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# A Comparation Study of Transmission Line Routing Based on A* and RRT Algorithms

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## ABSTRACT

Transmission line design is an important part of power grid engineering design, and transmission line path selection is the basis of line design. Transmission line route selection is to select a line path that can not only meet the requirements of power transmission and consumption, but also consider the cost control of the line, and avoid the farmland, highways, ecological exclusion zone between the start and end of the transmission line. The path scheme is constrained by geographical factors, project cost, construction conditions, operation and maintenance conditions, which makes the path selection show the characteristics of comprehensive diversity, spatial complexity, policy influence and so on. In the traditional route selection of transmission lines, line design specialists need to go through blind route selection, site survey and other steps to determine the path scheme, but because of insufficient effectiveness of the map, it is difficult to reflect the real environmental information, resulting in repeated route selection work to determine the final path scheme. In this paper, the selection principle of transmission line path is introduced first. Then, two path optimization algorithms, i.e. A* algorithm and rapidly expanding random tree (RRT) algorithm, are used to select transmission lines respectively. Finally, the advantages and disadvantages of these two algorithms in practical engineering line selection design are comparatively analyzed. Compared with the way of A* algorithm, RRT algorithm is more suitable for practical application of power system. It aims to provide a reference for the method of intelligent line selection in subsequent transmission design.

***Keywords:*** A* algorithm; Rapidly expanding random tree (RRT) algorithm; Transmission line design

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# 1. Introduction

With the concept of "new infrastructure construction" proposed by the National Development and Reform Commission of China in 2020, electricity is one of the basic industries of the country and a crucial basic energy industry in the development of China's national economy. In the process of China's rapid economic development, its construction scale is also expanding with the increasing demand for electricity. The advanced level of transmission line equipment quality and technology has also been significantly improved, and the previous transmission line maintenance management mode and operation overhaul mode can no longer meet the needs of modern power grid production management [1,2].

Transmission line path optimization not only affects the overall planning of the power grid, but also affects the continuous coordinated and stable operation of the power system, not only affects the investment, but also affects the construction quality and operation safety [3,4]. Transmission line path design is a basic content of line engineering design, and there are mature method systems in this field. However, with the development of computer technology and the wide application of remote sensing and GIS geographic information science in power system, more effective technical means are provided for the optimal design of transmission line paths [5].

In recent years, many common path optimization algorithms and corresponding improvement algorithms have appeared. These algorithms have their own characteristics in terms of space complexity, time complexity, ease of implementation and scope of application [6–8]. Wang [9] provides an improved Dijkstra labeling algorithm, which effectively solves the shortest path problem of connected undirected weight graphs and directed weight graphs. Then, they [10] improved Dijkstra's algorithm and effectively solved the problem of multiple adjacency points and multiple shortest paths. The improved algorithm based on Floyd algorithm can effectively solve the problem of multiple equivalent shortest circuits [11]. The A* algorithm has simple principle, high path planning efficiency [12] and high success rate of searching the optimal path. The RRT algorithm has simple modeling [13], strong searching ability and is suitable for high-dimensional environment. Each shortest path algorithm has its own advantages and is suitable for different network structures [14].

In this paper, the path optimization problem is analyzed, A* algorithm and RRT algorithm are described comprehensively, and the advantages and disadvantages of the two algorithms in the actual transmission line selection design are compared, which aims to provide intelligent solutions and strategies for the pre-construction of transmission systems.

# 2. Methods

## 2.1 Selection Principles of Transmission Line Routing

In the process of transmission line routing, it is necessary to consider many factors, including geographical environment, regional planning, line construction cost and so on.

(1) In line selection, the line should avoid crossing important units, such as military areas, airports, large industrial and mining enterprises, etc., to ensure the normal order or production safety of these units.

(2) Attention should be paid to avoid the poor geological areas in the area where the line is located, such as areas prone to landslides and debris flows, complex topographic structures and high-risk forest fires, to ensure the safety of the line operation and the convenience of maintenance.

(3) Pay attention to the crossing of the whole line, the general line needs to avoid crossing roads, railways, communication lines, power lines, rivers, etc., and reduce the crossing along the line to save the cost of line construction.

(4) The path selection should consider the housing demolition and deforestation that may be caused by the construction, and save the economic compensation of the line project.

The influencing factors are divided into four aspects: land use type, crossing, landform and building facilities.

(1) The land type criteria include four factors: ag-

ricultural land, forest land, planned land and artificial landform.

