Find Thevenin's and Norton's Equivalent Circuits

Notes

Find Thevenin's and Norton's Equivalent Circuits:

Suppose that $R_1 = 5\Omega R_1 = 5\Omega$, $R_2 = 3\Omega R_2 = 3\Omega$ and $I_S = 2A I_S = 2A$.

Solution

The circuit has both independent and dependent sources. In these cases, we need to find open circuit voltage and short circuit current to determine Norton's (and also Thevenin's) equivalent circuits.

Open circuit voltage

Open circuit voltage means the voltage across the terminals of the network without connecting any extra element or connection:

Since there is no connection, the current of $R_2 R_2$ is zero. To solve the circuit lets write KVL for the left hand side loop assuming I_{R_1} defined from left to right:

$$+V_x + R_1 \times I_{R_1} + V_x = 0$$
$$\rightarrow 2V_x = -R_1 \times I_{R_1}$$
$$\rightarrow V_x = -\frac{R_1 \times I_{R_1}}{2}$$

But what is I_{R_1}? R_1 is in series with the current source; they have only one node shared and there is no other element connected there. This means that all current of I_S must pass through R_1. Therefore, $I_{R_1} = I_S = 2A$.
If we apply this to the equation above, we have

$$V_x = -\frac{R_1 \times I_{R_1}}{2} \rightarrow V_x = -5V.$$

Since no current passing through R_2 we can easily see that $V_{OC} = V_x$. If it is not clear, you could find this by applying KVL to the right hand side loop:

$$-V_x + R_2 \times I_{R_2} + V_{OC} = 0$$
$$\rightarrow -V_x + R_2 \times 0 + V_{OC} = 0$$
$$\rightarrow V_{OC} = V_x = -5V$$

Short circuit current

Next, we need to find the short circuit current. It means we need to connect terminals of the network and calculate the current passing through the connection:

Doing so, we get a circuit with two loops. **It is very important to note that all values might be changed and we are not allowed to use values/formulas of the open circuit voltage calculation.** Just forget all and analyze the new circuit and calculate short circuit current I_{SC}.

Please note that the mesh currents (loop currents for not-shared portion of loops) are as shown above. For the left hand side loop it is equal to the current of the current source as current sources enforce their current to go through all elements in series with them. For the right hand side loop it is I_{SC} and there is no benefit in defining a new label for current.

KVL for the left loop:
$+V_x + R_1 \times I_{R_1} + V_x = 0$
Again, here the current of I_{R_1} is equal to I_S and
$I_{R_1} = I_S = 2A.$
$+V_x + 5 \times 2 + V_x = 0$
$\rightarrow V_x = -5V.$
We get the same value for V_x. This is not a general rule and value could be different.
For the right hand side loop:

$-V_x + R_2 \times I_{SC} = 0$
$I_{SC} = \frac{V_x}{R_2} = -\frac{5}{3}A$

Thevenin's and Norton's Equivalent Networks

The only thing left is to calculate R_{th} which can be easily found by
$R_{th} = \frac{V_{OC}}{I_{SC}} = \frac{-5}{-\frac{5}{3}} = 3\Omega$

Thevenin's Equivalent Network

$V_{th} = V_{OC} = -5V$
$R_{th} = 3\Omega$

Norton's Equivalent Network

$I_{no} = I_{SC} = -\frac{5}{3}A$
$R_{no} = R_{th} = 3\Omega$

Now, assume that a $2V$ voltage source is connected to the terminals of this network, what would be its current?

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