# *ECET 4520*

***Industrial Distribution Systems, Illumination, and the NEC***

# Introduction
## to the
# National Electric Code

## Electric Distribution System Design

**During normal operation, an electric distribution system must be able to safely deliver power to the loads that it serves by nature of its design.**

**<u>Safety</u> must be the #1 priority when designing, installing, and operating an electric distribution system.**

**But, there are many other considerations that also come into play when designing a system, including:**

**Cost, Practicality, Efficiency, Personal Preference, Flexibility, and Future Growth/Expansion.**

# Electric Distribution System Design

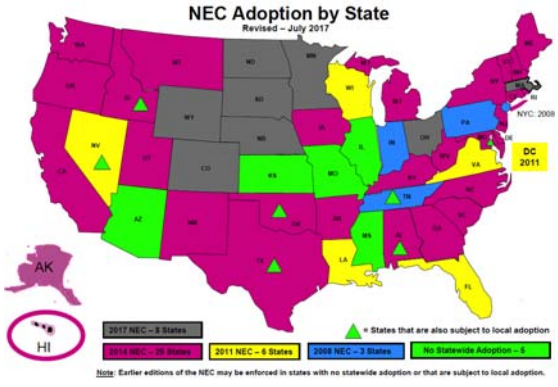
**Many different groups publish standards relating to electric distribution systems:**

- **National Fire Protection Association (NFPA) – NEC**
- **Institute of Electrical and Electronics Engineers (IEEE) – NESC**
- **National Electrical Manufacturers Association (NEMA)**
- **International Electro-technical Commission (IEC)**
- **International Organization for Standardization (ISO)**

**Yet, each system has its own unique set of design challenges, some of which can be addressed by applying standard design practice, others of which may require the knowledge gained from years of experience. For this reason, system design can be viewed as both an art and a science.**

# Design Standards

**In the United States, the most widely adopted set of standards relating to electric distribution systems is the National Electric Code (NEC). It is the official installation code used in almost all 50 states and all US territories.**



# National Electrical Code

- Sponsored by the National Fire Protection Association (NFPA) since 1911
- Updated every 3 years
- Provides a set of standards that:

  "cover the installation of electrical conductors, equipment and raceways for… public and private premises, including buildings, structures, mobile homes, recreational vehicles, and floating buildings… yards, lots, parking lots, carnivals, and industrial substations"

  NFPA 70 – National Electrical Code – Article 90.2

# National Electrical Code

The purpose of the National Electrical Code (NEC) is:

"the practical safeguarding of persons and property from hazards arising from the use of electricity."

NFPA 70 – National Electrical Code – Article 90.1(A)

The standards presented in the National Electric Code have been developed over the past 100+ years in order to provide a minimum set of rules for designing, installing, and operating a safe electric distribution system.

# National Electrical Code

**It is important to note that the code is:**

**"not intended as a design specification or an instruction manual for untrained persons"**

**NFPA 70 – National Electrical Code – Article 90.1(A)**

**and that compliance results in an installation that is safe:**

**"but not necessarily efficient, convenient, or adequate for good service or future expansion of electrical use."**

**NFPA 70 – National Electrical Code – Article 90.1(B)**

# NEC – Chapter Highlights

## Chapter 1 – General Provisions

- **Article 100 – Definitions**

  Article 100 contains only those definitions essential to the proper application of the Code.

- **Article 110 – Requirements for Electrical Installations**

  Article 110 covers general requirements for the examination and approval, installation and use, access to and spaces about electrical conductors and equipment; enclosures intended for personnel entry; and tunnel installations.

# NEC – Chapter Highlights

## Chapter 2 – Wiring and Protection

- **Article 200 – Use and Identification of Grounded Conductors**

  Article 200 provides requirements for the identification of terminals, grounded conductors in premises wiring systems, and identification of grounded conductors.

- **Article 210 – Branch Circuits**

  Article 210 covers branch circuits that don't supply only motor loads.

  Branch Circuits are the circuit conductors between the final overcurrent device protecting the circuit and the outlet(s)…

# NEC – Chapter Highlights

## Chapter 2 – Wiring and Protection

- **Article 215 – Feeders**

  Article 215 covers the installation, overcurrent protection, minimum size, and ampacity requirements of conductors for feeders.

  Feeders are the circuit conductors between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device.

- **Article 220 – Branch-Circuit, Feeder, and Service Calcs.**

  Article 220 provides requirements and methods for calculating branch-circuit, feeder, and service loads.

# NEC – Chapter Highlights

## Chapter 2 – Wiring and Protection

- **Article 225 – Outside Branch Circuits and Feeders**

  Article 225 covers requirements for outside branch circuits and feeders… and electrical equipment and wiring for the supply of utilization equipment that is located on.. the outside of buildings…

- **Article 230 – Services**

  Article 230 covers service conductors, equipment for control and protection of services, and their installation requirements.

