Lab 5:

Three-Phase Transformers, Residential Distribution

Portland State University

Maseeh College of Engineering & Computer Science
Department of Electrical & Computer Engineering

Authors:

Student Kai Boldt

Student Ryan Nand

Student Lihong Zhao

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ECE 347L

Power Systems I Laboratory

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3ϕ Transformer Equations

Δ-Wye

$$V_{LP} = V_{\phi P} \tag{1}$$

$$V_{LS} = \sqrt{3}V_{\phi P} \tag{2}$$

Δ-Δ

$$V_{LP} = V_{\phi P} \tag{3}$$

$$V_{LS} = V_{\phi P} \tag{4}$$

Wye-Δ

$$V_{LP} = \sqrt{3}V_{\phi P} \tag{5}$$

$$V_{LS} = V_{\phi P} \tag{6}$$

Wye-Wye

$$V_{LP} = \frac{V_{\phi P}}{\sqrt{3}} \tag{7}$$

$$V_{LS} = \sqrt{3}V_{\phi P} \tag{8}$$

Universal

$$I_{\phi} = \frac{S}{3V_{\phi}} \tag{9}$$

$$I_{Bank} = \frac{S_{Bank}}{\sqrt{3}V_{Bank}} \tag{10}$$

$$\frac{V_p}{a} = V_s + R_{eq}I_s + jX_{eq}I_s \tag{11}$$

Three-Phase Transformers

	$V_{L,P}$	$V_{ø,P}$	$V_{L,S}$	$V_{ø,S}$
Measured	209.3V	209.0V	208.8V	120.4V

Table 1: Δ-Y Measurements

	S	$V_{Bank,P}$	$V_{\phi,P}$	$I_{Bank,P}$	$I_{\phi,P}$	$V_{Bank,S}$	$V_{\phi,S}$	$I_{Bank,S}$	$I_{\phi,S}$
Δ - Wye	750	208	208	2.08	1.2	208	120	2.08	2.08
Δ - Δ	750	208	208	2.08	1.2	120	120	3.6	2.08
Wye - Δ	750	360	208	1.2	1.2	120	120	3.6	2.08
Wye - Wye	750	120	208	3.6	1.2	208	120	2.08	2.08

Table 2: Three-Phase Transformer Calculations

From Table 2, we can observe that our calculations for the Delta-Wye configuration match the measurements observed within Table 1. While this analysis isn't complicated to complete, but it does prove the theory of three-phase transformers. Also this information will be vital for our analysis for residential distribution system in the next section. However, we were tasked to make all the calculations for all four different configurations of three-phase transformers. Therefore, we utilized equations 1-8 to determine our calculations depending on the respective configuration. Overall, the numbers that we calculated support the theory of how the line and phase voltages change regarding to the exact combination of transformers.

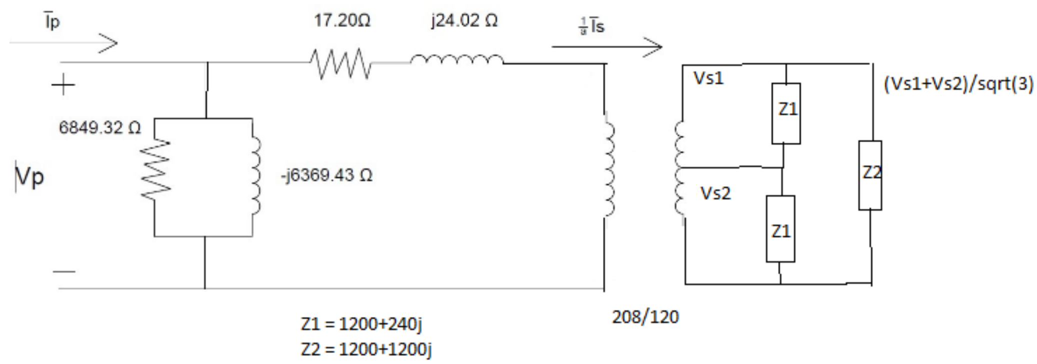


Figure 1: Transformer Model

Residential Distribution System

	S	V_P	I_P	V_{240}	V_{120}	I_H	I_{H2}	I_N	S_{120}
Measured (No Load)	/	/	/	240	120	.008	.008	0	/
Measured (Full Load)	/	/	/	228	114	.091	.093	.017	/
Measured (Imbalance)	/	/	/	231	115	.091	.008	.091	/
Calculated (No Load)	60	208	.29	240	120	0	0	0	0
Calculated (Full Load)	60	208	.29	236	118	.096	.098	0	11.3
Calculated (Imbalance)	60	208	.29	236	118	.096	0	0.96	11.3

