Microgrid codes and standards
White paper

7 key electric codes impacting microgrid design

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Microgrids have emerged as an ideal solution to improve energy resilience, provide independence from an aging utility grid and reduce carbon emissions. However, the effective design and installation of a microgrid and its components hinges on in-depth knowledge of multiple electric codes.

This white paper will explore how key articles of the National Electric Code (NEC) impact microgrid design and engineering to ensure safe and reliable operation.

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Overview

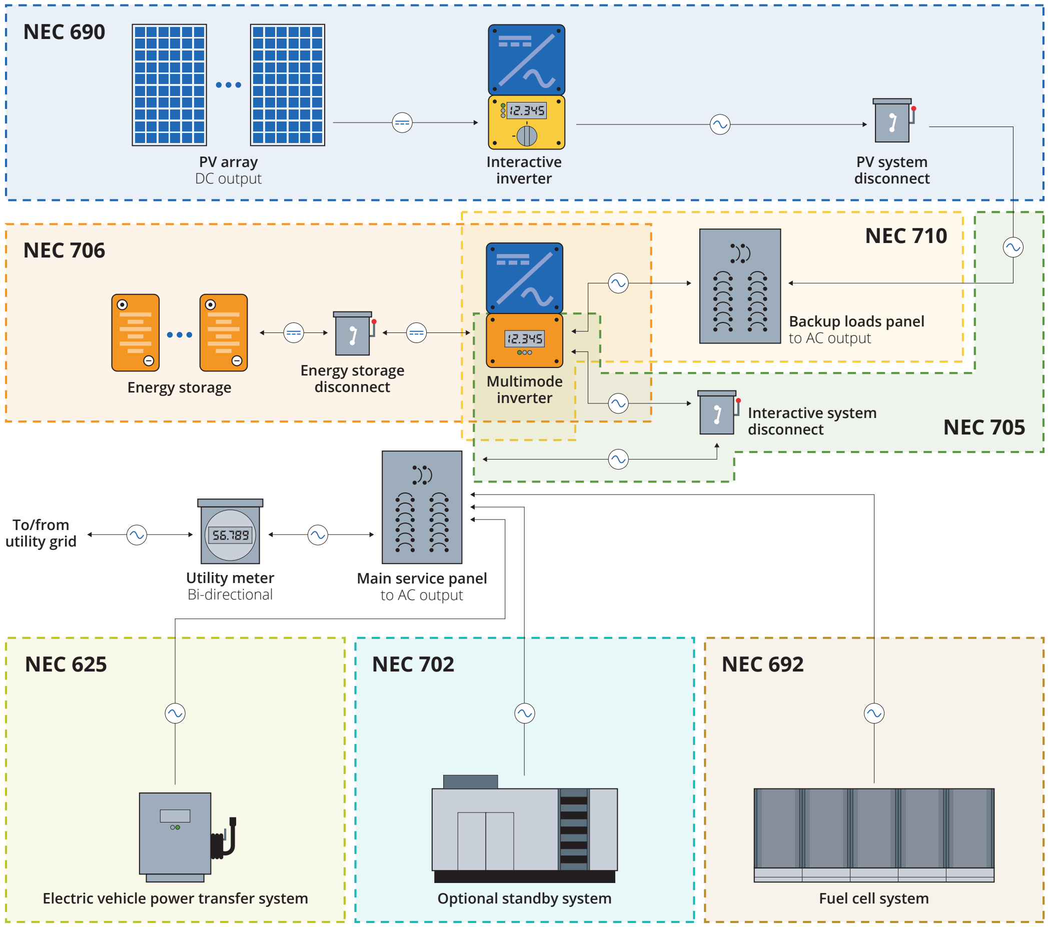
The decarbonization, decentralization and digitalization of energy systems puts immense pressure on the electrical grid. At the same time, building and home energy systems need to work harder and smarter to enable electrification of everything without breaking the bank, while also supporting resilient, sustainable electricity. Microgrids provide a powerful tool to help.

Universities, hospitals, businesses and communities are steadily turning to microgrids that incorporate distributed energy resources (DERs). Microgrids enable far greater control of energy systems, accelerating clean energy goals, providing greater energy resilience and providing some support for the grid.

That said, designing a microgrid is complex. These systems should optimize existing energy assets and often incorporate onsite DERs, which can include solar arrays, battery systems, fuel cells and traditional generators. So, there are numerous electric codes you need to know to install equipment safely and reliably.

