New Energy Consumption Analysis Based on Power Flow Tracing

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Abstract. As energy and environmental issues become more severe, the proportion of new energy into the grid is also increasing year by year, and the accompanying process of consumption requires more accurate methods for analysis. Flow tracing has always been the basis of network loss allocation and economic and economic accounting, which can ensure fairness at the physical and economic levels. Through the flow tracing, the injection power and network loss of each power source can be obtained, and the power source problem of any branch or load of the power grid can be solved. By tracing the power of the node, the correspondence between the power generation and the power consumption and the power generation and power consumption are determined. The power relationship flows through the power transmission element. In this way, when new energy is connected, in order to understand the consumption of new energy, the power flow tracing method can be used to obtain the power distribution of new energy in the power grid. This paper will use the 6-node distribution network to join the new energy, use the power flow tracing to form a new energy consumption map, and analyze the power distribution of the new energy in the power grid.

1. Introduction
Since the release of the China national “13th Five-Year Plan” energy plan, it has had a profound impact on the development of new energy and promoted the rational consumption of new energy. With the launch of the “14th Five-Year Plan” energy plan, the consumption of new energy will surely develop steadily. Extensive research has been carried out on the integration of new energy into the grid at home and abroad, but most of them only analyze the location and consumption of consumption, but the process of dissipating new energy has not been analyzed.

To study the process of new energy consumption, we can use the trend tracing method for analysis. The trend tracing method has always been the closest to the basic theory of the circuit, and it is more accurate and clear to analyze the new energy consumption process. The trend tracing proposed by Bialek.J and Kirschen.D in 1996-1997 is to solve the power distribution relationship between generators, loads and lines, initially to solve the network loss allocation problem, but only for lossless networks¹¹,². Various tracing methods are then formed, such as current tracing in forward tracing,¹³, electrical profiling,¹⁹, power component method,¹⁰, and countercurrent tracing.¹¹ Among them, the current tracing method is essentially a principle of proportional sharing, and the rationality has not been confirmed. However, the electrical analysis method does not define the multiple injection power form, and performs the equivalent calculation on the network, trying to achieve the purpose of port equivalence.
It is difficult to give the public because it is difficult to give theoretical proof. The countercurrent tracing method must also apply the power component theory when multiple power supplies are used. The power component theory is based on the power flow. The circuit analysis method is used to establish the relationship between the node voltage and the power injection current. The relationship between the power injection power, the load power, the branch loss power and the power component of the branch injection power is described. The power attribute divides the power supply share of the power in the grid.

The power component power flow tracing method uses the basic theory of the circuit to analyze the physical distribution characteristics of the grid power from the perspective of injection power decomposition, and obtains the analytical expression of the power of the multi-supply current component in any node and branch of the electric network. The source of the power cross term is clarified. The power component is proposed according to the theory of network independent distribution, which reveals the distribution law of multi-power network power. For the distribution network with new energy access, the new energy is equivalent to a current source, and then the trend tracing is used to form a new energy consumption analysis chart, and the new energy consumption is analyzed.

2. Power flow tracing

Power flow tracing based on power component theory derives power decomposition results from the global distribution of power using the distribution of power, and can obtain the results of network loss allocation. Therefore, the power flow tracing based on the power component theory does not need to consider the problem of the positive direction of the power flow, and there is no problem of circulating current and determining the directed graph. From the physical point of view of the power component, the downstream tracing is a normal sequence, reflecting the physical process of power supply, line transmission, and load consumption.

The derivation of the power component theory using the superposition theorem. The steady-state distribution network can be equivalent to a circuit network, and its node voltage equation is

\[ YU = I_s \]

In the middle, \( Y \) is the node admittance matrix, \( U \) is the node voltage column vector, \( I_s \) is the power injection current column vector. The above formula can be written as

\[ \hat{U} = Y^{-1}I_s = ZI_s \]