Table 3: Open, Full, and Imbalance Loads for Residential Distribution Systems

The rough calculations were put together using the model above from Figure 1. For the most part, phase voltages were given from the power supply and the transformer characteristics determined within lab 4. For the no load case, common sense was used to determine the hot line currents (H1 and H2) and the neutral current since the load was opened. The opened load has a theoretical impedance of infinity, which results in all of the open circuit currents have a magnitude of 0A. For the rest of the currents and voltages for the full load and imbalance, equation (11) was used to bridge the relationship of the primary and secondary sides of the model.

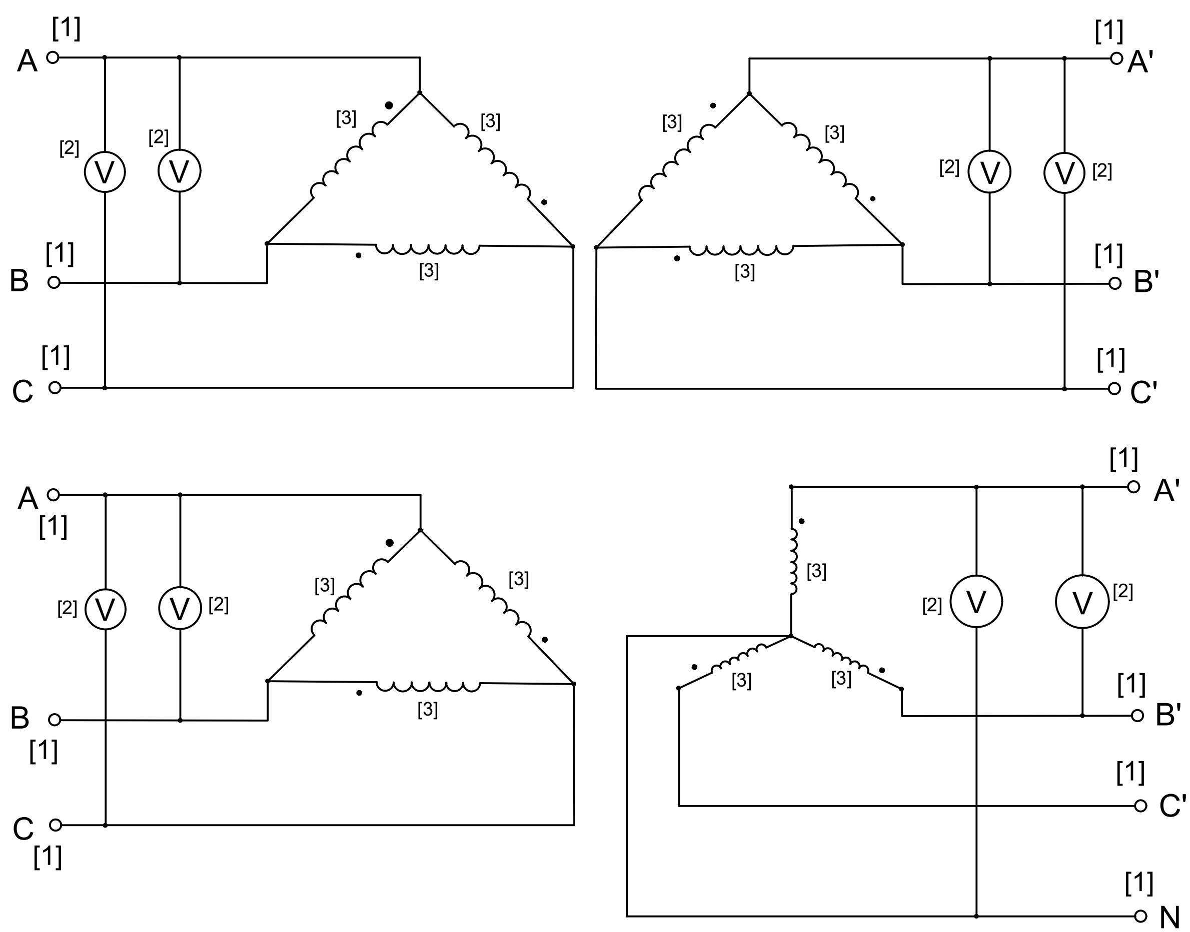
When comparing the results with the calculations we can see slight differences. The table does a good job showing losses in the system not identified by the simple model. These losses can be from obstacles such as dissipation or tolerance levels of the components. Also our model is for a theoretical application therefore it doesn't directly represent the voltage drops across the parallel components of the cantilever circuit. However, our calculations are similar to the measured values, so the theory from lecture does hold to be true in a real world application.