  Services are the conductors and equipment for delivering electric energy from the serving utility to the premises wiring system.

# NEC – Chapter Highlights

## Chapter 2 – Wiring and Protection

- **Article 240 – Overcurrent Protection**

  Article 240 provides the general requirements for overcurrent protection and overcurrent protective devices.

- **Article 250 – Grounding and Bonding**

  Article 250 covers general requirements for grounding and bonding of electrical installations…

  Bonding is the permanent joining of metallic parts to form an electrically conductive path that ensures electrical continuity and the capacity to conduct safely any current likely to be imposed.

# NEC – Chapter Highlights

## Chapter 3 – Wiring Methods & Materials

- **Article 300 – Wiring Methods**

  Article 300 covers wiring methods for all wiring installations unless modified by other articles.

- **Article 310 – Conductors for General Wiring**

  Article 310 covers general requirements for conductors and their type designations, insulations, markings, mechanical strengths, ampacity ratings, and uses…

# NEC – Chapter Highlights

## Chapter 4 – Equipment for General Use

**The articles in this chapter cover the general requirements, applications, and construction specifications for:**

- **Flexible Cords and Cables**
- **Switches**
- **Receptacles**
- **Switchboards and Panelboards**
- **Lighting Fixtures**
- **Motors and Motor Controllers**

# NEC – Chapter Highlights

## Chapter 5 – Special Occupancies

**The articles in this chapter cover the requirements for equipment and wiring in special occupancies, such as:**

- **Hazardous Locations**
- **Locations with Specific Purpose Branch Circuits:**
  - **Health Care Facilities**
  - **Theaters**
  - **Amusement Parks**
  - **RV Parks**

# NEC – Chapter Highlights

## Chapter 6 – Special Equipment

**The articles in this chapter cover the installation of conductors and equipment for special utilization equipment, such as:**

- **Electric Signs and Outline Lighting**
- **Electric Vehicle Charging Systems**
- **Elevators**
- **Swimming Pools**
- **Photovoltaic Systems**
- **Welders**

# NEC – Chapter Highlights

## Chapter 7 – Special Conditions

The articles in this chapter apply to the electrical safety of the installation, operation, and maintenance of systems that require special conditions, such as:

- Emergency (Lighting and Power) Systems
- Fire Alarms
- Low Voltages Systems (<50V)
- Optical Fiber Cables

# NEC – Chapter Highlights

## Chapter 8 – Communication Systems

The articles in Chapter 8 cover the requirements for and the equipment used in:

- Communication Circuits
  - voice (telephone), data, fire alarm, burglar alarm…
- Radio and Television Equipment
- Broadband Communication Systems

# NEC – Chapter Highlights

## Chapter 9 – Tables

Chapter 9 contains tables that are either required for or can assist in the application of the code's requirements.

The tables cover a variety of topics, such as:

- Table 8 – Conductor Properties
- Table 9 – AC Resistance and Reactance of Three Phase Cables in Conduit

Table 8 Conductor Properties

| | Conductors | | | | | | | | | Direct-Current Resistance at 75°C (167°F) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stranding | | | Overall | | | | | | Copper | | | | | |
| Size (AWG or kcmil) | Area | | | Diameter | | Diameter | | Area | | Uncoated | | Coated | | Aluminum | |
| | mm² | Circular mils | Quantity | mm | in. | mm | in. | mm² | in.² | ohm/ km | ohm/ kFT | ohm/ km | ohm/ kFT | ohm/ km | ohm/ kFT |
| 14 | 2.08 | 4110 | 1 | — | — | 1.63 | 0.064 | 2.08 | 0.003 | 10.1 | 3.07 | 10.4 | 3.19 | 16.6 | 5.06 |
| 14 | 2.08 | 4110 | 7 | 0.62 | 0.024 | 1.85 | 0.073 | 2.68 | 0.004 | 10.3 | 3.14 | 10.7 | 3.26 | 16.9 | 5.17 |

# NEC – Chapter Highlights

## Annexes A – G

The Annexes are not a part of the NEC requirements. They are included for informational purposes only.

The Annexes cover a variety of topics, such as:

- A – Product Safety Standards
- B – Application Information for Ampacity Calc.
- C – Conduit and Tubing Fill Tables
- D – (Calculation) Examples

# Sampling of NEC Design Concerns

**A new industrial machine (460V, 3Φ, 90A) will be located on the plant floor in a vacant location. It requires the addition of an new branch circuit.**

**Some of the design concerns that must be considered are:**

**What type of load is the machine?**

# Sampling of NEC Design Concerns

## Article 210 – Branch Circuits

- **210.1 – Scope**

  This article covers branch circuits except for branch circuits that supply only motor loads, which are covered in Article 430…

  *Reminder – Branch Circuits are the circuit conductors between the final overcurrent protection device and the outlet.*

**Does the machine consist primarily of a motor-type load?**

# Sampling of NEC Design Concerns

### 210.2 – Other Articles for Specific-Purpose Branch Circuits

Branch circuits shall comply with this article and also with the provisions for branch circuits supplying equipment listed in Table 210.2 that amend or supplement the provisions in this article.

