HDU-ITMO Joint Institute

Electrical Engineering

Laboratory work 3

Research on three-phase circuits

Authors:

Artur Abdullin (assoc. prof., artur.abdullin@itmo.ru)

Konstantin Gorshkov (assoc. prof., k.gorshkov@itmo.ru)

Sergey Lovlin (assoc. prof., sjlovlin@itmo.ru)

Contents

Laboratory work № 3: «Research on three-phase circuits»

Objectives

to study linear three-phase sinusoidal circuits with star and delta connections in cases of balanced (symmetrical) and unbalanced load.

Program of work

Part 1

Experimental study of the main concepts in three-phase circuits with the star-star (Y-Y) connection of the load for the following cases:

1. Balanced (Symmetrical) load with neutral wire.
2. Balanced (Symmetrical) load without neutral wire.
3. Unbalanced load with neutral wire.
4. Unbalanced load without neutral wire.
5. Line wire breakage with neutral wire.
6. Line wire breakage without neutral wire.
7. One phase of load short circuit without neutral wire.

Part 2

Experimental study of the main concepts in three-phase circuits with the star-delta (Y-Δ) connection of the load for the following cases:

1. Balanced (Symmetrical) load
2. Unbalanced load.
3. One phase of load breakage.
4. Two phases of load breakage.
5. Line wire breakage with balanced (symmetrical) load.
6. Line wire breakage with unbalanced load.

Overview

This lab covers the three-phase circuits, which are the widespread implementation of AC circuits.

Students investigate the advantages and disadvantages of three-phase circuits by simulating the circuits with balanced and unbalanced loads in regular and special operating mods.

After performing the lab task students can analyze the efficiency of the distribution of electric energy over different consumers.

GUIDANCE

Part 1

1. Assemble an equivalent circuit presented in Figure 3.1 in the «LTspice» application. The source and load parameters are defined by the instructor. R_{Nn} = 0.09 [Ω] - active resistance of a copper wire with a cross-sectional area of 0.196 [mm^2] and a length of 1 [m]. When performing part 1, paragraph 7, use the resistance $R = R_{Nn}$ instead of the load in the corresponding phase.
2. Measure RMS values of currents, voltages and powers in phases according to the circuit modes described in Part 1 of the Program of work. Put the measurement results in the Table 3.1.

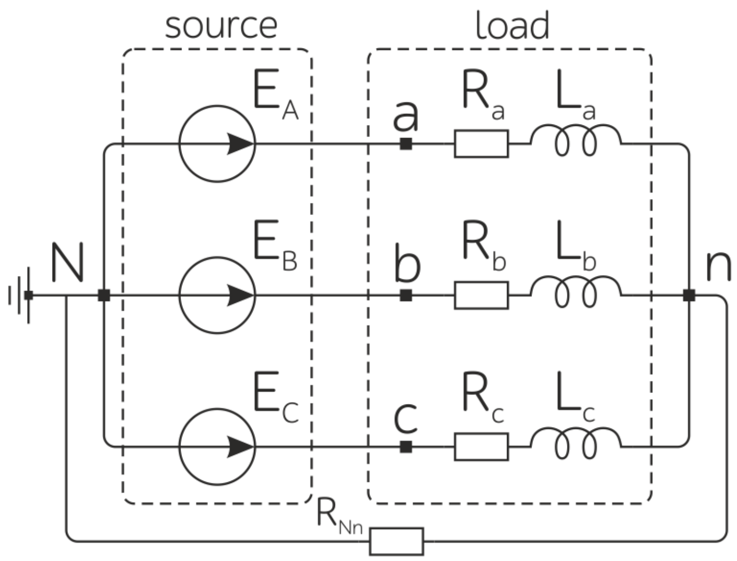


Figure 3.1 - The equivalent circuit of a three-phase circuit with the star-star connection.

Part 2

1. Assemble an equivalent circuit presented in Figure 3.2 in the «LTspice» application. The source and load parameters are defined by the instructor.

