Design Optimization for Battery Energy Storage System Facilities

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PURPOSE

Utility scale battery energy storage systems (BESS) will be a critical path to decarbonization to address the variability of solar and wind generation. BESS projects are becoming exceedingly common additions for both new and existing solar fields. The design methods and decisions employed involve an iterative process in order to optimize the physical and electrical design of these systems. Key design decisions can ensure reductions in project costs, improve constructability while simultaneously meeting target project capacities. These decisions can have significant benefits for various stakeholders including developers, contractors, and the utility. The following illustrates core methods that can be utilized during the design process to deliver cost-effective and constructable BESS projects.

DESIGN CONSIDERATIONS

DUE DILIGENCE

Prior to starting a site layout, it is critical to define existing conditions, understand the scope of the work and relevant design constraints, and perform due diligence. As information becomes available, site plans evolve. Land surveys can expend a significant portion of a development budget if done prematurely. As a result, they are usually completed after the initial layouts and interconnection application have been submitted. Any surprises uncovered late in a project could result in reduced project capacity.

Existing Conditions

The easiest way to mitigate project risk is to perform desktop reviews of all available records and leave adequate space to adjust a layout as information is gathered about the following conditions:

- Topography
- Easements
- Subsurface conditions
- Flood zones
- Cultural resources
- Environmental conditions including wetlands, waters, endangered or at-risk species.
- Zoning requirements including, but not limited to setbacks, landscape buffers, ornamental walls, parking.

Figure 1A and 1B shows how conservative assumptions about wetland offsets allowed for a significant redesign later in the project upon receipt of actual environmental constraints and requirements defined by the AHJ (Authority Having Jurisdiction). Since the first design iteration was conservative, project constructability increased in the second iteration which made the project financials more appealing.

With desktop reviews performed, there will be reduced impact to project costs until land, interconnection and offtake agreements have been executed and the project has received planning and zoning approval.

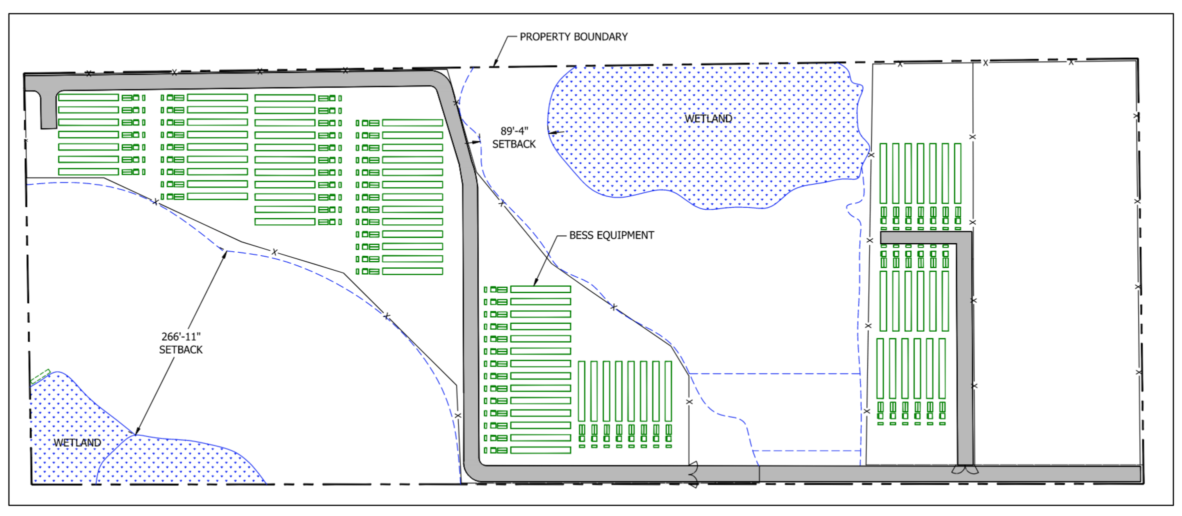

Figure 1A
Inclusion of conservative wetland setbacks, guaranteed the project could meet capacity requirements

