Technical Summary of Battery Energy Storage Systems

Based on the 2017 Massachusetts Electrical Code

This document summarizes the new Article 706 in the Massachusetts Electrical Code (MEC). Article 706 *Energy Storage Systems (ESS)* was created to simplify and consolidate Articles 480 and part VIII of 690 in the 2014 edition of the MEC. The MEC is based on the National Electrical Code (NEC) with amendments.[1] Local codes and standards may supersede any of the references below. Article 706 applies to all permanently installed ESS operating at over 50 volts AC or 60 volts DC, and may be stand-alone or interactive with other electric power production sources. The primary focus of this document is battery energy storage systems, and gives an overview of specific requirements within Article 706. Please note that other code sections may also be relevant to storage systems.

New Definitions and ESS Classifications

Energy storage systems are assembled components (one or more) that have the capability of storing energy for later use. These systems are classified as one of the following: self-contained, pre-engineered of matched components, or other. Self-contained units are the most recent technology.

System Classifications (Article 706.4)

- **706.4 (1) ESS, self-contained**
  - All components of the ESS are contained in a single unit.
- **706.4 (2) ESS, pre-engineered of matched components**
  - Components are not self-contained but are pre-engineered and field-assembled. These components are generally designed by the same entity and are intended to be installed together as a single system.
- **706.4 (3) ESS, other**
  - Individual components that are installed in the field to create an ESS but are not necessarily designed by the same entity.

Figure 1. Self-contained energy storage system

Figure 2. Pre-engineered energy storage system of matched components

Figure 3. Other energy storage system of individual components

1 Commonwealth of Massachusetts. 527 CMR 1.00, 2012 edition. *The Massachusetts Comprehensive Fire Safety Code and Base Code*. 2012. Available online: http://www.mass.gov/eopss/agencies/dfs/osfm/fire-prev/527-cmr-index.html.

Technology

Two primary ESS technologies exist in wide usage today: DC coupled and AC coupled systems. When connected to a solar photovoltaic (PV) system, Article 690 provides additional requirements and diagrams to help identify key system components.

DC Coupled Multimode System

DC coupled is the oldest type of battery backup. The PV system directly charges a battery bank through a charge controller(s). The inverter supports protected loads through an internal transfer switch, drawing energy from the batteries. A DC coupled system can be designed to be exclusively a backup system, to sell excess PV production back to the grid, or perform both functions.