It's critical to keep up with these electric codes as they evolve. Every three years, the National Fire Protection Association (NFPA) assembles technical committee members to review, modify and add new National Electrical Code (NEC) or NFPA 70 requirements to enhance electrical safety in the workplace and the home. One recent area of focus in the NEC is safety for the interconnection of technologies found in microgrids including power control systems, renewable energy generation, energy storage, electric vehicle (EV) charging and more.

To help you stay up to date on the electric codes impacting microgrid design in commercial and industrial applications, here are 7 key articles of the NEC affecting microgrid designs.



Source: Mayfield Renewables, Inc.

Figure 1 NEC Articles that dictate how microgrid components should be installed for safe and reliable performance

1. NEC Article 690 – PV electrical systems

Article 690 addresses safety standards for the installation of photovoltaic (PV) electrical systems, array circuits and inverters, which may be interactive with other electrical power sources or stand-alone.

For example, grounding is a fundamental technique to protect PV assets against lightning damage, which can be prevented by following NEC articles 690.43, 690.45 and 690.47. For ground-mounted solar PV arrays, the metal support structures installed in the ground serve as additional grounding electrodes. An insertion depth of 10 feet or more provides additional support for wind loading and meets NEC requirements for grounding electrodes.

The article also includes a requirement for a rapid shutdown (690.12) function to protect emergency responders.

2. NEC Article 706 – Energy storage systems

Battery energy storage systems enable renewables, which are an intermittent energy source, to match energy production and peak usage requirements, regardless of whether the wind is blowing or the sun is shining. Article 706 provides the requirements for installation of these storage systems, input connections to energy sources and output connections to the circuits that are powered from the energy storage system. It also covers disconnect and overcurrent protection requirements within the system for both DC and AC circuits and controls of the charging process.

3. NEC Article 710 – Stand-alone systems

When interconnection with the grid is not allowed by the utility, specific loads can be designed as a stand-alone system. As shown in Figure 1, the stand-alone system's power panel would be normally connected to a multimode inverter that is capable of operating independent from the grid.

4. NEC Article 705 – Interconnected electric power production sources

This article applies to a microgrid when an energy-generating source is interconnected to a prime power source such as the local electric utility.

It is important to pay attention to Article 705 because it defines the operation and requirements for an electronic device commonly referred to as a power control system (PCS). The PCS is considered the "brains" of the DER or microgrid system, because it enables the internal DER energy sources to back-feed power onto the grid or operate in parallel with the utility source.

Article 705 allows for interactive devices to communicate through a PCS or other means to island the system from the utility source in the event of an outage. This is required for the safety of any utility lineman who may be working to restore power.

Other important safety requirements include 705.10, which indicates the placement of a placard or directory to denote the location of the disconnection point for each power source in the building or structure.

5. NEC Article 625 – EV charging systems

Article 625 provides installation requirements for EV supply equipment (EVSE), whether it is for charging, exporting power or providing bi-directional current flow.

This is important because EV charging systems may be used to store and export power from vehicles back to the grid (V2G). Because this is an emerging capability and the electric codes surrounding its safe application are evolving, we believe it is critical to maintain knowledge of code updates impacting EV charging systems.

For example, the 2023 NEC 625.48 included an update that covers interactive equipment for bidirectional chargers. Depending on power export capabilities, you will need to follow the guidance listed in Article 702 or 705.

And, for sizable installations, 2023 NEC 625.42(A) now permits energy management systems to limit power to EV chargers, potentially reducing the required service size. This is important to safely maximize an existing site's ability to incorporate additional EV chargers without upgrading the incoming utility service.

6. NEC Article 700-702 – Standby systems

Standby generation sources are typically a necessary part of a microgrid because they provide a reliable source of continuous power when there is otherwise no alternate source of power. The NEC includes guidance for each type of these standby systems in the following articles:

- Article 700: Emergency systems
- Article 701: Legally required standby systems
- Article 702: Optional standby systems

It is important to understand the distinction between the three sections that govern the design and installation of standby systems.

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7. NEC Article 692 – Fuel cell systems

Fuel cells use a chemical reaction to convert hydrogen or a hydrogen-rich fuel such as natural gas to produce electricity. Similar to solar PV, electricity is produced as direct current (DC) power and normally uses an inverter to convert the power from DC to alternating current (AC).

Article 692 focuses on the requirements for electrical connections to the fuel cell system and the distribution components needed to distribute that power from the fuel cell.

Additional microgrid design considerations

Although we've identified the 7 NEC Articles above as the most foundational for safe microgrid system design, we recognize that every microgrid application is unique and there are a multitude of other requirements system designers should be familiar with to optimize installations.

