2 Understanding Utility-Scale and Large Commercial-Scale ESS Projects

While there is no universally accepted definition for "utility-scale" energy storage, the US Department of Energy's Energy Information Administration uses a nameplate capacity of 1 MW as its threshold for "large-scale" energy storage systems. More distinctively than capacity of the system, utility-scale ESS (such as the one shown in Figure 2-1) are generally installed at a dedicated point on the distribution network or in front of the meter at a commercial facility. This allows the ESS to participate in a variety of potential markets and revenue streams, such as:

- Capacity market participation
- Frequency regulation
- Spinning reserve
- Energy arbitrage

With these revenue streams comes added financial opportunity for owners but this also creates added complexity, as discussed in this chapter.

Figure 2-1

This utility-scale ESS in Vermont is using li-ion batteries to provide peak reduction and frequency regulation services. Photo courtesy of WEG.

2.1 Major Parties Involved in Utility-Scale ESS Projects

Utility-scale ESS projects are typically financed and may involve complex ownership structures with multiple financing parties. In these cases, the project developer, site owner, project owner, technology vendor and engineering, procurement and construction (EPC) contractor may all be distinct firms or entities; the role of each of these participants is summarized in Table 2-1. The development process for utility-scale ESS can vary widely but the projects are generally easier to construct than other types of large energy projects and typical construction timelines range from 6 to 12 months, including site preparation, civil infrastructure, electrical works, installation and associated commissioning and performance testing.

Table 2-1 *Summary of Main Participants in Utility-Scale ESS Projects*

ROLE	RESPONSIBILITIES
Developer	Developers find potential projects and pursue the initial work of securing land/site control, obtaining initial permits and interfacing with the utility to receive interconnection approvals. These longer lead time items require engineering, surveying, and financial analysis but the purpose is to package a potential project for construction. Developers may sell the rights to a project, including all permits and interconnection approvals, to another firm for construction or they may continue managing construction.
Integrator	BESS are made of many components and the Integrator is the party responsible for assembling these subsystems into a functional BESS that includes enclosures, battery modules, PCS, transformers and associated software controls. Note that, in some cases, the integrator, EPC contractor and supplier may overlap. Some (typically larger) suppliers will provide a fully packaged BESS (enclosure, batteries, software, PCS), eliminating the need for a separate Integrator.
EPC Contractor	The engineering, procurement and construction (EPC) contractor handles the physical design, equipment procurement and construction of the project. Their scope of work usually includes permitting, design, equipment procurement, installation, site work, commissioning and obtaining the necessary operating permits/permissions for the project. If there is a separate integrator, the EPC contractor will likely manage construction of the overall project except for the BESS enclosures and subsystems. The exact division of labor will vary but, in these cases, close coordination between the integrator and the EPC contractor is essential.
Supplier	Typical utility-scale ESS may involve multiple equipment suppliers or manufacturers who are responsible for supplying key equipment, such as enclosures, modules, inverters or transformers. The project owner will procure equipment directly or via the EPC contractor and the key equipment will be provided under the terms of a supply agreement.
Site Owner	The site owner is the entity owning the real estate that the project is located on. This entity will often simply lease the land to the project owner and, as a result, be a passive participant in the BESS project.
Project Owner	The project owner is an entity, usually a special purpose corporate entity (such as a LLC) that owns the project and assumes all operating costs and revenues. Behind this corporate entity will often sit a financier, such as a private equity investor, that maintains the controlling interest in the project. Typically, the project owner will purchase the project once it reaches key development milestones (i.e., from a developer).