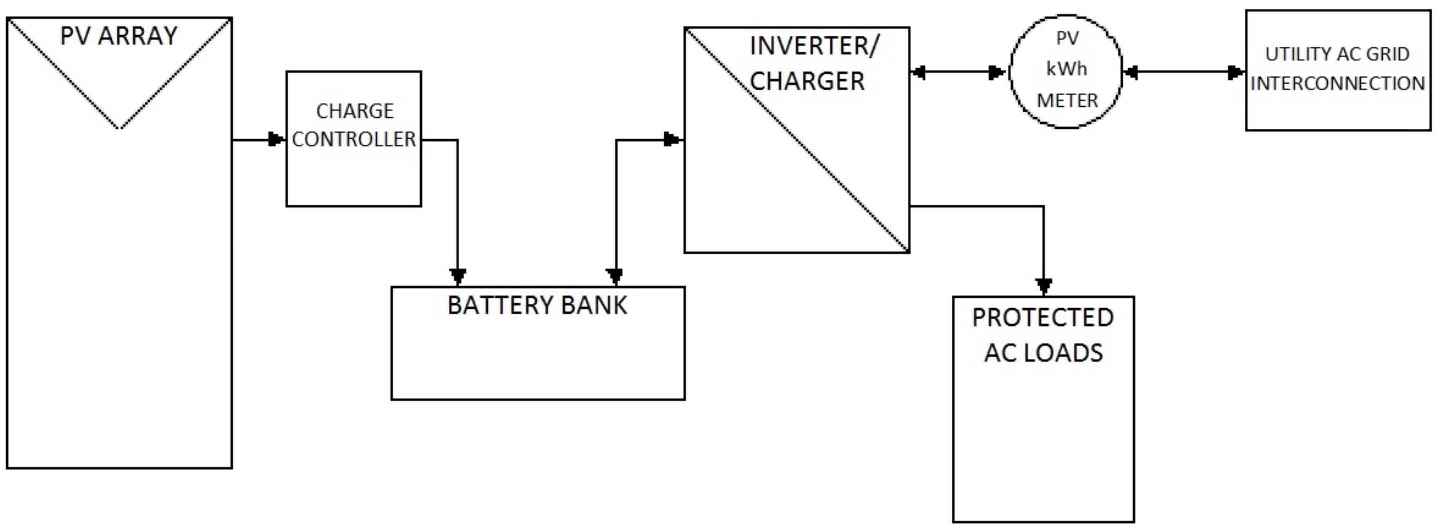

Figure 4. DC coupled multimode system

AC Coupled Multimode System

AC coupled systems are a newer concept in which a protected loads center is served by an inverter and its battery storage; however, the PV component of the system operates as a grid-tied inverter, interconnected in the protected loads center. AC coupled systems can be used without the presence of a PV system. The ESS is tied to the load panel and can be charged with power from the grid. This is useful in application where loss of power is frequent or if peak demand prices are much higher than regular electricity demand prices.

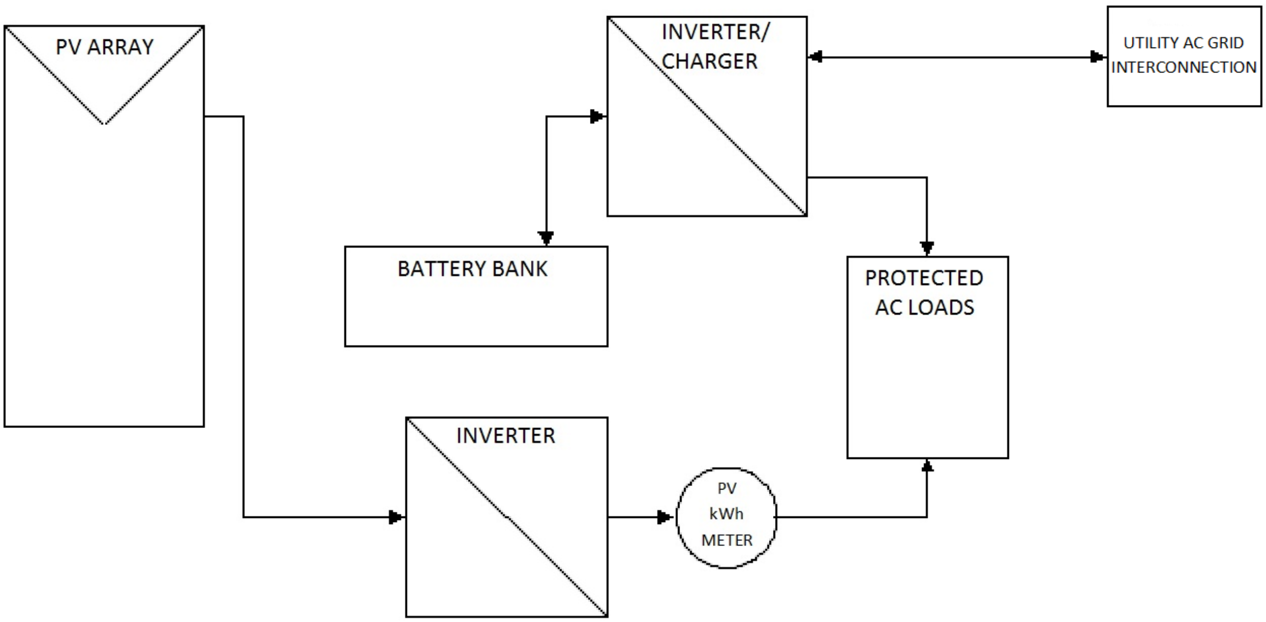

Figure 5. AC coupled multimode system

Installation Requirements

Disconnecting Means (Article 706.7)

