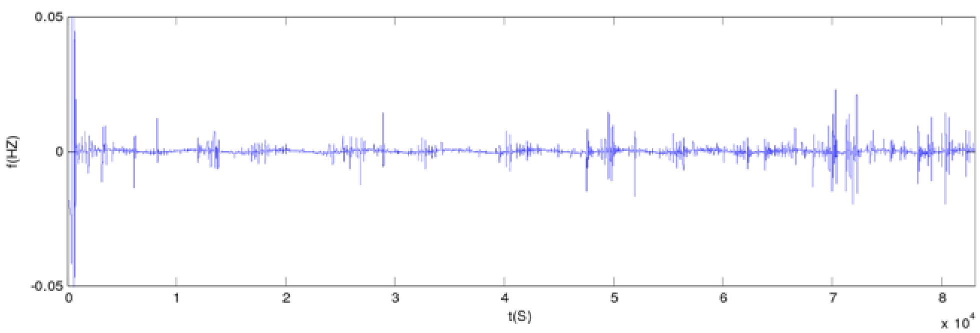


Figure 8. Wind power breeze off-grid for grid customer distribution network in rainy conditions



(a)Comparison of AGC regulation command and actual unit processing



(b) Micro grid frequency

Figure 9. Wind power strong wind off-grid for grid customer distribution network under clear weather conditions

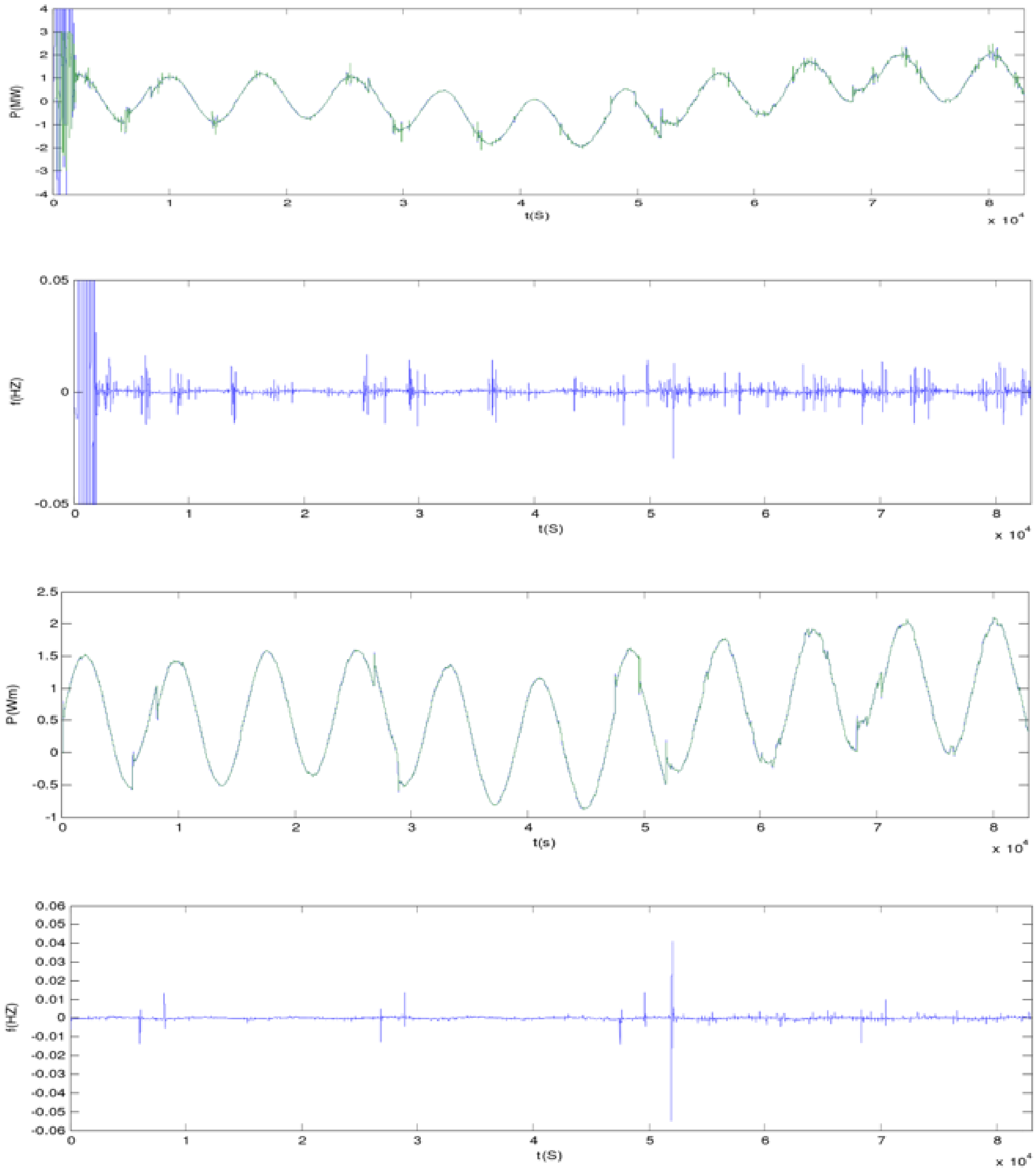


Figure 10. PROP simulation results

load tracking of small hydro and gas turbines, which is shown in the graph as a large burr. At 52,000s, the wind power suddenly went off-grid due to a fault, and the scheme in this paper also tracked the load change in time to avoid the sudden drop in frequency caused by the wind power going off-grid. Similarly, Figure 9 reacts to the strong wind off-grid of the grid user's distribution network under clear weather conditions[29].

In this paper, distribution optimization is introduced as the comparison algorithm for this paper's scheme. The simulation results of the distribution optimized controller are shown in Figure 10 under the same microgrid LFC model, using exactly the same parameters.

Distributed Optimization is able to track the output of AGCs from 0S onwards because it does not need to go through a pre-learning process, whereas reinforcement learning requires a lot of ”trial and error learning” upfront. In terms of tracking the output of the AGC, distributed optimization is more effective, but in terms of the frequency of the microgrid, distributed optimization has a large frequency change and does not improve every time there is a sudden surge (drop) in load or a sudden drop in generation load. If the system is subject to long term transient changes in load or generation, which is more likely to occur in the case of microgrids, then it may cause irregularities or even failures in the microgrid. This means that distribution optimization can only respond 'mechanically' to changes in load, but not 'intelligently' to learn how to solve the same problem the next time it is encountered.

7. Conclusion

In this paper attention has been paid to algorithms for optimizing the configuration of medium voltage overhead line switches. In order to answer for the segmentation configuration of distribution networks, the issue of more complicated computer models is addressed. However, the results acquired through simulation are frequently not universal. This research offers a theoretical framework for segmenting feeders in order to address this issue, although all theoretical analyses make the assumption that users are distributed uniformly without taking into account the implications of uneven user distribution. The impact on line reliability and optimal number of segments when users are unevenly distributed is further investigated. The experiments show that the distribution optimization works well in terms of tracking the output of the AGC, but in terms of the frequency of the microgrid, the frequency of the distribution optimization changes significantly and does not improve each time there is a sudden surge (drop) in load or a sudden decrease in generation load.

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Conflict of interest

The authors declare no conflict of interests.

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