Probe into the Teaching Thought of Circuit Analysis Methods

Li Chunling

Nanchang Institute of Science &Technology Nanchang Jiangxi China

Email:2835621308@qq.com

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Abstract: circuit analysis methods mainly include branch current method, loop current method, node voltage method, equivalent transformation method, Thevenin (Norton) theorem, superposition principle, etc. This paper expounds the teaching ideas of circuit analysis methods, mainly including: branch current method, loop current method, node voltage method equation relations; The special treatment of the controlled source circuit analysis method and the simplified analysis method of the ideal current source being connected in the branch circuit and the ideal voltage source being connected in the nodes .The purpose is to guide students to explore knowledge independently through the teaching of circuit analysis method, so as to cultivate students' innovation ability.

1. Introduction

Circuit analysis method is one of the important teaching contents in electrotechnics. Circuit analysis methods mainly include the branch current method, loop current method, the node voltage method, the equivalent conversion method, Thevenin theorem and superposition theorem (NORTON), in the teaching process, if can consciously purposefully grasp certain teaching ideas, the spirit can stimulate students to explore in the learning process, compared with mechanically directly relate, has better teaching effect, and can stimulate students' innovation ability, rather than just passively accept knowledge.

2. Teaching ideas

The teaching ideas of circuit analysis methods are mainly reflected in the following aspects:

2.1 Clarify the relationship between various circuit analysis methods

The branch current method, loop current method and node voltage method are all system analysis methods, the essence is the same, that is, the equations are set based on KVL and KCL theorems, but the unknowns are different and the equations are different. Among them, the branch current method is the most basic. In general, when introducing KVL and KCL theorems, the circuit analysis method is also introduced, so that the teaching process can be compact with fewer class hours. In the application of this method, students will feel that the number of equations in the column is more, the solution is also complex, so guide students to analyze: can you reduce the number of equations in the column? How to reduce? According to the mathematical knowledge, the process of solving the equation is a process of constantly substituting and reducing unknown quantities. Therefore, the students are guided to imagine: can we substitute some unknown quantities before setting up the equation so as to reduce the number of equations in the column? We analyze the branch circuit method: this method lists both KVL equation and KCL equation. Can we first use KCL theorem to replace some unknown variables and only list KVL equation? Or replace the unknowns with KVL theorem and just write the KCL equation? From this way of thinking to guide students to think, let themselves to explore the new circuit analysis method impulse. In the next link, the former circuit analysis method that only lists KVL equation is circuit current analysis method, and the latter one that only lists KCL equation is node voltage method.
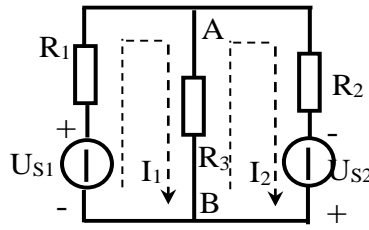
Figure 1

In the learning process of the loop current method, since only KVL equation is listed, the number of unknown variables is the number of independent loops, first lead the students to think: what should be unknown variables? In particular, the unknown circuit current of the circuit analysis method is imaginary, so students should be guided to understand it. At the same time, it leads students to think: when has this method applied KCL theorem? In figure1, I_1,I_2 Are the circuit current of two independent circuits respectively, and the current I_{AB} of branch circuit AB is I_1- I_2, this is the application of KCL theorem, so the essence of loop current method is to first use KCL theorem to reduce the number of unknown variables, and then only list KVL equation.

In the node voltage method, only the KCL equation is listed, and the unknown quantity is the number of nodes minus 1, which also guides the students to think: what shall be the unknown quantity? This method lists the current equation, and the unknown quantity is the node voltage, so the current of each branch shall be first expressed by the node voltage, which is actually to use KVL theorem to reduce the number of unknown quantity, and then only list the KCL equation.

After guiding students to understand the essential relationship of the three methods, students will have the impulse to think about the other analysis method from one analysis method, and their creative thinking ability will also be cultivated in the learning process of circuit analysis method.

Power supply equivalent transformation method and Thevenin (Norton) theorem is essentially the same, the so-called equivalent essentially two ports have the same circuit volt-ampere characteristic, but the power supply the equivalent conversion of equivalent transformation method is gradually process, this process must draw again and again, so it can guide students to think: is there a method can be directly to the two port equivalent circuit for voltage source model? This circuit analysis method simplifies the step by step equivalent analysis process into two steps. Relatively speaking, superposition principle is independent.