- **706.7 (A) ESS Disconnecting Means**
  - A means to disconnect all ungrounded conductors from an ESS is required to be readily accessible *and* within sight of the ESS.
- **706.7 (B) Remote Actuation**
  - Controls can be used to activate the ESS disconnect. If the controls are not located within sight of the ESS, the location of the controls shall be field marked on the disconnecting means.
- **706.7 (C) Busways**
  - The disconnecting means can be incorporated into busways on a DC busway system.
- **706.7 (D) Notification**
  - A label is required to be marked in the field with the following values:
    1) Nominal ESS voltage
    2) Maximum available short-circuit current derived from the ESS
    3) The associated clearing time or arc duration based on the available short-circuit current from the ESS and associated overcurrent protective devices (OCPD) if applicable
    4) Date the calculation was performed

Figure 6. ESS disconnecting means

Connection to Other Energy Sources (Article 706.8)

ESS can be connected to other energy sources but must comply with Article 705.12. This means the interconnection between an ESS and the grid is accomplished the same way as PV. Depending on the situation, the interconnection can be on the supply side (upstream of the main breaker) or load side (downstream of the main breaker). The two most-common types of load-side connections are feeder taps and back-fed breakers in panelboards.

Figure 7. Example of a supply-side connection

A situation may arise during the installation of an ESS in which the capacity of a service may be exceeded. In one scenario, as outlined in *Figure 8*, a dwelling with an existing 200A service, a supply side connection is performed. A 60A protected loads panel is installed, and some loads are relocated from the main service panel to the protected loads panel. The service now has the capability to draw 260A for loads. Exception 3 to Article 230.90(A) may permit this; however, a service calculation will need to be performed any time loads are added. This is rarely standard practice in the field.