For example, **Article 750.20** provides guidance for **load shedding in critical applications**. This is important when configuring a microgrid in applications such as healthcare environments —where emergency power, or legally required standby power systems, can automatically remain powered in the event of outage, impacting the main power source. **NEC Article 750.30** provides further load shedding restrictions, as well as guidance for the disconnection of power and avoiding the overloading of circuits by energy management systems.

Another critical design consideration is how the various energy sources will contribute to fault current. **NEC Section 705.16** highlights this issue, stating: all interconnected power sources shall be considered in the contribution of fault currents when sizing interrupting and short-circuit ratings for equipment and devices. A solution to this issue can be addressed as follows:

1. Perform a short-circuit study simulating the various energy sources individually
2. Perform a short-circuit study of the variation of potential energy sources that may be operating in parallel
3. Evaluate the worst-case scenario, while also considering the scenario reflecting the most common operating mode
4. Determine appropriate settings for protective devices, including ground fault protection, for the various scenarios to provide proper system coordination and the required selective coordination
5. Apply microprocessor relays, equipped with the capability for multiple sets of protective settings
6. Design the PCS to monitor the various energy sources and depending on the system configuration, activate the appropriate set of protective device settings by signaling the microprocessor relay to switch to the proper set of protective settings

Further, with the implementation of various energy-producing sources, **NEC Article 250** should be reviewed to ensure a stable, interconnected grounding and bonding system.

Going beyond the NEC

In addition to the NEC, consulting engineers should stay informed on the applicable fire and structural codes, as well as legislation, supporting emergency power microgrids in healthcare applications.

The most common fire codes are NFPA 1, Fire Code and International Code Council's (ICC) International Fire Code (IFCT). In microgrid applications, these codes typically impact the physical layout of the PV modules on the roof of a building, with the intent to provide safe access around the equipment in order to put out a structure fire from the building rooftop. Many jurisdictions may also require ICC's International Building Code (IBC) and ASCE 7 to guide the structural components of a PV installation. The consultant engineer will also need to review references to other DER power production sources, in addition to solar installations, as well as review ongoing updates to all applicable codes and standards.

NFPA 855 can also be referenced for guidelines supporting safe energy storage installations and most manufacturers provide a temperature range for their batteries. It is important to follow these recommendations, as operation outside of an acceptable temperature range can lead to energy storage systems not working as intended, aging more quickly or even causing a complete failure that can result in fire and explosion.

Additionally, we've recently seen legislation updates that are permitting microgrids as a source of emergency power for healthcare facilities. As of March 2023, Centers for Medicare & Medicaid Services (CMS) announced a categorical waiver permitting new and existing healthcare facilities to use alternative sources of emergency power. In other words, this program enables emergency power for an essential electrical system to be supplied by sources other than a generator, such as a microgrid system, opening the door to decarbonization. However, not all U.S. States and regions have formally embraced this categorical waiver, so it is vital to perform due diligence before starting on a microgrid project for emergency power in healthcare applications.

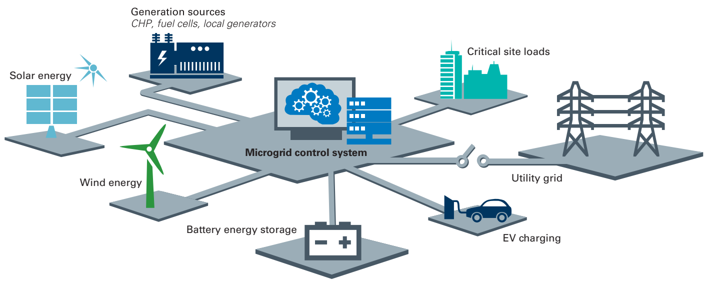

Figure 2 Microgrid control system

Microgrid success starts with a comprehensive design

Microgrids can provide many benefits for organizations looking to take greater control over their energy systems, but the requirements and specifications you need to consider when building a microgrid are unique to your application. This means it is critical to first understand the specific electrical codes and standards guiding effective microgrid component installation and operation before beginning to engineer the right solution for an application.

This isn't always a straightforward task. The technologies and power system strategies employed across microgrid systems are constantly evolving and the NEC is updating its installation guidelines accordingly. Further, because some states delay code adoption, many of the technologies involved in a microgrid project may not be governed by the most recent version of the code. This is when it is important to consider going beyond your local code requirements to ensure a safe and functional design.

If you need further assistance, we've developed the **Eaton DER and Microgrid design guide** to help readers better understand the basics of microgrid engineering. And if you need support, our expansive North American team of power systems engineers can provide the extensive electric code knowledge and industry experience you need to design a microgrid to meet your unique resilience, sustainability and electrification goals safely and reliably.

To learn more, visit
Eaton.com/microgrid

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