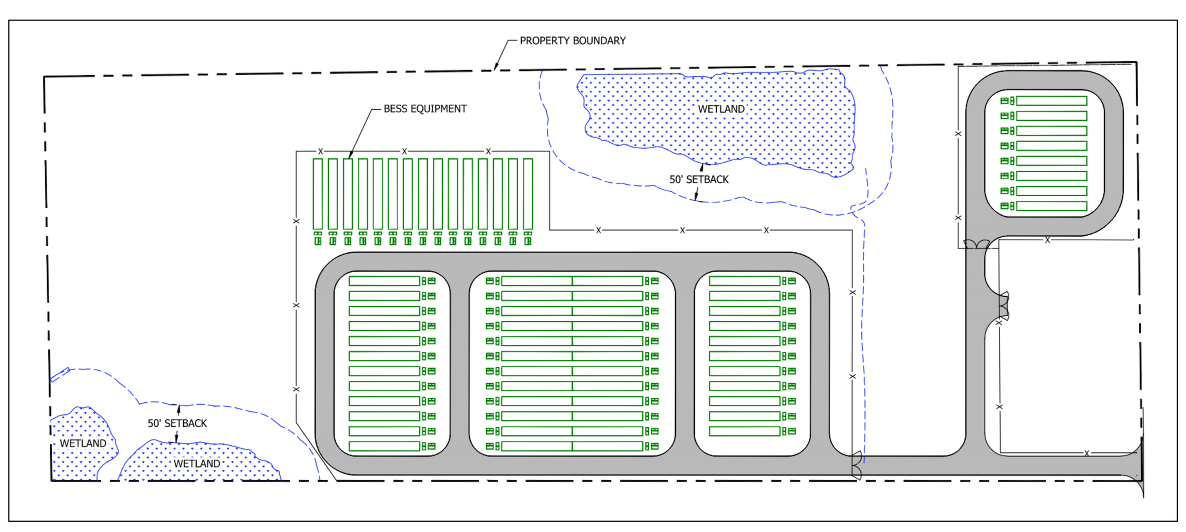

Figure 1B
The addition of a AHJ required landscape buffer, larger setbacks, parking were easily incorporated to allow for a more cost-effective layout.

EQUIPMENT SELECTION

The layout of a BESS project is dictated by the equipment selection at the beginning of a project. Equipment selection will inherently drive electrical and structural design as well as the ability to meet project capacity requirements. Working and operational clearance requirements from both the equipment installation manuals as well as code requirements are critical to consider for designing an optimized site layout. Clearance requirements of equipment impact the quantity of equipment that can fit within a project boundary.

Integrated Systems

There are now various models of energy storage systems on the market. Some manufacturers are offering BESS models with integrated. Power Conversion Systems (PCS) or PCSs that integrate with a transformer to form a containerized solution. These integrated systems prove advantageous from several aspects including:

- Eliminating the need for a DC design
- Reducing conductors, conduits, and trenching
- Removing the need for additional foundations
- Reducing grading and construction costs
- Minimizing ecological impacts
- Ensuring larger capacity projects / energy dense sites

Figure 2 highlights the significant reduction in overall footprint of the equipment block when using containerized systems in Project A & B versus in Project C. We see up to a 41 ft decrease in the size of the overall equipment block with the integrated equipment.

Equipment Clearances

Site footprints are also dictated by the operational and working clearances as required by manufacturers and electrical code. Figure 2 highlights the clearances for each of the equipment blocks in Projects A, B, & C. There are several design considerations that drive the overall site layout:

- Manufacturers have different operational requirements
- Equipment door locations and swing radius dictate working clearance requirements
- Back-to-back spacing is dependent on anchoring requirements
- Client requirements for use of access aisles between equipment blocks