In the middle, \( Z \) is the inverse of the node admittance matrix. The above formula can be written as

\[
\begin{bmatrix}
\hat{U}_1 \\
\hat{U}_2 \\
\vdots \\
\hat{U}_{q+1} \\
\vdots \\
\hat{U}_n \\
\end{bmatrix} = \begin{bmatrix}
Z_{11} & Z_{12} & \cdots & Z_{1q} & \cdots & Z_{1n} \\
Z_{21} & Z_{22} & \cdots & Z_{2q} & \cdots & Z_{2n} \\
\vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\
Z_{q1} & Z_{q2} & \cdots & Z_{qq} & \cdots & Z_{qn} \\
\vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\
Z_{n1} & Z_{n2} & \cdots & Z_{nq} & \cdots & Z_{nn} \\
\end{bmatrix} \begin{bmatrix}
I_{s1} \\
I_{s2} \\
\vdots \\
I_{sq} \\
\vdots \\
I_{sn} \\
\end{bmatrix}
\]

Node any node \( i \) voltage is

\[ \hat{U}_i = \sum_{m=1}^{q} Z_{im}I_{sm} \quad (i = 1, 2, \ldots, n) \]

Equation gives an analytical relationship between the node voltage and the power injection current. The internal resistance of the current source is incorporated into the network-to-ground branch. At this time, the power supply is an ideal constant current source, and the port power of the ideal source must be completely output by itself and does not contain the power components of other power sources.
This is very important, indicating that the independent nature of the power supply. The power injection power $\hat{S}_{Sk}$ obtained according to the basic circuit theory is as shown in the following equation:

$$\hat{S}_{Sk} = \hat{U}_k \cdot \hat{I}_{Sk} = \sum_{m=1}^{q} Z_{mi} \hat{i}_{Sm} \hat{i}^*_{Sk} (k = 1, 2, \cdots, n)$$

Contact branch power $\hat{S}_{ij}$ and power to the ground branch $\hat{S}_i$ is

$$\hat{S}_{ij} = (\hat{U}_i - \hat{U}_j) \cdot \hat{i}^*_{ij} = -y_{ij}^*(\hat{U}_i - \hat{U}_j)(\hat{U}_i - \hat{U}_j)^*$$

$$\hat{S}_i = \hat{U}_i \cdot \hat{i}^*_{i} = \hat{U}_i \cdot \left(\frac{\hat{U}_i}{z_i}\right)^*$$

$$= \sum_{m=1}^{q} z_{mi} y_i^* \hat{U}_i \hat{i}^*_{ms}$$

Further derivation

$$\hat{S}_{ij} = (\hat{U}_i - \hat{U}_j) \cdot \hat{i}^*_{ij} = -y_{ij}^*(\hat{U}_i - \hat{U}_j)(\hat{U}_i - \hat{U}_j)^*$$

$$= -y_{ij} \sum_{m=1}^{q} \sum_{l=1}^{q} (z_{mi} - z_{mj})(z_{li} - z_{lj})^* \hat{i}^*_{ms} \hat{i}^*_{ls}, (i, j = 1, 2, \cdots, n)$$

In addition to the power component of the $\hat{i}^*_{ms} \hat{i}^*_{ls}$ form, the power expression also contains power components of the form $\hat{i}^*_{ms} \hat{i}^*_{ls}$, and these components clearly indicate the attribution of power. Therefore, the self-power is defined as: a power component having a shape of $\hat{i}^*_{ms} \hat{i}^*_{ls}$, representing the power that the power source $k$ acts on the network alone; the mutual power is defined as: a power component having a shape of $\hat{i}^*_{ms} \hat{i}^*_{ls}$, representing the power emitted by the power source $k$ by the power source $i$. Obviously, self-power is a special case of mutual power. Each power supply in the network can only provide $q$ kind of power components, $q$ kind of power supplies provide $q^2$ kind of components, and the branches contain all $q^2$ kinds different forms of power components. To this end, the power component theory is proposed as follows: any power component of each power supply is consumed in the network independently of other components; the power component coefficients indicate their distribution law and are determined by the structure and parameters of the network.

3.Consumption analysis

The analysis method has been used. After the new energy is added to the power system, in order to analyze the consumption path of the new energy consumption, according to the trend tracing, the consumption analysis chart can be obtained.