(2) The cross-crossing criteria include four factors: railway, intercity highway, oil and gas pipelines, power lines and communication lines.

(3) The building facilities criteria include four factors: scattered houses, public facilities, industrial and mining enterprises and important areas.

(4) The topographic and geomorphic criteria include four factors: flat land, river, mud and mountain.

## 2.2 Algorithm of Transmission Line Routing Optimization

The minimum cost overhead model of transmission line path is established, and the optimal path of transmission line is solved automatically by A* algorithm or RRT algorithm, and alternative routes are given. Each line provides specific parameters including the exact position, height, model, wire diameter and so on.

### *A* Algorithm*

A* algorithm searches the target location through heuristics, and can find the shortest path by using edge cost and Euclidean distance based heuristics. The A* algorithm takes the starting point as the first current node, calculates the generation value of adjacent nodes of the current node, selects the node with the least generation value among all nodes to be searched as the current node of the next round of search, and repeats this process to expand the search nodes until the target point is reached. Typically, the A* algorithm searches for 4 adjacent nodes in each extension, as shown in **Figure 1 (A)**. However, fixing and limiting each turn Angle to 90° affects the search efficiency and increases the path length and turn Angle. In this paper, an 8-connected approach is used to improve the path planning efficiency and path quality. As shown in **Figure 1 (B)**, the number of adjacent nodes for each expansion has been increased from 4 to 8, and the steering Angle is set to 45° or 90°.

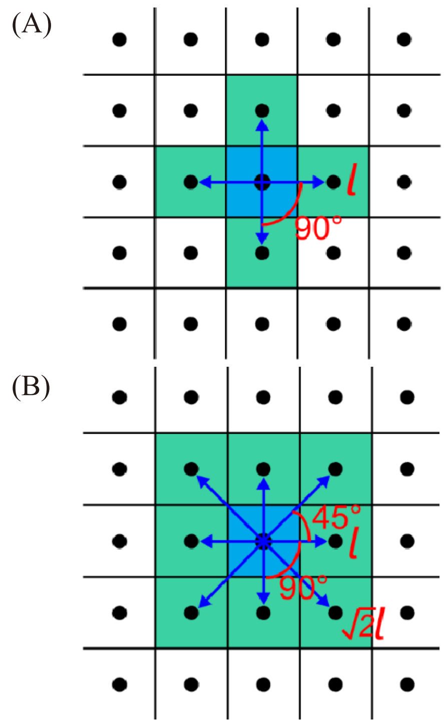



**Figure 1.** The connected types of the grid cells of A* algorithm. (A) 4 adjacent nodes are connected; (B) 8 adjacent nodes are connected.

In the process of searching the path of the A* algorithm, the basic idea of calculating the cost of each node by using the cost function is to evaluate the node by combining the cost $g(n)$ of the arrival node and the cost $h(n)$ from the node to the target node. The cost function is defined as follows:

$$f(n) = g(n) + h(n) \tag{1}$$

$n$ on behalf of the current node type, cost function $f(n)$ is the total of the current node $n$ generation value, $g(n)$ representative from starting point to the current node $n$ the value of generation, $h(n)$ representatives from the current node $n$ estimates of the generation of value to the target node need.

When selecting a heuristic function, if $h(n) = H(n)$ ($H(n)$ is the actual path cost from the current node $n$ to the target point), the A* algorithm will only search for the optimal path node, which will greatly reduce the computation. The commonly used heuristic functions $h(n)$ include Euclidean distance function, Manhattan distance function and Chebyshev distance function. In this paper, considering that A* algorithm searches 8 adjacent nodes in each extension, the path estimated by Euclidean distance function as a heuristic function is closer to the actual path. Assuming that the current node is ($x_n$, $y_n$), the target node for ($x_G$, $y_G$) heuristic function based on Euclidean distance function can be expressed as follows:

$$h(n) = \sqrt{(x_G - x_n)^2} + \sqrt{(y_G - y_n)^2} \tag{2}$$

The Manhattan distance function between the current node ($x_n$, $y_n$) and the target node ($x_G$, $y_G$) can be expressed as:

$$h(n) = |x_G - x_n| + |y_G - y_n| \tag{3}$$

The Chebyshev distance function between the current node ($x_n$, $y_n$) and the target node ($x_G$, $y_G$) can be expressed as:

$$h(n) = \max(|x_G - x_n|, |y_G - y_n|) \tag{4}$$

***RRT Algorithm***

The RRT algorithm sets the starting point as the first node of the random tree, that is, the root node, and then performs random sampling in the entire workspace to complete the expansion of the random tree. Each expanded new node can be added to the random tree after passing the collision detection. The above process is repeated continuously until the point on the random tree is within the scope of the target point. Then the target point is added to the random tree and the sampling is stopped. Finally, a feasible path connecting the start point and the target point is obtained through path backtracking.