Conclusion

Overall we observed that our calculations for both parts are very similar to the measurements observed through the demonstration. While there are slight differences between parameter results, we do know that this will in evidently occur due to our model being a simplification of the actual circuit and the losses observed through the transformer based on the core and copper losses. Altogether the theory displayed in lecture and building off from lab 4, we can say that we are confident that the calculations are supported by the theory of three-phase transformers and residential distribution systems.

A Appendix: Engineering Deliverables

Order of Deliverables



Notes

[1] LabVolt Power Supply, 8821

[2] Data Acquisition and Control Interface, 9063

[3] Three Phase Transformer Bank, 8348-40

Designed Team 3	6/11
Drawn Lihong	6/11
Checked	

EE 347 Lab 5

Three-wire diagram of transformers

Approved ______ Date ____

Title ______

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Sheet 1 of 1

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POINT ASSIGNMENT INDEX		
PAGE NO.	**NO. OF SHEETS**	**DESCRIPTION**
1	1	This index
2	1	LabVolt Power Supply, 8821 (Single Phase and Three Phase)
3	1	Three Phase Transformer Bank (Delta-Wye), 8348-40
4	1	Three Phase Transformer Bank (Delta-Delta), 8348-40
5	1	Data Acquisition and Control Interface, 9063

NOTES

REV	DATE	DESCRIPTION	Created By	Checked by
1	6/11/2020	LabVolt Power Supply connection to Three Phase Transformer Bank (Delta-Wye)	LZ	RN
2	6/11/2020	LabVolt Power Supply connection to Three Phase Transformer Bank (Delta-Delta)	LZ	KB

Delta-Wye

LabVolt Power Supply, 8821		POINT TYPE								
		Hardware Point					Virtual			
Point Description	Origin Address	DO	DI	AO	AI	Pwr	Point	Destination Address	Destination Description	Notes
AC 0~120/208 V Phase A	4	0	0	0	0	1	0	1	Three Phase Transformer Bank Red Section	
AC 0~120/208 V Phase B	5	0	0	0	0	1	0	6	Three Phase Transformer Bank Black Section	
AC 0~120/208 V Phase C	6	0	0	0	0	1	0	11	Three Phase Transformer Bank Blue Section	
	Total Points	0	0	0	0	3	0			

Delta-Delta

LabVolt Power Supply, 8821		POINT TYPE								
		Hardware Point					Virtual			
Point Description	Origin Address	DO	DI	AO	AI	Pwr	Point	Destination Address	Destination Description	Notes
AC 0~120/208 V Phase A	4	0	0	0	0	1	0	1	Three Phase Transformer Bank Red Section	
AC 0~120/208 V Phase B	5	0	0	0	0	1	0	6	Three Phase Transformer Bank Black Section	
AC 0~120/208 V Phase C	6	0	0	0	0	1	0	11	Three Phase Transformer Bank Blue Section	
	Total Points	0	0	0	0	3	0			