ROLE	RESPONSIBILITIES
Equity Investor	In addition to the project owner, which typically provides equity for the project, other firms may contribute equity as well. This could be in the form of "tax equity" (i.e., cash in exchange for access to lucrative tax credits or other benefits) or direct equity. In either case, the investor's income is tied to their level of ownership in the project, so they have a vested interest in things like safety, performance and technology and may be able to influence design and technology elements of the project.
Lender/Bank	Many utility-scale ESS projects are financed through a combination of equity and debt. The equity generally comes from the project owner but debt may be provided by specialized financiers, regional banks, credit unions or other types of financing institutions. Typically, these entities will provide a portion of the overall project cost, in exchange for repayment over several years. Such loan payments are generally not tied explicitly to project performance, so lenders are exposed to less risk and have corresponding less influence over design and technology than investors contributing equity to the project.
Asset Manager	Asset managers are employed by asset owners to provide administrative oversight for projects, covering aspects such as invoicing, periodic reporting, interfacing with utilities and overseeing operations and maintenance (O&M) activities.
Operations and Maintenance (O&M) Contractor	The O&M contractor is responsible for maintaining the ESS, performing routine site maintenance, managing warranties, performing periodic testing and similar activities.
Energy Manager	Energy managers are employed by project owners to manage the participation of the project in relevant markets and revenue streams. While not generally responsible for physical maintenance of the project and its facilities, the energy manager will make charge and discharge decisions (possibly several times per day) for the project, generally in an attempt to maximize revenues for the project owner.
Authorities Having Jurisdiction (AHJs)	Local entities, including the building inspector, electrical inspector and fire official, that have a role in reviewing, permitting and/or inspecting the project. These individuals will be acting on behalf of the municipality or local government in which the project is located and will have substantial ability to influence the design and technology of the project.
Owner's Engineer (OE)	The OE is generally hired by the project owner to provide technical oversight of project design and construction. The OE may perform activities such as design reviews, reviewing key warranties and agreements, equipment selection, field inspections, construction monitoring, and commissioning oversight on the project, acting as the owner's technical representative, particularly in reviewing and approving routine technical matters related to the project. Project owners will generally select third-party technical consultants and engineering firms as OEs based on ESS technology and construction expertise.
Independent Engineer (IE)	While performing functions similar to the OE, the IE represents the project investors, as a whole, and their interests in the project. The IE will review the contractual and technical aspects of the project and provide the investors with a detailed report noting any potential risks associated with the project. The IE's findings will potentially influence how the investors participate in the project. The IE will be a third-party technical consultancy with relevant ESS expertise.

2.2 Major Equipment on Utility-Scale ESS

The majority of utility-scale ESS consists of arrangements of battery enclosures, either large (40 foot or 53 foot) enclosures or smaller, more modular units. Each enclosure includes racks of batteries and the battery management system, HVAC systems and fire safety systems. The ESS may also include a power conversion system (PCS) or inverter, often located adjacent to the enclosure. From there, the output of the PCS (alternating current) is stepped up via a transformer to reach the relevant distribution voltage compatible with the local distribution system, as shown in Figure 2-2. Additional equipment onsite will include code-required disconnects, overcurrent protection devices, system control and data acquisition (SCADA) systems, metering equipment and similar electrical infrastructure. Major equipment found on a utility-scale ESS is discussed further in subsequent sections.

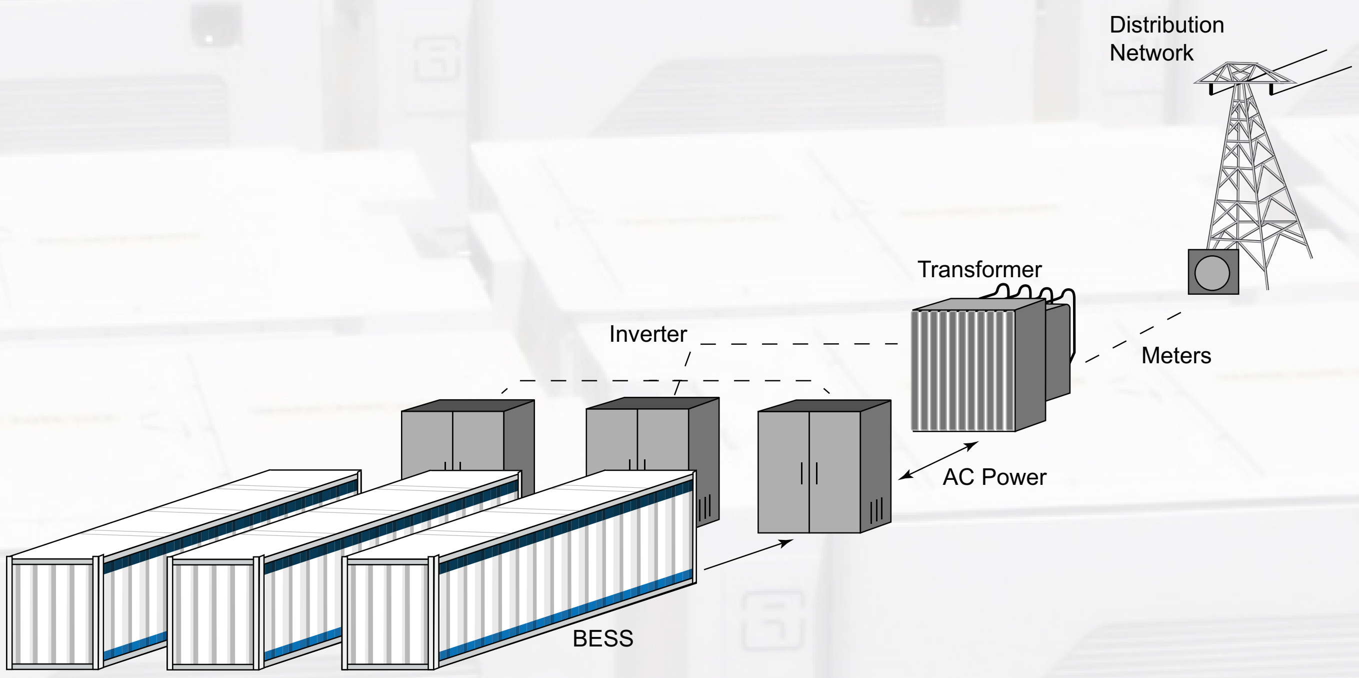

Figure 2-2

This diagram illustrates a typical utility-scale ESS layout and major components.