Table 210.2 Specific-Purpose Branch Circuits

| Equipment | Article | Section |
|---|---|---|
| Air-conditioning and refrigerating equipment | | 440.6, 440.31, 440.32 |
| Audio signal processing, amplification, and reproduction equipment | | 640.8 |
| Busways | | 368.17 |
| Circuits and equipment operating at less than 50 volts | 720 | |
| Central heating equipment other than fixed electric space-heating equipment | | 422.12 |

**Does the type of machine cause the branch circuit to be classified as a "Special-Purpose Branch Circuit"?**

# Sampling of NEC Design Concerns

**A new industrial machine (460V, 3Φ, 90A) will be located on the plant floor in a vacant location. It requires the addition of an new branch circuit.**

**Some of the design concerns that must be considered are:**

- What type of load is the machine?
- **What type of branch circuit is required?**

# Sampling of NEC Design Concerns

**210.3 – Rating**

Branch circuits recognized by this article shall be rated in accordance with the maximum permitted ampere rating or setting of the overcurrent device (that is protecting the circuit).

The rating for other than individual branch circuits shall be:

15, 20, 30, 40, or 50 amperes.

**Since it is a 90A machine, the circuit must be rated >50A**

**➡ The machine requires an Individual Branch Circuit.**

# Sampling of NEC Design Concerns

**A new industrial machine (460V, 3Φ, 90A) will be located on the plant floor in a vacant location. It requires the addition of an new individual branch circuit.**

**Some of the design concerns that must be considered are:**

- What type of load is the machine?
- What type of branch circuit is required?
- **Are there any circuit limitations based on the rated voltage of the machine?**

# Sampling of NEC Design Concerns

**A 460V, 3Φ load is designed to operate on a 480/277V circuit.**

**210.6 – Branch-Circuit Voltage Limitations**

The nominal voltage of branch circuits shall not exceed the values permitted by 210.6(A) through 210.6(E).

...

**(C) 277 Volts to Ground.** Circuits exceeding 120 volts, nominal, between conductors and not exceeding 277 volts, nominal, to ground shall be permitted to supply the following:

...

**(6)** Cord-and-plug-connected or permanently connected utilization equipment

# Sampling of NEC Design Concerns

**A new industrial machine (460V, 3Φ, 90A) will be located on the plant floor in a vacant location. It requires the addition of an new branch circuit.**

**Some of the design concerns that must be considered are:**

- **What are the minimum ampacity and/or size requirements for the branch-circuit conductors?**

# Sampling of NEC Design Concerns

**210.19 – Conductors – Minimum Ampacity & Size**

**(A) Branch Circuits Not More Than 600 Volts.**

**(1) General.** Branch-circuit conductors shall have an ampacity not less than the maximum load to be served. Conductors shall be sized to carry not less than…

**(a)** Where a branch circuit supplies… any combination of continuous and non-continuous loads, the minimum branch-circuit conductor size shall have an allowable ampacity not less than (100% of) the non-continuous load plus 125 percent of the continuous load.

**Will the machine be used continuously?**
**(I.e. – where the maximum current is expected to continue for 3+ hours)?**

**Note – there are many additional concerns that must also be addressed when sizing conductors.**

# Sampling of NEC Design Concerns

**A new industrial machine (460V, 3Φ, 90A) will be located on the plant floor in a vacant location. It requires the addition of an new branch circuit.**

**Some of the design concerns that must be considered are:**

- What are the minimum ampacity and/or size requirements for the branch-circuit conductors?
- **What is the rating of the overcurrent protection device that should be used to protect the circuit?**

# Sampling of NEC Design Concerns

**210.20 – Overcurrent Protection**

Branch-circuit conductors… shall be protected by overcurrent protective devices that have a rating… that complies with 210.20(A) through (D).

**(A) Continuous and Non-continuous Loads.** Where a branch circuit supplies… or any combination of continuous and non-continuous loads, the rating… shall not be less than the non-continuous load plus 125 percent of the continuous load.

**240.6(A) – Standard Amp Ratings – Fuses and CB$^s$**

The standard ampere ratings for fuses and inverse-time circuit breakers shall be considered:

15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125…

# Sampling of NEC Design Concerns

**There are many additional concerns that should also be addressed, such as:**

- **Does the addition of the new branch-circuit cause any of the existing system's ratings to be exceeded?**
- **Are there an excessive voltage-drop on the new branch-circuit or on any of the system's feeders due the addition of the new branch-circuit?**
- **…**