Delta-Wye										
Three Phase Transformer Bank, 8348-40		POINT TYPE								
		Hardware Point					Virtual			
Point Description	Origin Address	DO	DI	AO	AI	Pwr	Point	Destination Address	Destination Description	Notes
Three Phase Transformer Bank Red Section	1	0	0	0	0	1	0	4	AC 0~120/208 V Phase A	
Three Phase Transformer Bank Red Section	1	0	0	0	0	1	0	12	Three Phase Transformer Bank Blue Section	
Three Phase Transformer Bank Red Section	2	0	0	0	0	1	0	6	Three Phase Transformer Bank Black Section	
Three Phase Transformer Bank Red Section	5	0	0	0	0	1	0	10	Three Phase Transformer Bank Black Section	
Three Phase Transformer Bank Black Section	6	0	0	0	0	1	0	5	AC 0~120/208 V Phase B	
Three Phase Transformer Bank Black Section	6	0	0	0	0	1	0	E2 Black	Voltage COM, DAC, 9063	
Three Phase Transformer Bank Black Section	7	0	0	0	0	1	0	11	Three Phase Transformer Bank Blue Section	
Three Phase Transformer Bank Black Section	9	0	0	0	0	1	0	E4 Black	Voltage COM, DAC, 9063	
Three Phase Transformer Bank Black Section	10	0	0	0	0	1	0	15	Three Phase Transformer Bank Blue Section	
Three Phase Transformer Bank Blue Section	11	0	0	0	0	1	0	6	AC 0~120/208 V Phase C	
Three Phase Transformer Bank Blue Section	11	0	0	0	0	1	0	E1 Red	Voltage 500V, DAC, 9063	
Three Phase Transformer Bank Blue Section	11	0	0	0	0	1	0	E2 Red	Voltage 500V, DAC, 9063	
Three Phase Transformer Bank Blue Section	12	0	0	0	0	1	0	E1 Black	Voltage COM, DAC, 9063	
Three Phase Transformer Bank Blue Section	14	0	0	0	0	1	0	E3 Red	Voltage 500V, DAC, 9063	
Three Phase Transformer Bank Blue Section	14	0	0	0	0	1	0	E4 Red	Voltage 500V, DAC, 9063	
Three Phase Transformer Bank Blue Section	15	0	0	0	0	1	0	E3 Black	Voltage COM, DAC, 9063	
	Total Points	0	0	0	0	16	0			

Delta-Delta

Three Phase Transformer Bank, 8348-40		POINT TYPE								
		Hardware Point					Virtual			
Point Description	**Origin Address**	DO	DI	AO	AI	Pwr	Point	**Destination Address**	**Destination Description**	**Notes**
Three Phase Transformer Bank Red Section	1	0	0	0	0	1	0	4	AC 0~120/208 V Phase A	
Three Phase Transformer Bank Red Section	1	0	0	0	0	1	0	12	Three Phase Transformer Bank Blue Section	
Three Phase Transformer Bank Red Section	2	0	0	0	0	1	0	6	Three Phase Transformer Bank Black Section	
Three Phase Transformer Bank Red Section	4	0	0	0	0	1	0	15	Three Phase Transformer Bank Black Section	
Three Phase Transformer Bank Red Section	5	0	0	0	0	1	0	9	Three Phase Transformer Bank Black Section	
Three Phase Transformer Bank Black Section	6	0	0	0	0	1	0	5	AC 0~120/208 V Phase B	
Three Phase Transformer Bank Black Section	6	0	0	0	0	1	0	E2 Black	Voltage COM, DAC, 9063	
Three Phase Transformer Bank Black Section	7	0	0	0	0	1	0	11	Three Phase Transformer Bank Blue Section	
Three Phase Transformer Bank Black Section	9	0	0	0	0	1	0	E4 Black	Voltage COM, DAC, 9063	
Three Phase Transformer Bank Black Section	10	0	0	0	0	1	0	14	Three Phase Transformer Bank Red Section	
Three Phase Transformer Bank Blue Section	11	0	0	0	0	1	0	6	AC 0~120/208 V Phase C	
Three Phase Transformer Bank Blue Section	11	0	0	0	0	1	0	E1 Red	Voltage 500V, DAC, 9063	
Three Phase Transformer Bank Blue Section	11	0	0	0	0	1	0	E2 Red	Voltage 500V, DAC, 9063	
Three Phase Transformer Bank Blue Section	12	0	0	0	0	1	0	E1 Black	Voltage COM, DAC, 9063	
Three Phase Transformer Bank Blue Section	14	0	0	0	0	1	0	E3 Red	Voltage 500V, DAC, 9063	
Three Phase Transformer Bank Blue Section	14	0	0	0	0	1	0	E4 Red	Voltage 500V, DAC, 9063	
Three Phase Transformer Bank Blue Section	15	0	0	0	0	1	0	E3 Black	Voltage COM, DAC, 9063	
	Total Points	0	0	0	0	17	0			