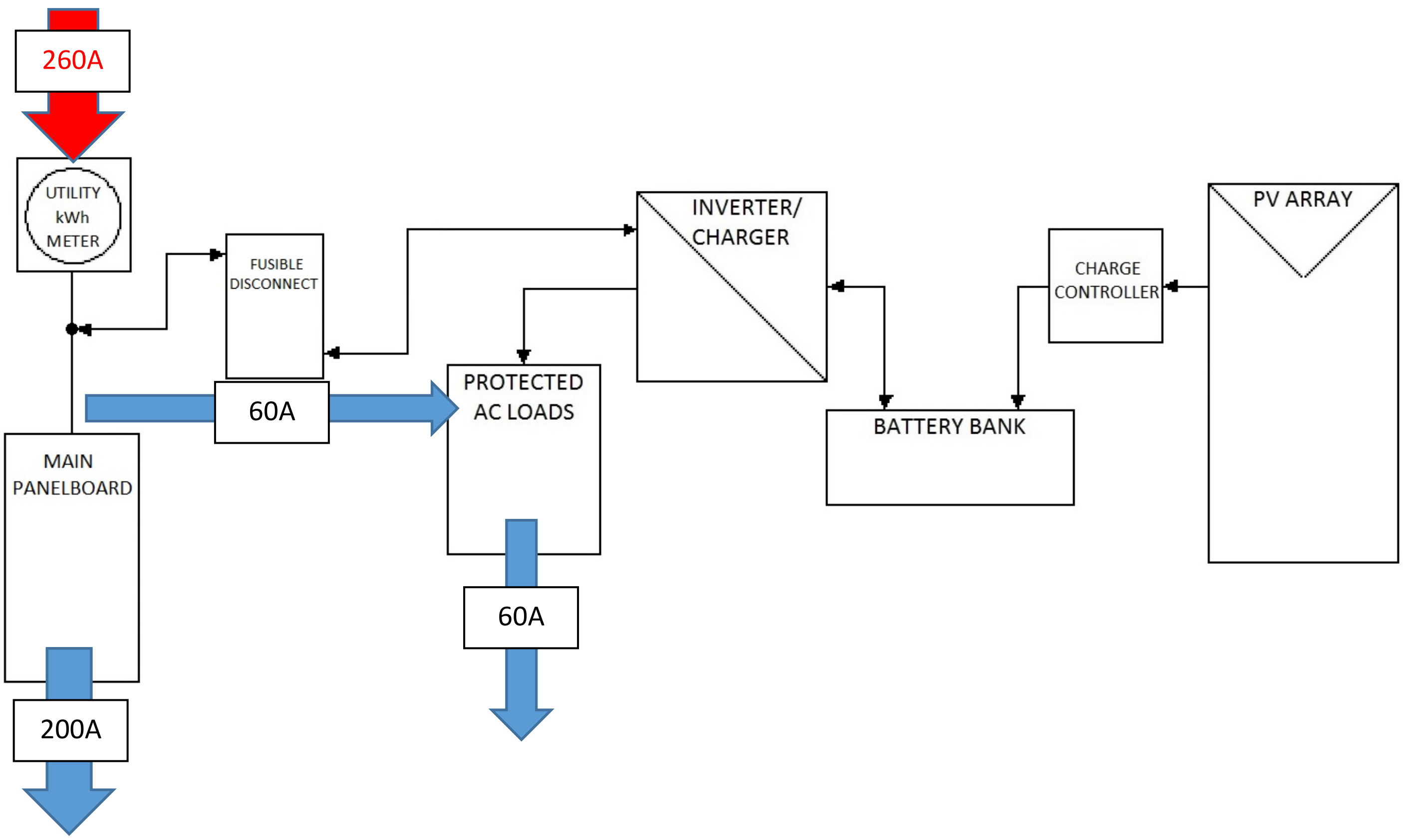

Figure 8. Example of supply-side connection with overloaded service conductors

Directory Requirements (Article 706.11)

Like other interconnected electric power production sources, ESS requires "a permanent plaque or directory denoting all electric power production sources on or in the premises." It should be installed at each service location and the location(s) of all other power sources. Article 110.21(B) is also referenced, outlining general requirements for field-applied hazard markings.

Figure 9. Permanent plaque indicating all power sources on or in the premises

Field-Applied Hazard Markings (Article 110.21(B))

- Labels must be sufficient to withstand the environment involved
- Labels shall be permanently affixed and shall not be handwritten
- Informational note to follow ANSI Z535.4-2001, words, colors, symbols

Circuit Requirements

Circuit Sizing and Current (Article 706.20)

Figure 10. Example of ANSI Z535.4-2001 markings

Maximum current can be calculated using the nameplate rated current found on the ESS and inverter. Conductor ampacity and overcurrent device ratings must not be less than the greater of (1) the nameplate current rating for the ESS or (2) the overcurrent device protecting the ESS.

Overcurrent Protection (Article 706.21)

ESS circuits must be protected with overcurrent devices. The rating of the overcurrent device shall not be less than 125% of the nameplate current found on the ESS and inverter. If fuses are used, means must be provided to disconnect them if exposed to unqualified personnel. Where ESS terminals are more than 5 feet (or pass through a wall) from the connected equipment, overcurrent protection is required at the ESS. Fuses and circuit breakers that are used on DC conductors shall be rated appropriately.

Electrochemical Energy Storage Systems

Installation of Batteries (Article 706.30)

When installed in dwelling units, the voltage between conductors or to ground must not exceed 100, unless the energized parts are not accessible during routine maintenance. For series battery circuits over 240 volts nominal between conductors or ground, a disconnecting means shall be provided to isolate segments, not exceeding 240 volts. The disconnecting means may consist of non-load-break bolted or plug-in type. For systems over 100 volts, battery circuit conductors can operate ungrounded, if a ground-fault detector and indicator is installed.

Figure 11. 48-volt battery configuration in a residential application

Battery and Cell Terminations (Article 706.31)

Some battery manufacturers require the use of antioxidant material on terminations to prevent corrosion. The installation instructions must be followed to determine the appropriate type. For field-assembled intercell and interior connections, the conductor ampacity must be consistent with the maximum load conditions. Conductors that are installed between levels must not put mechanical strain on battery terminals.

Battery Interconnection (Article 706.32)

Within and around the battery enclosure, flexible moisture-resistant cables in sizes 2/0 and larger that comply with Article 400, are permitted to be used. If flexible fine-stranded cables are used, they must be connected to terminals, lugs, devices, or connectors in accordance with Article 110.14. *Figure 12* shows an example of welding cable that is not recognized by Article 400, as well as an improperly-terminated fine-stranded cable on a standard lug.