But from another Angle to think, as a kind of analysis method of the circuit, when we apply circuit superposition principle analysis, we can also keep the controlled source as independent source. The calculation process has incentive effect and independent power supply, only the incentive value in the form of control volume, the circuit of current and voltage also appear in the form of a control volume, thus expanded the superposition theorem: for linear circuits, any one branch of the current or voltage can be considered by the circuit in the power supply, respectively, in this branch of algebra and current or voltage, no effect of the voltage source with a short route to replace, not the role of the current source substitute circuit. Since the controlled source is a power source represented by an unknown control variable, when it is involved in the superposition, the key is that the unknown control variable cannot be changed. Assume it as a known power source, analyze the circuit, and then list the equation containing the unknown control variable according to the superposition principle.

2.2 Clarify the special treatment of various circuit analysis methods

When explaining each circuit analysis method, the application of the circuit analysis method in general cases is introduced first, and then students are guided to explore how each analysis method deals with special cases.

2.2.1 Controlled sources

Column system analysis method is KCL and KVL equation, and reflects the nature of controlled source. It is a branch between the relationship between current, voltage, in terms of external

characteristics it has the characteristics of the power supply, so we can guide students thinking: controlled source is regarded as the ideal power handling, first take control variables included in the equation, but such variables will increase, and the equation for the same, therefore, we should further handling controlled source, the control equation with an unknown quantity to solve the equation.

How does the superposition principle handle controlled sources? Can it be considered a standalone source? The essence of the controlled source is only to reflect the voltage and current control relationship between the branches, and it does not generate current and voltage independently. Therefore, the superposition principle is different from the treatment method of the controlled source and the independent power source. When each independent source ACTS alone, the controlled source must stay in the circuit.

The same principle guides students to understand the treatment of controlled sources in the solution of internal resistance by the theorem of Thevenin (Norton).

But from another angle to think, as a kind of analysis method of the circuit, the application circuit superposition principle analysis, we can also keep the controlled source as independent source, calculation process that has incentive effect and independent power supply, only the incentive value in the form of control volume, the circuit of current and voltage also appear in the form of a control volume, thus expanded the superposition Theorem: for linear circuits, any one branch of the current or voltage can be considered by the circuit in the power supply , respectively, in this branch of algebra and current or voltage, no effect of the voltage source with a short route to replace, not the role of the current source substitute circuit. Since the controlled source is a power source represented by an unknown control variable, when it is involved in the superposition, the key is that the unknown control variable cannot be changed. Assume it as a known power source, analyze the circuit, and then list the equation containing the unknown control variable according to the superposition principle.

However, the process of treating the controlled source as an independent source is only based on the circuit analysis method established by the mathematical model, which does not mean that the controlled source can constitute excitation in the circuit to generate current and voltage separately. The controlled source alone does not have the physical meaning of the circuit, which must be noted to prompt students' understanding. Use the superposition principle to analyze the U in the circuit in figure 2.
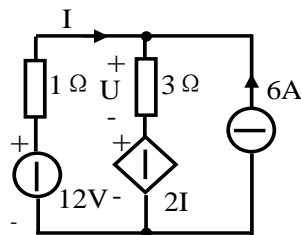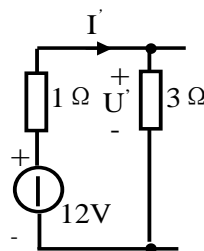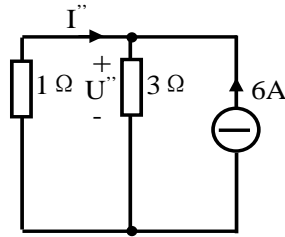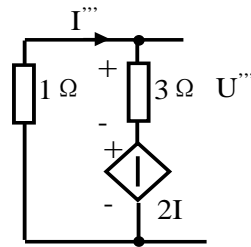

Figure 2

Figure 3

Figure 4

Figure 5

Since there are 3 power sources in FIG. 2, the circuit diagram under the separate action of each power source is respectively FIG. 3, FIG. 4 and FIG. 5.Figure 3 shows the circuit acted by 12V voltage source alone, in which the controlled voltage source is short-circuited and the independent current source is disconnected, I'=12/ (1+3) =3 (A), U' =9 (V).Figure 4 shows the circuit acted by 6A current source alone, in which both controlled voltage source and independent voltage source are short-circuited, I''= -6 *3/ (1+3) = -4.5 (A), U''= 4.5 (V).Figure 5 for the controlled voltage source separate function circuit, the voltage value of 2, I pay attention to the control variable I is unknown, it is not before the circuit decomposition of the original circuit under the action of all the power value, the value of the controlled source as independent source does not change, but in a controlled source alone under the action of current and voltage in the circuit is the third need stack component, with U''' and I''' , now will first controlled voltage source voltage value 2 (I) as a known quantity to analyze circuit: I''' = - 2 I/(1 + 3) = 0.5 (I) (A), U''' = 1.5 (V), then I listed according to the principle of superposition equation: I = I'+I''+I'''= 3-4.5-0.5 I, therefore, I =1(A), U'''= 1.5 (V).Using the superposition principle: U=U'+U''+U'''=9+4.5+1.5=15 (V).