Delta-Wye										
Data Acquisition and Control Interface, 9063		POINT TYPE								
		Hardware Point					Virtual			
Point Description	**Origin Address**	DO	DI	AO	AI	Pwr	Point	**Destination Address**	**Destination Description**	**Notes**
Voltage 500V	E1 Red	0	0	0	0	1	0	11	Three Phase Transformer Bank Blue Section	
Voltage 500V	E2 Red	0	0	0	0	1	0	11	Three Phase Transformer Bank Blue Section	
Voltage 500V	E3 Red	0	0	0	0	1	0	14	Three Phase Transformer Bank Blue Section	
Voltage 500V	E4 Red	0	0	0	0	1	0	14	Three Phase Transformer Bank Blue Section	
Voltage COM	E1 Black	0	0	0	0	1	0	12	Three Phase Transformer Bank Blue Section	
Voltage COM	E2 Black	0	0	0	0	1	0	6	Three Phase Transformer Bank Black Section	
Voltage COM	E3 Black	0	0	0	0	1	0	15	Three Phase Transformer Bank Blue Section	
Voltage COM	E4 Black	0	0	0	0	1	0	9	Three Phase Transformer Bank Black Section	
	Total Points	0	0	0	0	8	0			

Delta-Delta										
Data Acquisition and Control Interface, 9063		POINT TYPE								
		Hardware Point					Virtual			
Point Description	**Origin Address**	DO	DI	AO	AI	Pwr	Point	**Destination Address**	**Destination Description**	**Notes**
Voltage 500V	E1 Red	0	0	0	0	1	0	11	Three Phase Transformer Bank Blue Section	
Voltage 500V	E2 Red	0	0	0	0	1	0	11	Three Phase Transformer Bank Blue Section	
Voltage 500V	E3 Red	0	0	0	0	1	0	14	Three Phase Transformer Bank Blue Section	
Voltage 500V	E4 Red	0	0	0	0	1	0	14	Three Phase Transformer Bank Blue Section	
Voltage COM	E1 Black	0	0	0	0	1	0	12	Three Phase Transformer Bank Blue Section	
Voltage COM	E2 Black	0	0	0	0	1	0	6	Three Phase Transformer Bank Black Section	
Voltage COM	E3 Black	0	0	0	0	1	0	15	Three Phase Transformer Bank Blue Section	
Voltage COM	E4 Black	0	0	0	0	1	0	9	Three Phase Transformer Bank Black Section	
	Total Points	0	0	0	0	8	0			

NEC Code Summary Sheet for Residential Circuits

NEC Codes and requirements that an Electrical Contractor has to consider when designing electrical wiring for a residential residence.

Lighting and Switches (NEC 210.70A)
Dwelling Units 210.70(A)

1. Habitable Rooms

   – At least one wall switch-controlled outlet per habitable room and bathroom.

   Exceptions

   – No.1 - Besides kitchens and bathrooms, one or more receptacles controlled by a wall switch are permitted.

   – No.2 – Lighting outlets may be controlled by occupancy sensors: 1) in addition to wall switches or 2) equipped with a manual override that allows the sensor to operate like a wall switch

2. Additional Locations

   – At least one wall switch shall be installed in hallways, stairways, attached garages, and detached garages with power.

   – Dwelling Units – At least one wall switch shall be installed to provide illumination on the exterior side of outdoor entrance or exits with grade level access (A garage door is not considered a outdoor entrance or exit).

   – Where one or more lighting outlets are installed for stairways, there shall be a wall switch at each floor level, and landing level that includes an entryway. Hallways and stairs with more than six steps (risers) require the lights to be controlled by a switch at each end.

   Exceptions

   – Hallways, stairways, and outdoor entrances can have remote, central, or automatic control of lighting

3. Storage or Equipment Space
   - For attics, basements, utility rooms, and underfloor areas, at least one outlet containing a switch or controlled by a wall switch will be installed where these spaces are utilized for storage or contain equipment that require servicing.

