UNIT

8

VOLTAGE-DROP CALCULATIONS

Introduction to Unit 8—Voltage-Drop Calculations

When electrical current flows through a conductor, there's a certain amount of voltage drop in the conductor due to its inherent resistance. This is an example of Ohm's Law at work. Voltage drop, however, isn't useful work—it's wasted power that must be paid for on the utility bill. This results in (at the very least) inefficiency and even worse, overheated circuit conductors which can in turn lead to damage to the conductors and equipment.

Excessive voltage drop can also result in delivering a voltage to the load that's less than the rated voltage of the equipment. In some cases, this may not be a serious problem but for circuits such as sensitive electronic equipment it may be critical. The equipment manufacturer's nameplate, instruction manual, or industry standards should be consulted to determine the acceptable operating voltage range.

Ohm's Law shows that the amount of voltage drop present in any electrical circuit is directly proportional to the amount of current flow and resistance in the circuit. The resistance of a circuit is determined by its conductor material (copper or aluminum), cross-sectional area, length and conductor temperature.

In this unit, we'll show you how to find all the information necessary to make accurate voltage-drop calculations for both single- and three-phase circuits.

8.6 Voltage-Drop—Manufacturer and *NEC* Recommendations

Manufacturer Voltage-Drop Limitations [110.3(B)]

According to 110.3(B) in the *NEC*, equipment must be installed and used in accordance with the manufacturer's instructions included in the listing or labeling requirements. For this reason, circuit conductors to equipment must be sized in accordance with the manufacturer's requirements.

Therefore we must ensure the minimum voltage at the load is in accordance with industry standards and ANSI C84.1, *Voltage Ratings for Electric Power Systems and Equipment (60 Hz)*, states that the minimum voltage at utilization equipment should not be less than 90 percent of the nominal system voltage. This means that the maximum voltage drop for both the feeder- and branch-circuit conductors is 10 percent.

▶ Equipment Minimum Voltage Example 1

Question: *The minimum voltage at utilization equipment must not be less than 90 percent of the nominal system voltage. What's the minimum operating voltage permitted for a 115V rated load connected to a 120V source?*

(a) 108V (b) 109V (c) 110V (d) 111V

Solution:

The minimum operating voltage is based on the manufacturer's instructions.

Minimum Operating Voltage = Nominal System Voltage × 90%

Minimum Operating Voltage = 120V × 90%

Minimum Operating Voltage = 108V

Answer: *(a) 108V*

▶ Equipment Minimum Voltage Example 2

Question: *The minimum voltage at utilization equipment must not be less than 90 percent of the nominal system voltage. What's the minimum operating voltage permitted for a 208V rated load connected to a 208V source?*

(a) 187.20V (b) 191.20V (c) 199.29V (d) 202.20V

Solution:

The minimum operating voltage is based on the manufacturer's instructions.

Minimum Operating Voltage = Nominal System Voltage × 90%
Minimum Operating Voltage = 208V × 90%
Minimum Operating Voltage = 187.20V

Answer: *(a) 187.20V*

▶ Equipment Minimum Voltage Example 3

Question: *The minimum voltage at utilization equipment must not be less than 90 percent of the nominal system voltage. What's the minimum operating voltage permitted for a 230V rated load connected to a 240V source?*

(a) 187V (b) 202V (c) 199V (d) 216V

Solution:

The minimum operating voltage is based on the manufacturer's instructions.

Minimum Operating Voltage = Nominal System Voltage × 90%
Minimum Operating Voltage = 240V × 90%
Minimum Operating Voltage = 216V

Answer: *(d) 216V*

▶ Equipment Voltage-Drop Example 1

Question: *The minimum voltage at utilization equipment must not be less than 90 percent of the nominal system voltage. What's the maximum permitted voltage drop in volts for a 115V rated load connected to a 120V source?*

(a) 10V (b) 11V (c) 12V (d) 13V

Solution:

Maximum Voltage Drop = Nominal System Voltage × 10%
Maximum Voltage Drop = 120V × 10%
Maximum Voltage Drop = 12V

Answer: *(c) 12V*

▶ Equipment Voltage-Drop Example 2

Question: *The minimum voltage at utilization equipment must not be less than 90 percent of the nominal system voltage. What's the maximum permitted voltage drop in volts for a 208V rated load connected to a 208V source?*

(a) 18.80V (b) 20.80V (c) 22.80V (d) 24.80V

Solution:

Maximum Voltage Drop = Nominal System Voltage × 10%
Maximum Voltage Drop = 208V × 10%
Maximum Voltage Drop = 20.80V

Answer: *(b) 20.80V*

▶ Equipment Voltage-Drop Example 3

Question: *The minimum voltage at utilization equipment must not be less than 90 percent of the nominal system voltage. What's the maximum permitted voltage drop in volts for a 230V rated load connected to a 240V source?*

(a) 24V (b) 25V (c) 26V (d) 27V

Solution:

Maximum Voltage Drop = Nominal System Voltage × 10%
Maximum Voltage Drop = 240V × 10%
Maximum Voltage Drop = 24V