2. Measure RMS values of currents, voltages and powers in phases according to the circuit modes described in Part 2 of Program of work. Put the measurement results in the Table 3.2.

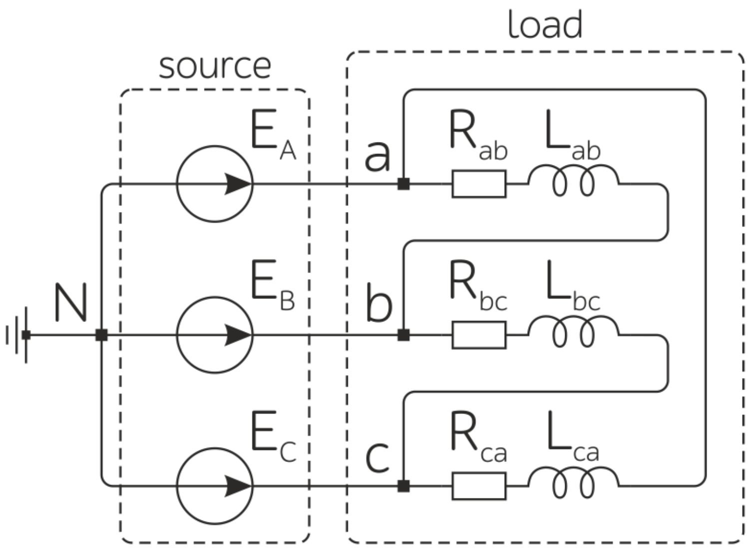


Figure 3.2 - The equivalent circuit of a three-phase circuit with the star-delta connection.

Expressions for calculations in the star-star circuit.

Neutral-point displacement voltage: $\underline{U}_{Nn} = \dfrac{\underline{E}_A\underline{Y}_a + \underline{E}_B\underline{Y}_b + \underline{E}_C\underline{Y}_c}{\underline{Y}_a + \underline{Y}_b + \underline{Y}_c}$, where

$\underline{E}_A = E_A \cdot e^{j0°}$, $\underline{E}_B = E_B \cdot e^{-j120°}$, $\underline{E}_C = E_C \cdot e^{j120°}$, E_A, E_B, E_C - RMS values of EMF in the source phases, $\underline{Y}_a, \underline{Y}_b, \underline{Y}_c$ - phasors (complex amplitudes) of phases conductance.

Phasors of RMS voltage in load phases: $\underline{U}_a = \underline{E}_A - \underline{U}_{Nn}$, $\underline{U}_b = \underline{E}_B - \underline{U}_{Nn}$, $\underline{U}_c = \underline{E}_C - \underline{U}_{Nn}$.

Phasors of RMS currents in the load and neutral wire: $\underline{I}_a = \underline{U}_a\underline{Y}_a$, $\underline{I}_b = \underline{U}_b\underline{Y}_b$, $\underline{I}_c = \underline{U}_c\underline{Y}_c$, $\underline{I}_{Nn} = \underline{I}_a + \underline{I}_b + \underline{I}_c$.