Receptacles (NEC 210.52A)
Requirements: 125-volt, 15- and 20-ampere receptacle outlets.
The receptacles within this section are in addition to:

1. Part of appliance
2. Controlled by a wall switch in accordance with NEC 210.70(A)(1)
3. Located within Cabinets or Cupboards
4. Loacated more than $5\frac{1}{2}$ft. (1.7m) above the floor

A. General Provisions
   1. Spacing
      - Receptacles will be installed that no point horizontally along the floor of any wall space is more than 6ft (1.8m) from a receptacle outlet.
   2. Wall Space
      - Any space 2ft or more (includes around corners)
      - The space occupied by fixed panels in exterior walls (excluding sliding panels).
      - The space afforded by fixed room dividers.
   3. Floor Receptacles
      - Receptacle outlets in floors do not need to be counted as a part of the required number of receptacle outlets, unless located within 18in. (450mm) of the wall.
   4. Counter-top Receptacles
      - Receptacles for counter-top surfaces (specified within NEC 210.52(C)) do need to be considered a receptacle required by NEC 210.52(A).

Overcurrent Protection for Small Conductors (NEC 240.4D)

Small Conductors 240.4(D)

Unless specified within NEC 240.4(E) or (G), the overcurrent protection shall not exceed the ratings required by 240.4(D)(1) through (D)(7) after correction factors for ambient temperature and number of conductors have been applied.

1. 18 AWG Copper - 7 Amperes, provided that these conditions be met:
   - Continuous loads do not exceed 5.6A.
   - Overcurrent Protection is provided by:
     a) Branch-circuit rated circuit listed for use with 18 AWG Copper wire
     b) Branch-circuit rated fuses listed for 18 AWG Copper wire.
     c) Class CC, Class J, or Class T fuses
2. 16 AWG Copper- 10 Amperes, provided that these conditions be met:
   - Continuous loads do not exceed 8A.
   - Overcurrent Protection is provided by:
     a) Branch-circuit rated circuit listed for use with 16 AWG Copper wire
     b) Branch-circuit rated fuses listed for 16 AWG Copper wire.
     c) Class CC, Class J, or Class T fuses
3. 14 AWG Copper - 15 Amperes
4. 12 AWG Aluminum and Copper-clad Aluminum - 15 Amperes
5. 12 AWG Copper - 20 Amperes
6. 10 AWG Aluminum and Copper-clad Aluminum - 25 Amperes
7. 10 AWG Copper - 30 Amperes

Branch Circuits

Branch-Circuit Voltage Limitations (NEC 210.6)

A. In dwelling units, the voltage shall not exceed 120V nominal that supply terminals of the following:

1. Luminaries
2. Cord-and-Plug loads (1440V nominal or less or $\frac{1}{4}$ hp)

B. Circuits not exceeding 120V nominal between conductors shall be permitted to the following:

1. The terminals of lampholders
2. Auxiliary equipment of electric-discharge lamps
3. Cord-and-Plug connected or permanently connected utilization equipment.

C. Circuits exceeding 120V nominal between conductors and not exceeding 277V to ground

Branch-Circuit Conductors – Minimum Ampacity and Size (NEC 210.19A)

A. Branch Circuits Not More Than 600V

1. General- Conductors shall have an ampacity that is not less than the maximum load.

   Where a branch circuit either supplies a continuous load or a combination of a continuous/noncontinuous load, then the conductor size shall have an ampacity not less than the continuous load plus 125% of the continuous load.

   Exceptions

   – If the branch-circuit (includes overcurrent devices) are listed for operation at 100% of its rating, then the allowable ampacity of the conductors will not be less than the sum of the continuous and noncontinuous loads.

2. Branch Circuits with More Than One Receptacle – Supplying more than one receptacle for cord-and-plug connected portable loads shall not have an ampacity not less than the rated branch circuit.
3. Household Ranges and Cooking Appliances– Wall mounted ovens, counter-mounted cooking units and other household appliances shall have an ampacity not less than the rated branch circuit and not less than the maximum load. For ranges of $8\frac{3}{4}$ kW or more, the minimum branch-circuit rating shall be 40 Amperes.

