Lab Four
Power Systems Analysis
EECE5682

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Abstract

This laboratory experiment explores three phase transformers in both voltage magnitude shifting and phase shifting applications. The simulated three phase circuits were balanced, and contained regulating transformers used to modify real and reactive power flow, as well as voltages.

KEYWORDS: three phase transformer, magnitude shifting, phase shifting, regulating, power flow

1 Introduction & Objectives

We begin by constructing a three-phase phase shifter as follows:

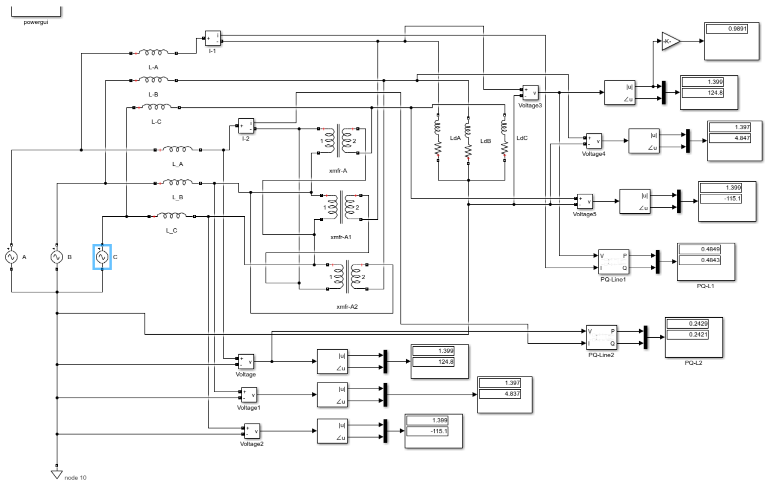

Figure 1: Initial Circuit Construction (Part A)

This circuit was then used to simulate the conditions indicated below.

2 Results & Analysis

2.1 Part B: Simulating with Ratio $V^n : \Delta V^n \rightarrow 100 : .01$

In the initial case, $V^n : \Delta V^n$ was simulated as $100 : .01$. This produced the following output:

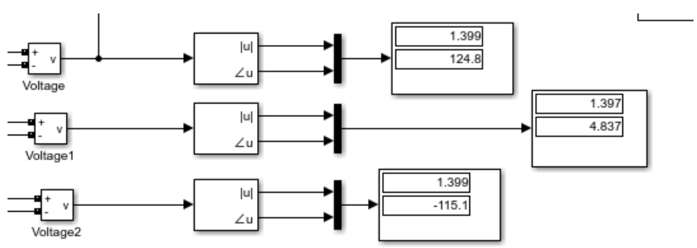

Figure 2: Secondary Line Voltage Magnitude and Phase Angle

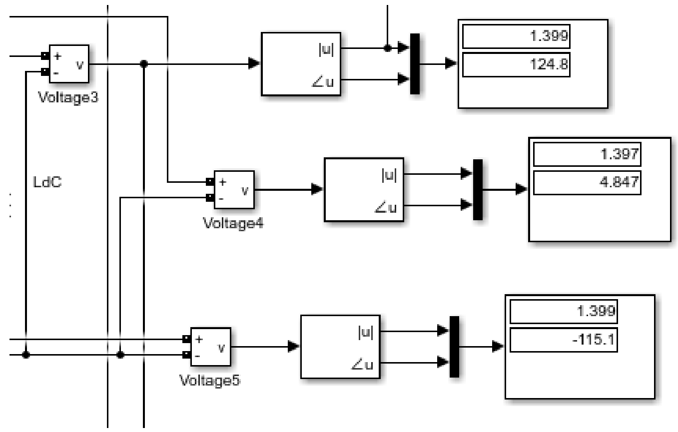

Figure 3: Primary Line Voltage Magnitude and Phase Angle

We may observe that the phases are near-identical. Measuring the real and reactive power flows through each line, we may find:

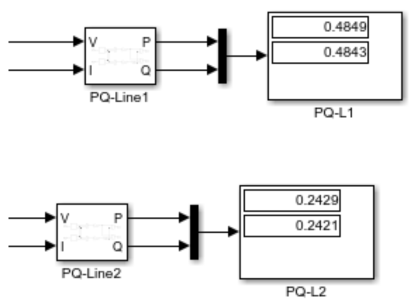

Figure 4: Real/Reactive Power Flows (Primary Line Top, Secondary Line Bottom)

We may, however, observe that the real and reactive power flows through the primary line are near double those of the secondary line, in per-unit.

