Portland State University

Electrical & Computer Engineering

EE 347 Power Systems I

- Lab 5: Three-Phase Transformers, Residential Distribution -

Introduction

This lab introduces students to three-phase transformers and their use in transmission, residential distribution, and voltage regulation. In the first part of the lab, students learn how to configure three-phase transformers. In the second part, students learn how to configure a residential distribution circuit originating from a 208 V three-phase source.

Objectives

Through observation, students:

- learn how to configure three-phase transformer banks
- learn how 120/240 V residential service is distributed from a three-phase line

Research NEC codes applicable to residential electrical service

Analyze and interpret data, and draw conclusions

Develop engineering documentation:

- Points lists
- Three-wire diagrams

Part 1: Circuit Build and Data Gathering

1.1 Three-Phase Transformers

Configure and measure the voltage of a three-phase transformer bank using the LabVolt 8348 three-phase transformers.

1. Connect a Δ-Wye three-phase transformer bank
    a. primary-side phase voltage: $V_{\phi p}$ = 208 V,
    b. secondary-side phase voltage: $V_{\phi s}$ = 120 V
2. Add metering to monitor one phase voltage and one bank voltage on the primary side of the bank
3. Add metering to monitor one phase voltage and one bank voltage on the secondary side of the bank
4. Apply 208 V three-phase voltage to the primary side of the bank
5. Follow the lock-out/tag-out start-up procedure
6. Energize the power supply
7. Observe measurements
8. De-energize the power supply
9. Follow the lock-out/tag-out shut-down procedure

1.2 Residential Distribution System

Configure a residential transformer to provide 120/240 V service from a 208 V primary voltage using the LabVolt 8341single-phase transformer.

1. Apply a line voltage from the 120/208 V three-phase power supply to the 208 V coil of the transformer, terminals 3 and 4 (X1 and X2).
2. Create two 120 V legs with a center neutral (N) by connecting a jumper between terminals 2 and 5. Hot lines come off terminals 1 (H1) and 6 (H2)
3. On the 120/240 V side of the transformer, connect residential-like loads:
    - across each of the two 120 V branches (1 to 2-5 and 6 to 2-5), $\mathbf{Z}_{L120}$ = 1200 + j240 Ω

- across the 240 V branch (1 to 6), $\mathbf{Z}_{L240}$ = 1200 + j1200 Ω. Note the voltage rating of the resitor banks is just 120 V, so two banks in series will be needed.

4. Primary side: add metering for
    a. line current
    b. line voltage
5. Secondary side: add metering for
    a. H1, H2, N currents
    b. 120 V and 240 V branches

Next, adjust the loading. Observe all voltages and currents in each case.

1. Follow the lock-out/tag-out start-up procedure
2. Energize the power supply
3. Open-circuit observation: open all loads
4. Full-load observation: connect all loads
5. Imbalance observation: disconnect one residential load
6. De-energize the power supply
7. Follow the lock-out/tag-out shut-down procedure

Part 2. Data Analysis and Interpretation, Drawing Conclusions

2.1 Three-Phase Transformers

Calculate the rated S, V_{bank}, I_{bank}, V_{phase}, I_{phase} of the Δ-Wye, Δ-Δ, Wye-Wye and Wye-Δ three-phase transformer configurations. Compare calculations with voltage measurement from the Δ-Wye demonstration.

2.2 Residential Distribution System

For the open-circuit, full-load, and imbalance demonstrations, create a circuit model of a residential transformer[1] consisting of the aforementioned loads. Use the model to calculate the expected $\mathbf{S}$, $\mathbf{V}_p$, $\mathbf{I}_p$, $\mathbf{V}_{240}$, $\mathbf{V}_{120}$, $\mathbf{I}_{H1}$, $\mathbf{I}_{H2}$, $\mathbf{I}_N$, $\mathbf{S}_{120}$. Compare calculations with measurements. Do the measurements conform to theory? Explain.

Part 3. Engineering Documentation Deliverables

For the Δ-Δ and Δ-Wye three-phase transformer bank configurations, prepare the following engineering documents:

1. Three-wire diagram of each bank
2. Points lists for each bank.

Research NEC codes and standards for building residential circuits, specifically:

- Requirements for lighting and switches, NEC 210.70A
- Requirements for receptacles, NEC 210.52A
- Overcurrent protective devices for small conductors, residential, NEC ?
- Wire sizing for typical branch circuits, NEC ?
- Sizing of residential service entrances, NEC ?
- Others?

Prepare a summary sheet that includes the NEC articles that your team feels an electrical contractor must be aware of when designing the electrical wiring of a residential home. Provide a brief justification for the inclusion of each article.

Submitted these documents via Canvas as a single pdf file.

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[1] Consider the paper by Kersting: W. H. Kersting, "Center tapped transformer and 120/240 volt secondary models," 2008 IEEE Rural Electric Power Conference, Charleston, SC, USA, 2008, pp. A1-A1-7