2.2.2 Ideal current source string in the branch

The branch current method and the loop current method in the system analysis method respectively take the branch current and the loop current as unknown variables, and guide the students to think: if there is an ideal current source in the branch, the unknown variables will certainly be reduced, so that the analysis of the circuit will be more simple. Further guide the students to think: reduce what equation? Take figure 9 as an example, if it is required to analyze the circuit with branch current method, because there are 6 branches and 2 strings with ideal current sources, only 4 unknown variables I need to be set I_1, I_2, I_3, I_4, we can also list three KCL equations, so KVL only need to list one, which loop shall we choose? Then guides the student to think: at the ends of the current source voltage has nothing to do with the element itself, is determined by the external circuit, so it can't use the voltage across the unknown will write the KVL equation, so the column to remove the current source before find independent circuit, in the rest of the circuit in figure 2 is removed after the current source is only one independent loop , KVL equations listed are: $R_1 i._1 + R_2 i._2 - R_4 i._4 - R_3 i._3 = 0$.

There is an ideal current source in the branch circuit, and the loop current method can also reduce the number of equations listed. In order to reduce the number of equations, the key is to guide students to think: how to choose the independent circuit? The conclusion is that the circuit current is equal to the current of the branch circuit with the current source, that is, the current of the current source. To achieve this effect, each current source must be in a separate circuit. FIG. 10 shows three independent loops. When independent loops are selected, let current source I_{S1}In loop 1

alone, the loop current is I_{S1}, current source I_{S2}In loop 2 alone, the loop current is I_{S2}, loop 3 is the independent loop selected after removing the current source, and its loop current is set as I, with only one unknown, so only the KVL equation of loop 3 is listed as $R_1I + R_2(I + I_{S2}) + R_4(I + I_{S2} + I_{S1}) + R_3(I + I_{S1}) = 0$.

2.2.3 An ideal voltage source directly connected between two nodes

The nodal voltage method takes the nodal voltage as the unknown quantity. The so-called nodal voltage is the voltage between a certain point in the circuit and the reference point. If an ideal voltage source is directly connected between the two nodes, it will also guide students to think: can the unknown quantity be reduced? How do I reduce the equation when I reduce it? In FIG. 11, there are four nodes, and three unknowns should be set initially, but there are two ideal voltage sources, so only one unknown need to be set. After selecting 4 as the reference nodes, the node voltage of node 1 is set as an unknown quantity, and the node voltage of node 2 is the value U of the voltage source, the node voltage of node 3 is V_1-u_{S1}, only one KCL equation needs to be listed, which can also guide the students to think: when selecting the node column KCL equation, the branch with ideal voltage source directly connected should be avoided, because the current flowing through the voltage source is determined by the external circuit, and it cannot be expressed by the node voltage with unknown quantity. In this circuit, all three nodes have such branches, so if you do not want to increase the number of unknowns and equations, you can choose the KCL equation of the plane where the dotted line is :$(V)_1$-$u_{S2})/R_1$+ $(V_1$-u_{S1}-$u_{S2})/R_2$+ $(V_1$-$u_{S1})/R_4$+ V_1/ R_4= 0.

2.3 Clarify the application characteristics of various circuit analysis methods

After guiding students to study and explore various circuit analysis methods, students should be further guided to think: generally, all kinds of analysis methods can be used to analyze the circuit, but the circuit structure is different, and the complexity of different analysis methods is different. As long as the above rules are followed, generally no errors will be made. If the equation is solved, the current or voltage of all branches can be obtained. It only takes time to solve the equation. When analyzing a circuit with only two nodes, the application of the node voltage method is the fastest. When there are more ideal current sources in the circuit connected in series in the branch, the application of branch current method or loop current method of the number of equations is less, the problem solving is faster; When there are more ideal voltage sources in the circuit and connected between nodes, the equation of nodal voltage method is less and the problem is solved quickly.

In the case of no controlled source, it is faster to analyze the circuit with the superposition principle. If only one branch of the current, voltage, power is to be solved ,we can use equivalent conversion method and Thevenin theorem, but with the help of Δ, Y type resistor network equivalent conversion of circuit to the power supply. It is easier to solve the problem if the remaining circuit can be divided into two when the branch circuit is removed by Thevenin theorem. Generally speaking, the Norton theorem is less used. The complexity of the circuit sometimes does not decrease after the short circuit is found to be branch circuit.

3. Conclusion

The teaching process is not only a process of imbuing knowledge to students, but also should guide students to actively participate in thinking, cultivate their exploration spirit and innovation ability. In the teaching process of circuit analysis method, I try to apply the above teaching ideas to achieve this goal.

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