2.2 Part C: Simulating with Ratio $V^n : \Delta V^n \rightarrow 100 : 3$

For the second case, $V^n : \Delta V^n$ was simulated as $100 : 3$. This produced the following output:

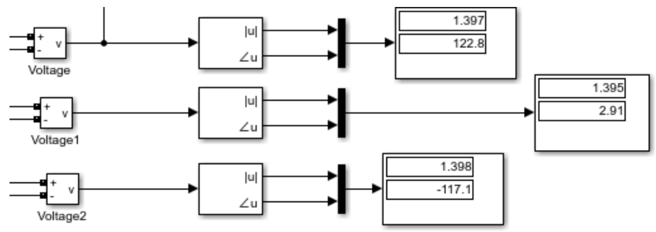

Figure 5: Secondary Line Voltage Magnitude and Phase Angle (100:3)

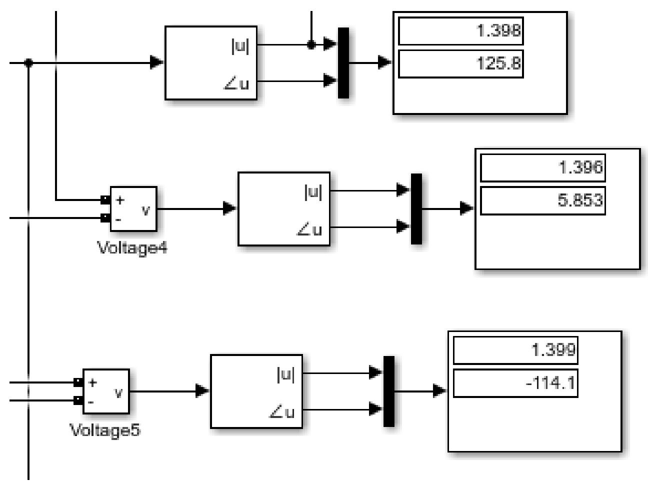

Figure 6: Primary Line Voltage Magnitude and Phase Angle (100:3)

We may observe that the phases now shift much more than in the initial case, with each phase in the secondary line lagging the phases in the first by about 3°. Measuring the real and reactive power flows through each line, we may find:

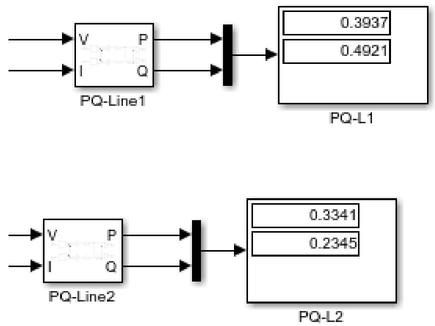

Figure 7: Real/Reactive Power Flows (Primary Line Top, Secondary Line Bottom, Voltage Ratio 100:3)

From the initial case, we may observe that the real power flows are much closer, while the ratio of reactive power flow between the primary and secondary line is even greater than two.