In order to understand the principle of RRT algorithm, it is assumed that the robot moves in the state space C, and the initial state space $C$ is divided into two parts: feasible region $C_{free}$ and obstacle region $C_{obs}$. **Figure 2** shows a diagram of a random tree expanding new nodes in a feasible space.

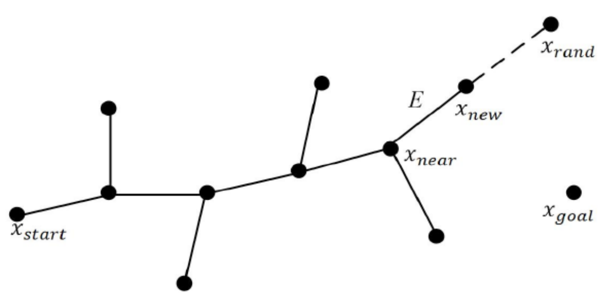



**Figure 2.** Expansion plot of nodes of a random tree.

In the execution of the algorithm, $T$ represents the random tree, $x_{start}$ represents the starting point of the random tree, $x_{goal}$ represents the end point of the planning, $x_{rand}$ represents the randomly generated points in the entire map during this expansion, $x_{near}$ is the point with the shortest distance between $x_{rand}$ and the existing nodes of the random tree, and a specific length is grown along the direction from $x_{near}$ pointing to $x_{rand}$ to get $x_{new}$. If the line $x_{near}$ to the line $x_{new}$ avoids all obstacles, then the growth succeeds and the new node is added to the random tree, otherwise the growth expansion fails, and then the next round of random points is generated. When the end point is successfully connected, it means that the path planning is successful, and then it continues to look for the parent node from the end point until it reaches the starting point, and all points can be connected to form a path.

When the RRT algorithm expands the random tree, the compensation for expanding the new node along the direction $x_{rand}$ points to $x_{new}$ is $\delta$. The coordinates of the newly expanded node $x_{new}$ are:

$$xnew = xnear + \frac{(x_{rand} - x_{near})}{\|x_{rand} - x_{near}\|} \times \delta \tag{5}$$

Where the value of $\|x_{rand} - x_{near}\|$ is equal to the length of the vector from $x_{near}$ to $x_{rand}$, and the coordinate of the new node $x_{new}$ is the coordinate of $x_{near}$ plus step size $\delta$ times the unit vector of ($x_{rand} - x_{near}$).

# 3. Results

## 3.1 Analysis of advantages and disadvantages of different algorithms

The A* algorithm is a search-based algorithm usually used for precise path planning problems, such as finding the shortest path in the graph structure, avoiding obstacles in the grid structure, and finding the optimal path.

RRT algorithm is a sample-based path planning algorithm that generates candidate paths by randomly sampling in a continuous or discrete space. The optimal path is then selected by evaluating the quality of these candidate paths. Suitable for continuous state Spaces or problems with many possible paths.

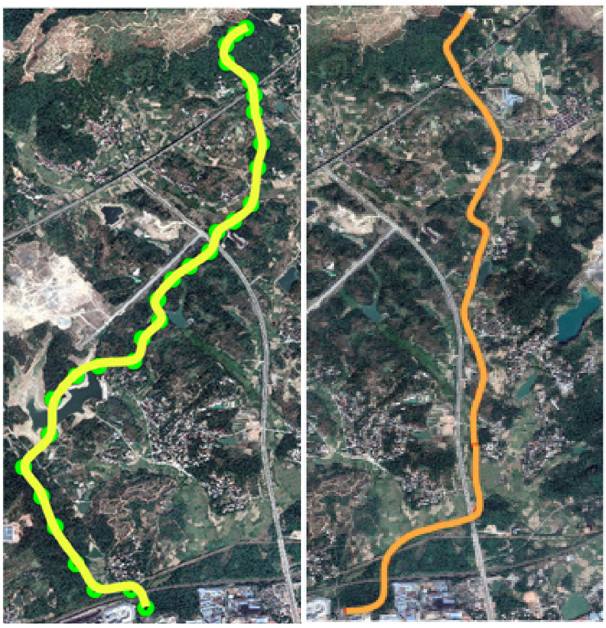
The A* algorithm excels in its ability to find the shortest path efficiently by utilizing a heuristic function to guide the search process. It is highly effective in static environments where the map is known and does not change. However, the A* algorithm may struggle in dynamic environments where the map is subject to change, as it requires frequent recalculations. Additionally, A* can be computationally expensive for large-scale problems due to its complete search approach.