Figure 12. Left: Wiring method not recognized by Article 400
Right: Fine-stranded cable on terminal not recognized by Article 110.14

Accessibility and Battery Locations (Articles 706.33 and 706.34)

The terminals of all cells or multicell units must be readily accessible. Article 100 defines readily accessible as "capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to take actions such as to use tools (other than keys), to climb over or under, to remove obstacles, or to resort to portable ladders, and so forth." The requirements of Article 110.27 must be followed to guard exposed live parts. Where top terminal batteries are installed on racks or shelves of cabinets, working space in accordance with the manufacturer's instructions must be provided. If batteries are installed in a dedicated room, gas piping is not permitted within the space.

Figure 13. Batteries installed in a cabinet with readily accessible terminals and proper clearance

APPENDIX 1 – Brief Listing of MEC Articles Relevant to Battery Storage

National Electrical Code

The following is a brief listing of many articles and code references that should be consulted and applied to energy storage installations. This list does not include all articles pertaining to energy storage systems.

Article 110.26

Working spaces is discussed in general electrical equipment requirements. More guidance is give in subsequent articles.

Article 230 Services

This article outlines the requirements to interconnect energy storage systems with the electric utility grid.

Article 240 Overcurrent Protection

This article provides the requirements for overcurrent protection of conductors used in battery systems and ESS.

Article 480 Storage Batteries

This article provides direction on the support of, locations for, ventilation, and labeling requirements for stationary storage battery systems. Currently, this Article and locally adopted codes provide the bulk of guidance for installing Energy Storage Systems that may be outside of the scope of Article 706.

480.1 Scope.

This article applies to all stationary installations of storage batteries.

480.4 Battery and Cell Terminations.

Corrosion protection and intercell and interior conductors and connections ampacity are discussed here. Battery terminal connections and mechanical strain are also discussed.

480.7 DC Disconnect Methods

Required labeling of disconnects.

480.8 Insulation of Batteries

If batteries are built with an electrically conductive container, they shall have insulating support if a voltage is present between the container and ground.

480.9 Battery Support Systems

Discusses the need for support systems (racks) to be corrosive resistant in design, and be nonconductive, as well as access to terminals for readings, inspection and cleaning.

480.10 Battery Locations

Discusses ventilation requirements, guarding of live parts, spaces about battery systems and the requirements for top-terminal batteries, as well as necessary illumination for battery working spaces.

480.11 Vents

Vented cells shall be equipped with a flame arrester. Sealed cells that may accumulate an excessive pressure during operation, a pressure release vent shall be provided. These requirements are applied at a battery cell level, and are most often addressed at the manufacturing level, not the ESS design or installation levels.

Article 690 Solar Photovoltaic (PV) Systems

690.11 Arc-Fault Circuit Protection (Direct Current)

Arc fault circuit protection is required on DC PV circuits (notable for DC coupled ESS).

690.12 Rapid Shutdown of PV Systems on Buildings

As this article is specific to PV systems, it does not directly apply to ESS. However, it may come down to local AHJ interpretation and require a conversation prior to system design.

690.15 Disconnection of Photovoltaic Equipment

Maximum current is greater than 30A, and equipment disconnecting means shall be provided for isolation. (A) Location – within the equipment or within sight and within 10 feet of the equipment. (B) Interrupt rating shall be sufficient for the maximum short-circuit current and voltage that is available at the terminals of the equipment.

690.41(B) System Grounding

Ground fault detection is required on DC PV arrays (notable for DC coupled ESS).

690.55 Photovoltaic Systems Connected to Energy Storage Systems

Polarity marking of conductors is required.

690.56 Identification of Power Sources

More required labeling for buildings containing energy storage, including locations.

690.71 General

Refers systems containing ESS to Article 706.

690.72 Self-regulated Charge Control

Describes applications where batteries may be directly charged from a PV system without a charge controller.