2.3 Part D: Simulating with Voltage Magnitude Regulation

We now change to a voltage magnitude regulator, implemented in the following schematic:

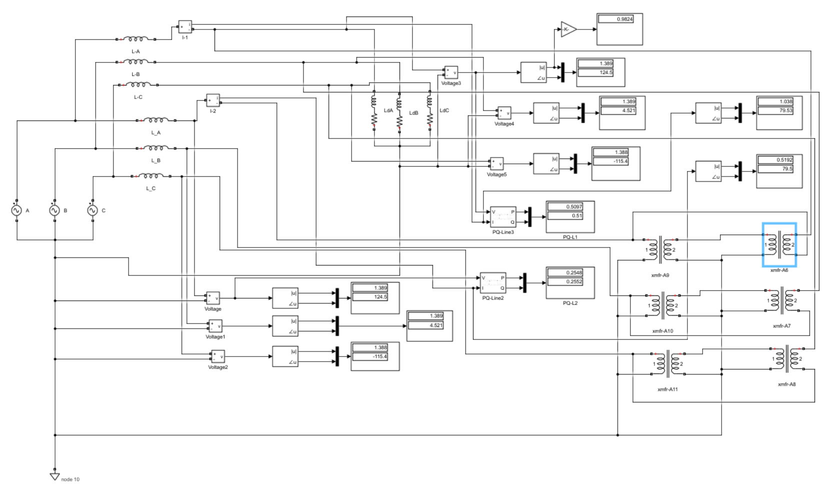

Figure 8: Voltage Regulator Schematic

2.3.1 Repeating Part B with Voltage Magnitude Regulation

Using the new schematic, we run Part (b) again. This gives us:

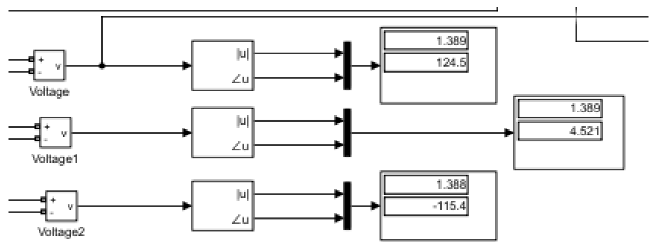

Figure 9: Secondary Line Voltage Magnitude and Phase (Regulator, 100:.01)

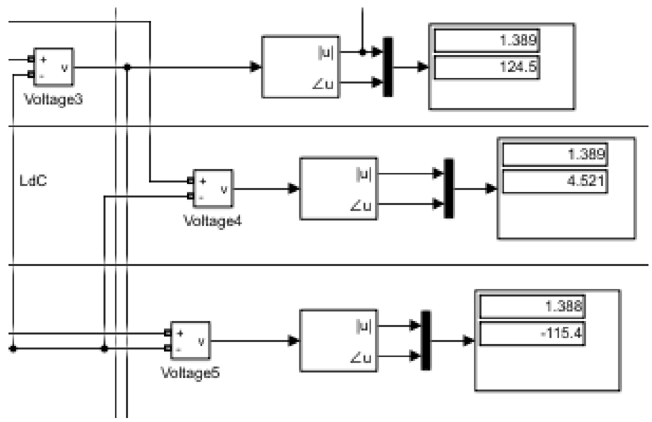

Figure 10: Primary Line Voltage Magnitude and Phase (Regulator, 100:.01)

We may observe that the line voltages and magnitudes are identical, as with the phase regulator with the same turns ratio. We now find the power flows:

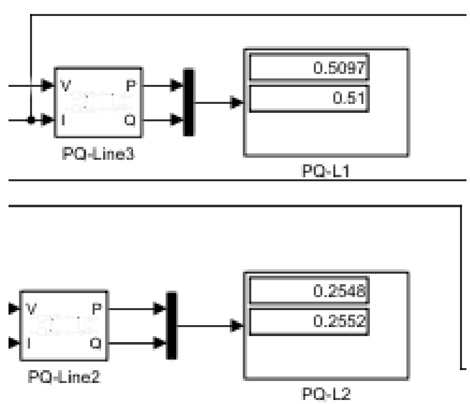

Figure 11: Real/Reactive Power Flows (Voltage Regulator, 100:.01)

As with the initial case, we see that the real and reactive power flows in the primary line are double those on the second line.

