Power Systems Lab

Experiment 4

Laboratory Report

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1 Objective

To write a MATLAB program to determine line currents to a Y-connected load by mesh analysis and by using symmetrical components.

Let the given problem be as follows:

A balanced three phase voltage of 120 V line to neutral is applied to a Y-connected load with ungrounded neutral. The three phase load consists of three mutually-coupled reactances. Each phase has a series reactance of $Z_s = j12\Omega$, and the mutual coupling between phases is $Z_m = j4\Omega$.

1. *Determine the line currents by mesh analysis.*
2. *Determine the line currents by using symmetrical components.*

2 Theoretical Background

Shown below is a 3-phase supply connected to a Y-connected load. Each of the voltages V_1, V_2 and V_3 represents the phase voltage which are 120 degrees out of phase with each other. The impedances are represented by Z_1, Z_2 and Z_3.

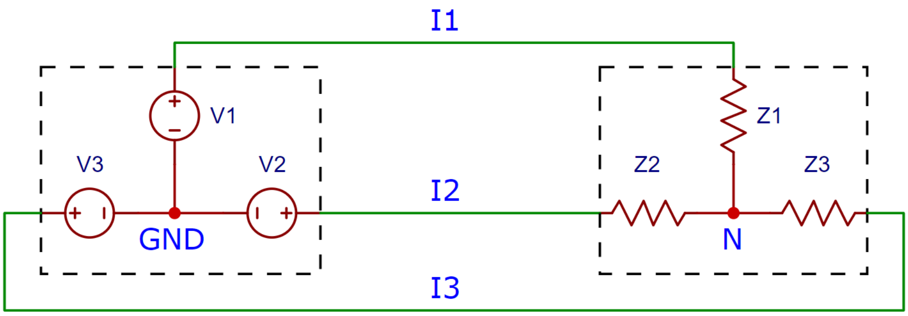

Figure 1: Y-connected load with ungrounded neutral.

2.1 Mesh Analysis

The Mesh-Current Method, also known as the Loop Current Method, is quite similar to the Branch Current method in that it uses simultaneous equations, Kirchhoffs Voltage Law, and Ohms Law to determine unknown currents in a network. It differs from the Branch Current method in that it does not use Kirchhoffs Current Law, and it is usually able to solve a circuit with less unknown variables and less simultaneous equations.

2.2 Sequence Components

A set of three balanced voltages (phasors) V_a, V_b, V_c is charactertzed by equal magnitudes and interphase differences of 120 deg. The set is said to have a phase sequence *abc* (positive sequence) if V_b lags V_a by 120 deg and V_c lags V_b by 120 deg.

The three phasors can then be expressed in terms of the reference phasor V_a as

$$\begin{aligned} V_a &= V_a \\ V_b &= \alpha^2 V_a \\ V_c &= \alpha V_a \end{aligned}$$

where the complex number operator α is defined as $\alpha = e^{j120\,\mathrm{deg}}$. The same applies to voltages or currents.

If the phase sequence is *acb* (negative sequence), then

$$\begin{aligned} V_a &= V_a \\ V_b &= \alpha V_a \\ V_c &= \alpha^2 V_a \end{aligned}$$

Thus a set of balanced phasors is fully characterized by its reference phasor (say V_a) and its phase sequence (positive or negative).

Consider now a set of three voltages (phasors) V_a, V_b, V_c which in general may be unbalanced. According to **Fortesque's theorem** the *three phasors can be described as the sum of positive, negative and zero sequence phasors.*

$$\begin{aligned} V_a &= V_a^1 + V_a^2 + V_a^0 \\ V_b &= V_b^1 + V_b^2 + V_b^0 \\ V_c &= V_c^1 + V_c^2 + V_c^0 \end{aligned}$$

The three phasor sequences (positive, negative and zero) are called the **symmetrical components** of the original phasors. These equations can be expressed in the matrix form

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha^2 & \alpha \\ 1 & \alpha & \alpha^2 \end{bmatrix} \begin{bmatrix} V_a^0 \\ V_b^1 \\ V_c^2 \end{bmatrix}$$

$$\mathbf{V_p} = \mathbf{A V_s}$$

To find the sequence components, we can invert the equation

$$\mathbf{V_s} = \mathbf{A^{-1} V_p}$$

$$\text{where } \mathbf{A^{-1}} = \frac{1}{3} \begin{bmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{bmatrix}$$

3 Implementation

```
% To write a MATLAB program to determine line currents to a Y-connected
% load by mesh analysis and by using symmetrical components.

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Vp = 120;       % 3-phase Supply Voltage

Zs = 1j*12;     % Branch series reactance
Zm = 1j*4;      % Branch mutual reactance

% 1. Line currents by mesh analysis
disp('1. Line currents by mesh analysis')
Vl=sqrt(3)*Vp;

Z = [ (Zs-Zm) -(Zs-Zm) 0
     0 (Zs-Zm) -(Zs-Zm)
     1 1 1];

V = [ Vl*(cos(pi/6) + 1j*sin(pi/6))
     Vl*(cos(-pi/2) + 1j*sin(-pi/2))
     0];

Iabc = Z \ V;
disp(Iabc)

% 2. Line currents by symmetric components
disp('2. Line currents by symmetric components')
a = cos(2*pi/3)+ 1j*sin(2*pi/3);

A = [ 1 1 1;
     1 a^2 a;
     1 a a^2];

Z012 = [ Zs+2*Zm 0 0
         0 Zs-Zm 0
         0 0 Zs-Zm];

V012 = [0; Vp; 0];
I012 = Z012 \ V012;

Iabc = A * I012;
disp(Iabc)
```

4 Observations

```
Command Window
>> SymComp
1. Line currents by mesh analysis
   0.0000 -15.0000i
 -12.9904 + 7.5000i
  12.9904 + 7.5000i

2. Line currents by symmetric components
   0.0000 -15.0000i
 -12.9904 + 7.5000i
  12.9904 + 7.5000i

>>
```

Figure 2: Result in MATLAB

The result of the above program with the given parameters is shown in figure 2.

5 Result

The line currents for the given problem **by mesh analysis** are found to be

0.0000 -15.0000i A
-12.9904 + 7.5000i A
12.9904 + 7.5000i A

and line currents for **by symmetric components** are found to be

0.0000 -15.0000i A
-12.9904 + 7.5000i A
12.9904 + 7.5000i A

It is observed that identical values are obtained by both methods.