In contrast, the RRT algorithm's strength lies in its ability to handle high-dimensional and non-convex spaces. It is particularly adept at dealing with dynamic obstacles and changing environments, as it can quickly adapt to new configurations. RRT does not require a priori knowledge of the environment, which makes it highly flexible. However, the paths generated by RRT may not always be optimal or the shortest, as the algorithm relies on random sampling, which can lead to suboptimal solutions.

### 3.2 Analysis of line selection results

In this work, based on the municipal power grid data of a certain city and combined with the actual demand, simulation experiments were conducted, and the results are shown in **Figure 3**. The RRT algorithm generates the same recommended path and can find the shortest path in the generated graph structure. The A* algorithm is a generative algorithm, which is planned by directly rasterizing the map to distinguish obstacles, and the obtained path is longer, which is more suitable than the path obtained by generating maps and combining the RRT algorithm. The reason is that in the transmission system problem, the generative algorithm cannot comprehensively consider the two methods of crossing and obstacle avoidance, and each step length is the same.

Furthermore, the A* algorithm, due to its fixed step length, struggles to efficiently navigate complex terrains or span larger gaps which are common in overhead power line routing. This limitation makes it less suitable for the dynamic and irregular nature of such environments. In contrast, the RRT algorithm offers greater flexibility in pathfinding. It can dynamically adjust its step size and direction, enabling it to effectively handle the diverse challenges presented by the terrain, such as avoiding obstacles and spanning large distances without predetermined constraints. Consequently, RRT is more adept at finding feasible and efficient routes for overhead power line planning, where adaptability and the ability to negotiate varied obstacles are crucial.



**(A)** **(B)**

**Figure 3.** Path planning results of different algorithm. (A) A* algorithm; (B) RRT algorithm.

# 4. Discussion

Digital technology has been widely used in power system, improving the stability, security and economy of power system operation. However, as the basic work of power system, grid engineering design from digital to intellient approach still needs to speed up. Power grid engineering design still adopts more traditional design methods, especially in the design of transmission lines, although there is a special automatic calculation software to assist the designer's work, but it has not fundamentally changed the engineering design mode. In route selection, the paper map used by the designer is often very old, and it is difficult to provide real geographic information, resulting in the primary route often cannot meet the requirements, and it requires repeated route plan modification and site survey, which is a time-consuming and personnel energy work.

In this paper, when A* algorithm and RRT algorithm are used to realize path generation, the result of path generation partially cannot meet the design requirements, and it needs to be manually corrected. In the further study of transmission line routing, the evaluation index system of routing scheme can be established to realize the quantitative evaluation of routing scheme. Nevetheless, the algorithmic comparison in this study illustrates the significance of intelligent route selection and has far-reaching im plications for the intelligent transformation of power lines in a broader context.

# 5. Conclusions

Power grid planning and design is the foundation of power grid construction, and scientific and reasonable power grid planning and design is an important premise to ensure the safe operation of power grid. With the rapid development of China's economy and the acceleration of energy base construction, higher requirements are put forward for power grid construction. The optimal selection of transmission line path is the basic content of line design, and determining a reasonable route scheme will directly affect the cost of line engineering and the reliability of system operation. In this paper, the environmental factors affecting transmission line routing are studied to provide data basis for the algorithm to search the optimal path, and the advantages and disadvantages of A* algorithm and RRT algorithm in transmission line routing are compared and analysed. The results found that RRT algorithm is more suitable for transmission line crossing and other requirements. Compared with the way of A* algorithm, RRT algorithm is more suitable for practical application of power system. The conclusion of this paper is expected to provide reference for the development of digital intelligence in the transmission link of new power systems.

# Author Contributions

Yun Cao- Resource provision
Xuanyuan Zheng - Transmission guidance
Qin Gu- Line design experience sorting
Lijun Hu- Fund acquisition
Yan Geng- Project management
Xiaoyan Zhu- Original writing
Jiahui Chen- Algorithm implementation
Ling Peng- Digital base and Supervision
Yinghui Han- Visualization, Approach, and Review

# Conflict of Interest

The authors declare no conflict of interest.

# Data Availability

The dataset supports the finding of the study are available from the corresponding author upon request.

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