2.3.2 Repeating Part C with Voltage Magnitude Regulation

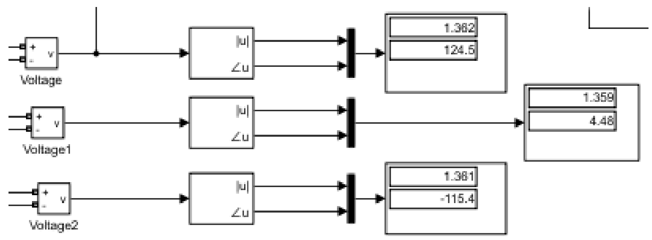

Figure 12: Secondary Line Voltage Magnitude and Phase (Regulator, 100:3)

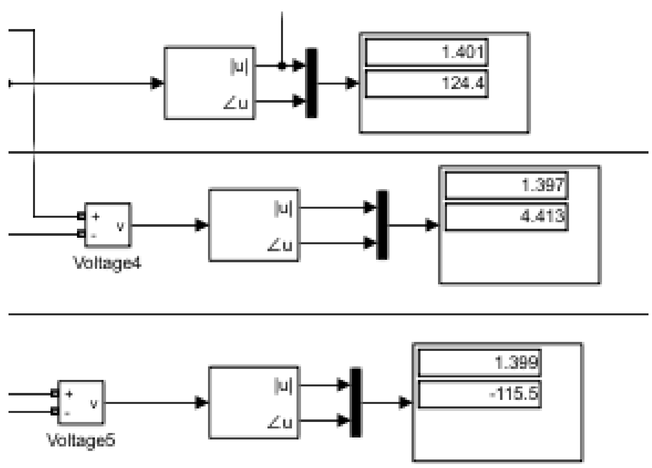

Figure 13: Primary Line Voltage Magnitude and Phase (Regulator, 100:3)

We may observe that the primary line voltage phases lead very slightly, by approximately .67°. On the other hand, secondary line voltage magnitudes lead slightly, by about .38[$p.u.$]. We now find the power flow:

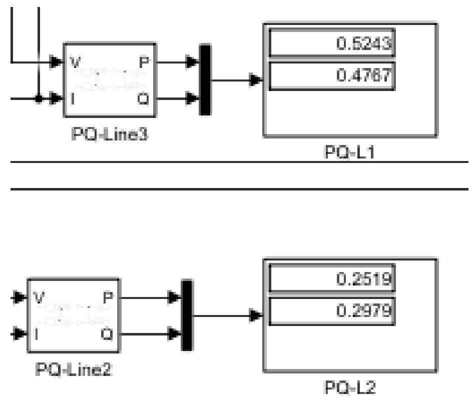

Figure 14: Real/Reactive Power Flows (Voltage Regulator, 100:3)

We may observe that the real power in the primary line is more than double that of the secondary line, while the ratio of the reactive power is just below 2. Thus, we see that this case is best for real power flow through the secondary line.

3 Conclusion

a. For the voltage regulating transformers, we may see that, in the first case (as with the phase regulating transformers) the voltage magnitudes and phases are equivalent, while the powers are doubled. For the second case (100:3), the phases are slightly lower and the magnitudes slightly higher in for the primary line voltages. When it comes to power, the ratio between the two lines is greater than two, while the reactive power ratio is less than two. Thus, we may conclude that reactive power is more affected by changes in voltage magnitude. We can assume this is so because, based on our equations, the reactive power would be proportional to the magnitude of the voltage squared over the reactance.

b. For the phase regulating transformers, we may see that, in the initial case, the line voltage magnitudes and phases were near identical; however, the power flows in the primary line were double those of the second line. On the other hand, in the second case (100:3), the magnitudes were the same, but the phases differed by nearly 3° (the secondary line lagged). For the power, we see that the initial case had double the real and reactive power flow on the primary line as the secondary, while the ratio for the real power decreased, while it increased for the reactive for the second case. As such, since the ratio decreased by a lot, we may conclude that the real power is greatly affected by changes in the phase. We may conclude that this is because, for real power flow, the conductances and susceptances (which are multiplied by trigonometric functions of the angle), are summed, while they are subtracted for reactive power flow. Increasing the angle thus increases the value of the sin and decreases the cos, which leads to this result.