3.1 Decomposition power according to power flow tracing

The classical circuit theory can effectively calculate the electrical parameters such as voltage and current of various components in the network through several basic theorems, which is sufficient for general calculation. So far, the circuit theory has not dealt with the problem of power distribution, but the view that the power cannot be accumulated and thus the power distribution cannot be obtained is also
inadequate. The classical circuit theory is quite complete. In fact, it already contains the relevant basic content of the power distribution. It is ready for power decomposition. It only needs to be carefully considered from different starting points to get the correct answer. The key is how to find this. Starting point. In fact, the above derivation process does not use other new principles, but uses the node voltage equation and the superposition theorem and combines the physical meaning of power to propose the power component theory. The theory uses the classical circuit theory to expand the network-based electrical parameter analysis and analysis method, and decomposes the power supply into component form, so as to obtain the independent distribution law of components in the network, that is, the multi-power network power distribution value is equivalent to The algebraic sum of the network power distribution values for the square power of the number of power sources (using the power injection power component as the power source). The power supply in the network is obtained in the form of superposition of self power and mutual power components. The self-power is the power injected into the grid by the power supply alone, which is a special case of mutual power; the mutual power is the power injected into the grid by the two powers of different power sources. This shows that although the specific values of power in multiple power networks are coupled, the coupling of the values just indicates the interaction between the power sources, but it is decoupled from the physical properties, so the points are very clear. The idea that power is not decoupled is to confuse the difference between specific numerical and physical meanings. In fact, they are two completely different concepts. How to evaluate the degree of interaction between power supplies is another problem. Simply put, although other power sources can affect the value of the power generated by a power source, the power of the port cannot be changed completely from the essence of the power source. The theoretical model of the power component is simple.

The concept is clear, no need to make any approximate assumptions, completely derived from classical circuit theory, reflecting the physical nature of power distribution.

3.2 Building a consumption analysis chart
Below we can get the power flow of new energy consumption according to the trend tracing. The consumption map based on the power flow of the new energy can clearly show the process of the new energy consumption. As shown in the 6-node distribution network, it is assumed that PV new energy is added at node 4.

![Fig. 1 Single-power 6-node system structure](image)

By equating the new energy into a current source and conducting power flow tracking, the power transmission path of traditional energy and photovoltaic can be obtained. The new energy consumption path is as shown in the figure.
As shown in the figure, the blue power direction is the transmission path of the new energy source, and the red power direction is the transmission path of the traditional energy source, so that the consumption path of different energy sources can be clearly seen from the consumption path map. Analyze the process of new energy consumption.

4. Case Analysis
Using the 6-node example of the distribution network to analyze the access point of new energy and the new energy consumption process, the power flow distribution is shown in Figure 3.

The load node power distribution and node voltage are shown in Table 1 and Table 2.

| Load node | 2       | 3       | 4       | 5       | 6       |
|-----------|---------|---------|---------|---------|---------|
| Power     | 0.17+j0.05 | 0.225+j0.06 | 0.165+j0.02 | 0.193+j0.05 | 0.1+j0.03 |
| Voltage   | 0.9885-j0.0242 | 0.9798-j0.0419 | 0.9757-j0.0507 | 0.9946-j0.0089 | 0.9923-j0.0128 |

The fourth node is selected as the energy access point. Firstly, the consumption of new energy is analyzed by the maximum amount of consumption. The following is an analysis of the new energy consumption path. The 6-node distribution network is connected to the PV for consumption analysis.
The power flow tracking is used to form a consumption map, and the power transmission paths and transmission powers of different energy sources in the consumption map are indicated in FIG. 4.

Fig. 4 Photovoltaic consumption map after photovoltaic access

As shown in FIG. 4, the red marked transmission path is a distribution path of a conventional energy source, and the blue marked transmission path is a consumption path of a new energy consumption. The PV consumption map formed by the trend tracing can clearly see the new energy consumption path, which is simple and clear.

5. Conclusion
Flow tracing has been used as an effective method for power decomposition and network loss allocation, and the power distribution of multiple power sources in the power network has been analyzed. Nowadays, the consumption of new energy is mostly the analysis of the location and consumption, but the analysis of the process has not been analyzed. The specific conclusions of this paper are as follows:
1) Use power flow tracing to analyze the power distribution of each power supply in the network. In particular, after the new energy is added, the power distribution of the new energy in the power network can be obtained, thereby forming a new energy consumption process;
2) The new energy consumption map obtained by the trend tracing can clearly and clearly indicate the consumption path and consumption of new energy, and can express the meaning of new energy consumption.

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