Article 705 Interconnected Electric Power Production Sources

Infrequent but important references to some applications should be reviewed in articles 705.14, 705.16, 705.32, 705.40, 705.80 and 705.143.

705.6 Equipment Approval

Requires that all equipment shall be approved for the intended use. They shall be listed or field labeled for the intended use of interconnection service.

705.10 Directory

Requires a directory be installed at each point of service equipment location, denoting the location of all electric power source disconnecting means, on or in the premises be also installed at each disconnect of each source capable of being interconnected. This would indicate that at the premises main service disconnect, at an inverter disconnect, and at a battery or ESS disconnect.

705.12 Point of Connection

Discusses the allowable points of power production sources, supply side of the service disconnecting means, or the load side, with a variety of methods.

705.22 Disconnect Device

Describes the requirements for disconnecting devices, including labeling.

705.23 Interactive System Disconnecting Means

Requires a means of disconnect be provided for every interactive system to isolate it from all wiring systems, including energy storage systems.

NFPA 1 – Fire Code

Chapter 52 presents requirements for Stationary Storage Systems, which includes batteries.

Section 52.1 defines this article as applicable to systems having an electrolyte capacity of more than 100 gallons in sprinklered buildings, or 50 gallons in unsprinklered buildings for FLA, NiCd and VRLA batteries, or 1000 lb. for lithium-ion and lithium metal polymer batteries used for facility standby power, emergency power or uninterrupted power supplies.

Section 52.2 indicates that where required, permitting shall comply with section 1.12 (Permitting and Approvals), and shall be submitted and approved by the Authority Having Jurisdiction (AHJ).

Section 52.3 describes safety features including safety venting, location and occupancy separation, spill control, neutralization, ventilation, acceptable environment, signage, seismic protection and smoke detection requirements.

International Fire Code

The international fire code follows the requirements of NFPA-1 very closely. Adoption may vary by building department, and it would be prudent to discuss this with your AHJ prior to system design.

Section 608

The trigger for this requirement is the use of a stationary storage battery having an electrolyte capacity of more than 50 gallons for FLA, nickel-cadmium (NiCd), and VRLA batteries; or lithium-ion and lithium metal polymer with a weight of more than 1,000 pounds.

Requirements cover safety caps for cells, thermal runaway management, spill control, neutralization, ventilation, signage, seismic protection, and smoke detection.

APPENDIX 2 – Best Practices

The following is a list of best practices to be considered when designing and installing Energy Storage Systems.

- Conduit interconnecting battery containers and other equipment should be sealed to prevent the migration of gases into switchgear where the possibility of arcing contacts may ignite gasses.
- Provide a source of electrolyte neutralization near the battery bank, as dictated by the chemistry type.
- Install smoke alarms near the storage area.
- Install catastrophic overcurrent protection (typically class T fuses) as close to the battery output connections as practical for both FLA and SLA technologies. These systems will allow significant discharges of stored energy during a short-circuit.
- Wire battery banks in a 'reverse return' fashion.
- Leave slight space between batteries for cooling and expansion/contraction.
- Reduce any mechanical stress on battery terminals imposed by interconnecting cabling.
- Properly clean terminals and lugs before mating.
- Properly torque battery terminals per the battery manufacturer's installation specifications.
- Protect the terminals and lugs from corrosion with a coating product.
- Limit strings of LA or LC batteries to three or less in parallel. Two is better, and a single string is best. Fewer paralleled strings is best – upsize lower voltage batteries or cells that have greater capacity instead of paralleling higher voltage strings. This exercises the bank in a more even fashion than with paralleled strings.
- When AC coupling a PV system, be sure to plan for diversion loads, or controlled shutdown of the PV system during off-grid operation. Frequency shift alone is not a best practice, and is limited to a backup plan for many systems.
- If performing a supply side connection for the ESS with PV, be sure no subsequent branch circuits are added to the protected loads subpanel in the future with clear labeling.
- PPE necessary for working on FLA or SLA batteries is different than that needed when working on electrical systems (AC or DC). Chemical splashes, burns and the exposure to toxic and possibly explosive gasses necessitate additional precautions based on the battery technology used.