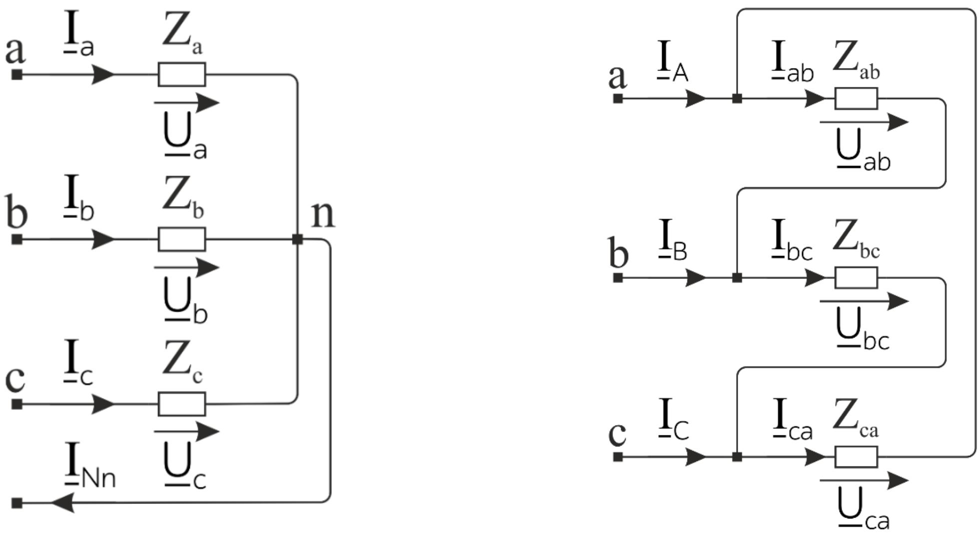
Active power of the load: $P_a = U_a I_a \cos\varphi_a$, $P_b = U_b I_b \cos\varphi_b$, $P_c = U_c I_c \cos\varphi_c$, where $\varphi_a, \varphi_b, \varphi_c$ - phase shift between current and voltage in the load phases.

Expressions for calculations in the star-delta circuit.

Phasors of RMS voltage in load phases: $\underline{U}_{ab} = \underline{E}_A - \underline{E}_B$, $\underline{U}_{bc} = \underline{E}_B - \underline{E}_C$, $\underline{U}_{ca} = \underline{E}_C - \underline{E}_A$.

Phasors of RMS currents in load: $\underline{I}_{ab} = \underline{U}_{ab}\underline{Y}_{ab}$, $\underline{I}_{bc} = \underline{U}_{bc}\underline{Y}_{bc}$, $\underline{I}_{ca} = \underline{U}_{ca}\underline{Y}_{ca}$.

Phasors of RMS currents in source phases: $\underline{I}_A = \underline{I}_{ab} - \underline{I}_{ca}$, $\underline{I}_B = \underline{I}_{bc} - \underline{I}_{ab}$, $\underline{I}_C = \underline{I}_{ca} - \underline{I}_{bc}$.



а) б)

Рисунок 3.3 - The equivalent circuit of a three-phase load with a) star and b) delta connections.

Table 3.1

№	Load type		U_a, [V]	U_b, [V]	U_c, [V]	I_a, [A]	I_b, [A]	I_c, [A]	P_a, [W]	P_b, [W]	P_c, [W]	U_{Nn}, [V]	I_{Nn}, [A]	Z_a, [Ω]	Z_b, [Ω]	Z_c, [Ω]
1	Balanced load with neutral wire	Exp.														
		Calc.														
2	Balanced load without neutral wire	Exp.														
		Calc.														
3	Unbalanced load with neutral wire	Exp.														
		Calc.														
4	Unbalanced load without neutral wire	Exp.														
		Calc.														
5	Line wire breakage with neutral wire	Exp.														
		Calc.														
6	Line wire breakage without neutral wire	Exp.														
		Calc.														
7	Short circuit of one load phase without zero wire	Exp.														
		Calc.														

Table 3.2

№	Load type		I_a, [A]	I_b, [A]	I_c, [A]	I_{ab}, [A]	I_{bc}, [A]	I_{ca}, [A]	P_{ab}, [W]	P_{bc}, [W]	P_{ca}, [W]	Z_{ab}, [Ω]	Z_{bc}, [Ω]	Z_{ca}, [Ω]
1	Balanced load	Exp.												
		Calc.												
2	Unbalanced load	Exp.												
		Calc.												
3	Breakage of one phase of the load	Exp.												
		Calc.												
4	Breakage of two phases of load	Exp.												
		Calc.												
5	Line wire breakage with balanced load	Exp.												
		Calc.												
6	Line wire breakage with unbalanced load	Exp.												
		Calc.												

Content of the report

1. The equivalent circuits.
2. Filled Tables 3.1 and 3.2.
3. Evaluation equations and calculation results. Comparison of experimental and calculated results.
4. Phasor diagrams of voltage and currents of the load for each case based on experimental results.