Answer: *(a) 24V*

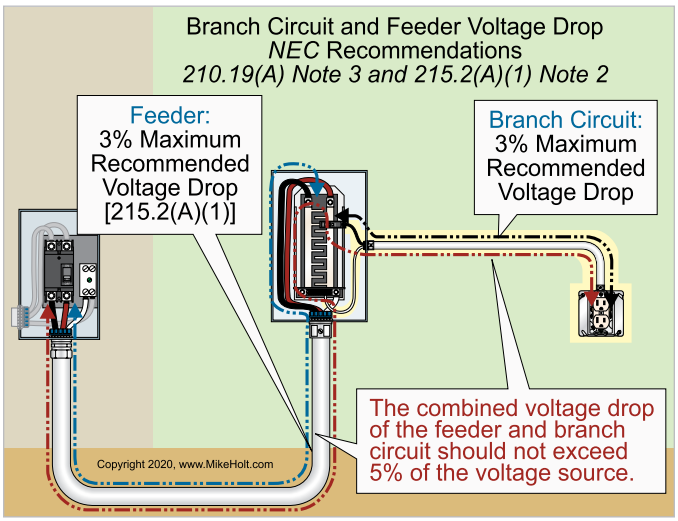
Energy Considerations. Current flow in a conductor results in energy losses (measured in watts) due to heat. The energy loss is called the "I^2R loss." According to this formula, increasing the conductor size (area) will result in lower resistance and lower power loss (heat). In addition, a larger conductor will result in lower circuit conductor voltage drop. Connected equipment will therefore operate at a higher voltage, resulting in improved efficiency and possibly lower circuit current. Some building codes have adopted an energy code to apply a maximum conductor voltage drop.

Fire Pump Installations [695.*7*]. For fire pump installations, the *NEC* has specific limitations on circuit voltage drop to ensure fire pump motors will operate when need. The voltage at the line terminals of a fire pump controller isn't permitted to drop more than 15 percent below the normal (controller-rated voltage) under the motor's starting conditions. The voltage at the load terminals of a fire pump controller isn't permitted to drop more than five percent below the voltage rating of the motor connected to those terminals when the motor operates at 115 percent of its full-load current rating.

Author's Comment:

- Sizing conductors for fire pumps must be performed by a qualified person who's familiar with fire pump applications and the impact of power factor on voltage drop. This topic is beyond the scope of this textbook.

National Electrical Code *Suggestions.* The final discussion about voltage drop centers on the Notes contained in Article 210 for branch circuits [210.19(A) Note 3] and Article 215 for feeder circuits [215.2(A)(1) Note 2]. The *Code* recommends that the maximum combined voltage drop for both the feeder- and branch-circuit conductors not exceed five percent, and the maximum on either the feeder- or branch-circuit conductors shouldn't exceed three percent. ▸Figure 8–21



▸Figure 8–21

Authors Comment:

- According to Article 100, the conductors between the final overcurrent device and the receptacle outlets, lighting outlets, or other outlets are known as branch circuits. The conductors between the service equipment, a separately derived system, or other power supply, and the final branch-circuit overcurrent device are feeders.

▶ *NEC* Branch-Circuit Voltage-Drop Recommendation [210.19(A) Note 3] Example 1

Question: *According to* NEC *recommendations, the minimum voltage at utilization equipment shouldn't be less than 95 percent of the nominal system voltage for both feeders and branch circuits. What's the minimum recommended operating voltage for a 115V rated load connected to a 120V source?*

(a) 111V (b) 112V (c) 113V (d) 114V

Solution:

According to the NEC, *the minimum recommended operating voltage is based on a maximum 5 percent voltage drop.*

Minimum Recommended Operating Voltage = Nominal System Voltage × 95%

Minimum Recommended Operating Voltage = 120V × 95%
Minimum Recommended Operating Voltage = 114V

Answer: *(d) 114V*

▶ *NEC* Branch-Circuit Voltage-Drop Recommendation [210.19(A) Note 3] Example 2

Question: *According to* NEC *recommendations, the minimum voltage at utilization equipment shouldn't be less than 95 percent of the nominal system voltage for both feeders and branch circuits. What's the minimum recommended operating voltage for a 208V rated load connected to a 208V source?*

(a) 195.60V (b) 197.60V (c) 199.60V (d) 200.60V

Solution:

According to the NEC, *the minimum recommended operating voltage is based on a maximum 5 percent voltage drop.*

Minimum Recommended Operating Voltage = Nominal System Voltage × 95%

Minimum Recommended Operating Voltage = 208V × 95%
Minimum Recommended Operating Voltage = 197.60V

Answer: *(b) 197.60V*

▶ *NEC* Branch-Circuit Voltage-Drop Recommendation [210.19(A) Note 3] Example 3

Question: *According to* NEC *recommendations, the minimum voltage at utilization equipment shouldn't be less than 95 percent of the nominal system voltage for both feeders and branch circuits. What's the minimum recommended operating voltage for a 230V rated load connected to a 240V source?*

(a) 224V (b) 226V (c) 228V (d) 230V

Solution:

According to the NEC*, the minimum recommended operating voltage is based on a maximum 5 percent voltage drop.*

Minimum Recommended Operating Voltage = Nominal System Voltage × 95%

Minimum Recommended Operating Voltage = 240V × 95%
Minimum Recommended Operating Voltage = 228V

Answer: *(c) 228V*