Exceptions

- No. 1 – Conductors tapped from a 50 Ampere branch-circuit supplying electric ranges, wall-mounted ovens, and countered-mounted cooking units will not have an ampacity greater than 20 Amperes. The taps shall not be longer than necessary for servicing the appliance.
- No. 2 – The neutral conductor of a 3-wire branch-circuit supplying a household electric range, wall-mounted oven, or a counter-mounted cooking unit can be smaller than the ungrounded conductors where the maximum of $8\frac{3}{4}$ kW or more has been calculated in accordance to Table 220.55. However, the conductor must have a current rating greater than 70% of the branch-circuit rating and not smaller than 10 AWG.

4. Other Loads– If branch-circuits that supply loads not specified in NEC 210.2 and excluding kitchen appliances (NEC 210.19(A)(3)) must have a sufficient ampacity rating and wire size will not be smaller than 14 AWG.

Branch-Circuit Conductors – Overcurrent Protection(NEC 210.20)

A. Continuous and Noncontinuous Loads - When a branch-circuit supplies continuous or a combination of continuous and noncontinuous loads, the rating of the overcurrent device will not be less than the noncontinuous load plus 125% of the continuous load.

   Exceptions

   - The overcurrent devices within the assembly is listed at 100% operation of its rating, the ampacity of the overcurrent device can be permitted to be less than the sum of the continuous load plus the continuous load

B. Conductor Protection - Conductors will be protected in accordance with NEC 240.4. Flexible cords/fixtures will be in accordance with NEC 240.5.

C. Equipment - For equipment the overcurrent protection device will not exceed the specifications in accordance with Table 240.3

D. Outlet Devices - Outlet devices will have an ampere rating greater than the load and will be in accordance with NEC 210.21(A) and (B)

Service Entrance

Minimum Size and Rating (NEC 230.42)

A. General -The service-entrance conductors before the application of any adjustment or correction factors shall not be less than either:

    1. The sum of the noncontinuous loads plus 125 percent of continuous loads.
       Exceptions
       - Grounded conductors that are not connected to an overcurrent device can be sized at 100% of the continuous and noncontinuous load.
    2. The sum of the noncontinuous load plus the continuous load if the service-entrance conductors terminates in an overcurrent device are listed for operation at 100% of their rating

B. Specific Installations - The minimum ampacity for ungrounded conductors will not be less than the rating of the service disconnecting means specified in NEC 230.79(A)-(D).

C. Grounded Conductors - Will not be smaller than the minimum size as required by 250.24(C).

Arc-Fault Circuit-Interrupter Protection(NEC 210.12)

Arc-Fault Circuit-Interrupter (AFCI) is a device (usually within a breaker) designed to give protection from arc faults

Dwelling Units (NEC 210.12)

Requirements: All 120-volt, single phase, 15 and 20-ampere branch circuits supplying outlets or devices installed in dwelling unit shall be protected by (1), (2), (3) and (4):

1. A listed type arc-fault circuit interrupter installed to provide protection to the entire branch circuit. [ROP 2–92]
2. Installed at the first outlet where all conditions must be met:
    a. Branch circuit overcurrent protection device listed as a circuit breaker having instantaneous trip (Not to exceed 300 Amperes).

  b. The branch circuit wiring shall be continuous from overcurrent protection device to AFCI.
  c. Maximum length of the branch circuit wiring should not exceed 50 ft. (15.2m) for 14 AWG or 70ft (21.3m) for 12 AWG conductor [ROP 2-92].
  d. The first outlet box in the branch circuit will be identified

3. AFCI installed at the first outlet on the branch circuit is installed using RMC, IMC, EMT, Type MC, or steel armored Type AC cables meet the NEC requirement of 250.118 and using junction boxes. [ROP 2-92]

4. AFCI installed at the first outlet on the branch circuit is installed using a listed metal or nonmetallic conduit or tubing encased in not less than 2 in. (50mm) of concrete. [ROP 2–92]

Article Justifications

Listed above are some basic NEC requirements that an electrical contractor should be aware of when designing residential circuits. Improper wiring in residential circuits can potentially correlate in the death of an individual or destruction of property. Some areas require only a licensed electrician wire the circuitry within a residence, but others allow untrained people to wire their own homes. Therefore it's imperative to understand these NEC codes to prevent any costly circumstances due to improper wiring. Furthermore, the NEC code changes on a regular basis and is also subject to local jurisdictions and standards, therefore some of these rulings are subject to correction depending on the location.