This section describes several of these specialized pieces of equipment that might be found on a BESS project during design review or inspection activities.

Enclosures

Battery cells are vulnerable to weather and temperature effects and are generally protected inside of some form of enclosure or container. These enclosures, broadly speaking, provide a physical structure to house and protect the sensitive electronics and batteries that allow the ESS to operate. Historically, BESS enclosures were made from ISO shipping containers, particularly for early BESS projects, as these containers were already designed to protect their contents against a variety of weather conditions and were structurally durable, with nonflammable construction. This led to the evolution of 20-foot, 40-foot, and 53-foot containers as a relatively standardized form factor. From there, containers were modified to add HVAC units to provide thermal management and various types of fire safety systems to reduce the risk from thermal runaway and fires. In a typical utility-scale BESS project, the enclosures are shipped to the site with racks installed but the added weight of the battery modules would preclude readily shipping and moving them, so the battery modules are shipped separately and installed by field crews.

Early, walk-in style enclosures required personnel to enter to service and monitor the batteries. These early enclosure interiors typically included a central walkway, computer terminals to access the battery management system and racks of batteries in all available space flanking the central corridor. This approach posed an increased safety risk as it required emergency personnel to enter enclosure interiors to assess conditions after an alarm event, as only minimal observations could be made from outside the enclosure. Today's larger enclosures provide for all equipment to be accessed via exterior doors around the perimeter of the enclosure, so technicians are not required to enter the enclosure during normal operations and maintenance activities. Figure 2-3 shows an example of an exterior access enclosure. With the door open, the battery racks and modules are accessible for inspection and servicing without entering the enclosure.

Figure 2-3

This image shows a utility-scale ESS enclosure with doors opened for easy access to key equipment. Photo courtesy of Matt Paiss, Pacific Northwest National Laboratory, and Snohomish PUD.

Figure 2-4

Cabinet-based ESS, like the Fluence 6th generation system shown here, provide site designers with a lot of flexibility and can be used from small commercial through large utility scale sites. Photo courtesy of Fluence.

Many of the major manufactures now offer enclosures that are even more modular and specialized. These cabinets may be approximately the size of a large refrigerator or freezer, with sufficient space to house one or two racks and associated hardware. A larger site may include many of these cabinets connected, with communications and controls routing to a central panelboard. In Figure 2-4, many of these sorts of modular units are shown in a typical utility-scale layout, with more modular units taking the place of the 40 foot or 53 foot larger enclosures seen on other sites and a central pathway for access and efficiently locating AC equipment such as inverters and transformers. These designs can be highly modular, giving more options for site layout and simplifying logistics. In addition, the smaller form factor allows for these enclosures to be fully assembled offsite (including the installation of battery modules) and shipped to the site as a fully integrated unit, requiring minimal field assembly. This greatly simplifies the installation process, as workers do not have to directly handle battery modules or be responsible for their installation.

Thermal Management

Battery cells typically have nuanced warranties governing their expected performance and one of the key variables in such warranties is the operating temperature of the batteries. All batteries, to some extent, experience a reduction in energy capacity based on temperatures; this effect can be seen at both high and low extremes, so keeping the batteries at approximately 68°F to 86°F (20°C to 30°C) (i.e., near room temperature) is key for maintaining warranty and overall health of the system. That said, batteries and associated equipment generate considerable heat during charging and discharging operations, with a typical rack of lithium iron phospate (LFP) batteries likely generating approximately 1kW of thermal load during operation. Batteries at standby dissipate much less heat but the trend for modern ESS is to keep batteries operating into a variety of revenue streams, so operation may be close to continuous for some use cases. A fully loaded 53-foot enclosure can easily require 5 to 10 tons[4] of cooling capacity, which is roughly equivalent to the air conditioning load of two average size homes in the United States.

Clearly, thermal management has a major impact on BESS performance and reliability, and this need is met through either air cooling (i.e.,

4. In this case, a "ton" refers to a unit of cooling equal to 12,000 Btu/hour of heat removal.