Article 210.70(A) pertains to lighting and switches within a home. This is one of the most commonly used applications of circuits within a residence. This is a necessity to maintain a standard of living for the population of people. This article is vital at laying the requirements for wall switches/outlets within rooms and extra areas. Every room must have at least one switch-controlled per habitable room and bathroom, but besides kitchens and bathrooms more than one may be permitted. This allow design freedom when structuring rooms, because the wall switches won't be affected due to size limitations while maintaining required current ratings.

Article 210.52(A) pertains to the requirements of receptacles within a home. A receptacle is an electrical outlet into which the plug of an electrical device may be inserted. Receptacles are essential to adding loads to your residential power system to complete tasks that the system wasn't designed for. For example, receptacles allows people to plug in appliances like vacuum cleaners for the maintenance of the current living condition. These guidelines are given so that outlets can be safely preserved without overloading the residential system. Keeping outlets 6ft. apart from each other limits the amount that can be held within a single living space maintaining the overcurrent protection.

Article 240.4(D) pertains to the overcurrent protection for small conductors. Overcurrent protection is the protection from excessive currents beyond an acceptable current rating for the load or equipment. Magnetic circuit breakers, fuses and overcurrent relays are commonly used to provide overcurrent protection. However, this article specifically deals with small conductors (wires). These devices respond by opening the circuitry when it detects excessive current. Depending on the specified current rating after correction factors for the ambient temperature and the total number of conductor. This correction factor with the specified wiring sizes ensures the overcurrent protection devices will operate at normal efficiency without detecting too much current when the temperature rises. This article is vital to making sure that the proper wiring sizes of the conductors are there to prevent any potential damage due to excessive current from temperature rise.

We listed several articles that pertain to branch-circuits that a contractor should be aware of. We listed NEC articles 210.6(A)-(C), 210.19(A), and 210.20(A)-(D). These the voltage limitations, current ampacity and size, and lastly overcurrent protection. A branch-circuit is the part of an electrical circuit extending beyond the last circuit breaker or fuse. They start at the breaker box and extended to the electrical device connected as a load. The reason why we listed many articles retaining branch-circuits are due to the amount of consideration since branch-circuits are used for appliances and general purpose (receptacles). Therefore it's imperative to know the regulations of voltage, sizing and overcurrent protection as observed with all the articles previously.

Article 230.42 pertains to service entrances into a residential home. A service entrance is where the wires connected to the load side of the meter enter the house or building. Typically these are in the form of a breaker box. This article is vital, because the service entrance meters and distributes all the electrical power to branch-circuits that are in turn fed into receptacles and wall switches. Therefore, these specifications are essential, because this is what supplies the home with power to run all of the circuits within their home. By making sure that the service entrances are sized properly by their rating is a crucial step from preventing loss of property.

The last articles is 210.12 that pertains to Arc-Fault Circuit-Interrupter protection.

Arc-Fault Circuit-Interrupter (AFCI) are device to protect from arc faults (arcing electrical current). This device is essential with the addition of branch circuits to prevent potential fires from occurring due to the arcing current. This article provides specific sizing requirements depending on the type of AFCI and how it's installed.

References

[1] S. Chapman, "Electric Machinery and Power System Fundamentals," New York: McGraw-Hill, 2002 pp.82-125
[2] Portland State University Power Lab, *347 Lab 5: Three-Phase Transformers and Residential Distribution* Accessed on: May 5, 2020. [Video File] Available: https://www.youtube.com/watch?v=NRBJZfDqsSwfeature=youtu.be
[3] National Electrical Code 2014 Edition," Quincy, MA: NFPA, 2012

Authors

Ryan Nand, is a BS candidate in the Electrical & Computer Engineering department at Portland State University. A PhD in Physics and an Olympic gold medalist. His research and studies have only just begun.

Kai Boldt, is a BS candidate in the Electrical & Computer Engineering department at Portland State University. World Renown Genius, Billonaire, Playboy, Philathropist. His research and studies have only just begun, but researches designing digital filters in his free time.

Lihong Zhao, is a BS candidate in the Electrical & Computer Engineering department at Portland State University. Passionate Power Student.

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