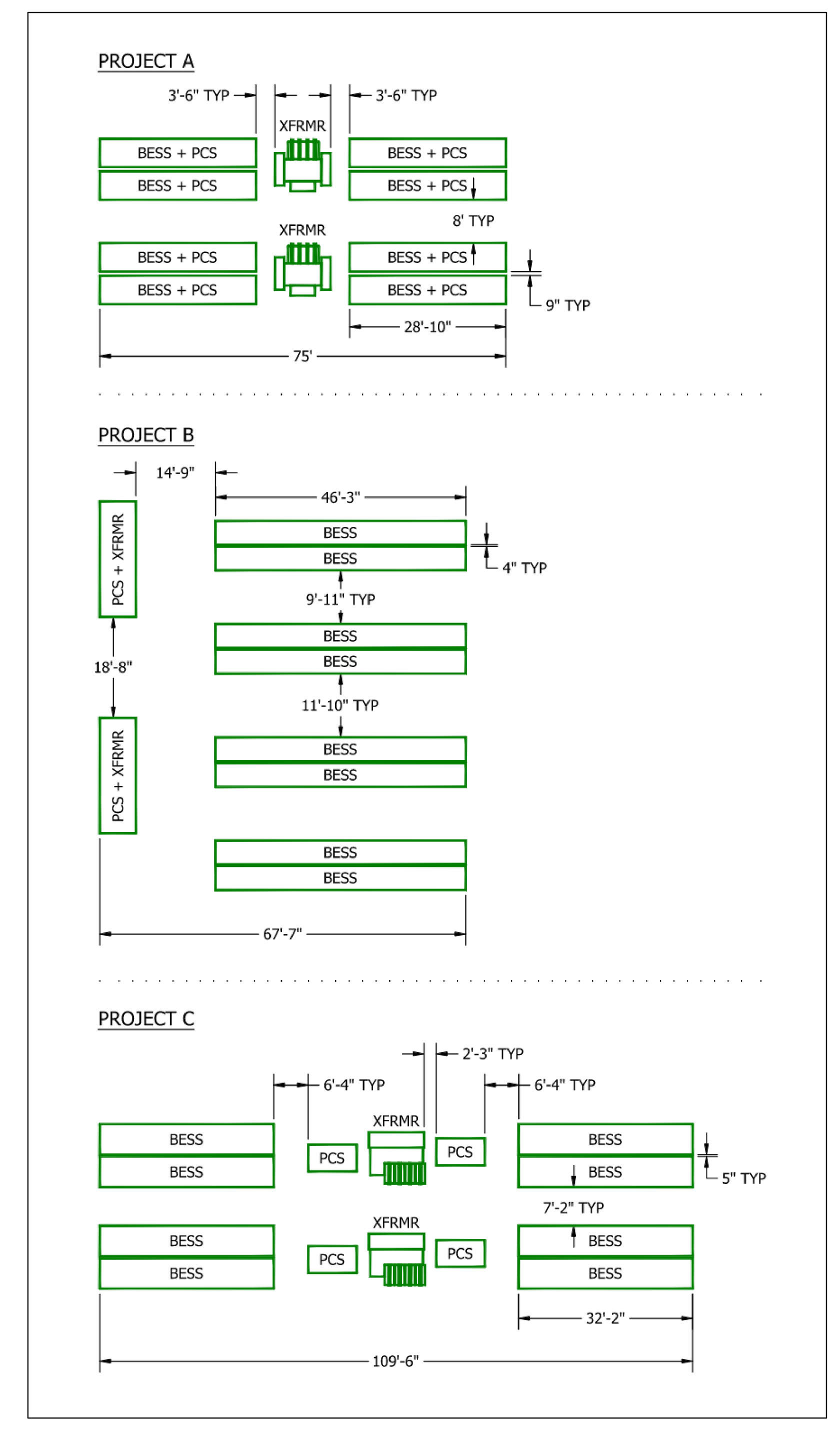

Figure 2
Equipment Block Dimensions & Clearances for Various Integrated & Non-Integrated Systems Projects

AUXILIARY TOPOLOGY

Auxiliary loads from energy management, fire detection, and HVAC systems are critical to site operation. As such, the auxiliary power distribution of a BESS project equally impacts the design when compared to primary power circuits. Due to the repetitive block configuration of BESS sites, the auxiliary distribution topology will have compounding affects. Whether they are positive or negative often stems from an engineer's understanding and selection of a distributed tap topology vs. a substation feeder based auxiliary system.

Substation Feeder

A dedicated feeder from the neighboring substation is a common way to power auxiliary loads. The availability of a dedicated feeder often depends on how the auxiliary loads are accounted for in the interconnection agreement and whether the substation is new or existing.

Advantages

- Auxiliary metering limited to one location
- Centralized location for backup power
- Clear scope delineation point
- Impact of changes to auxiliary loads is isolated to feeder

Disadvantages

- Complex routing to equipment across site
- Additional medium voltage design

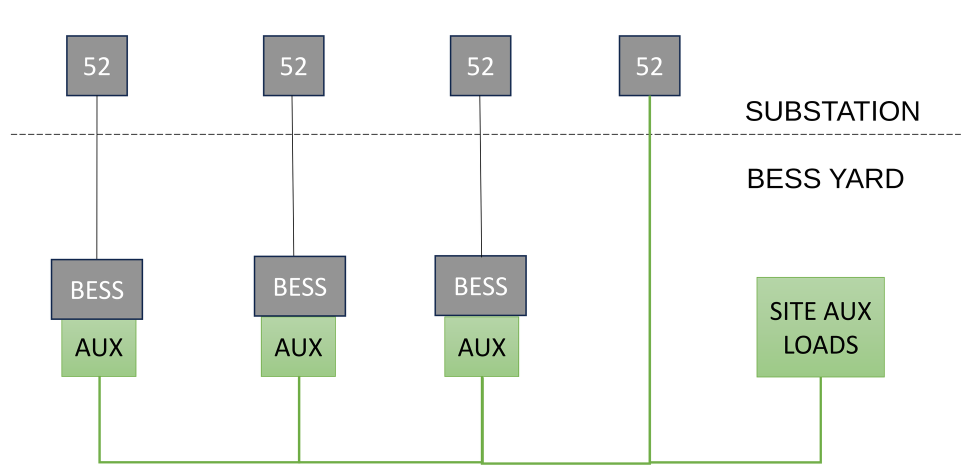

Figure 3
Block Diagram Schematic for auxiliary loads being fed from a singular substation feeder

Distributed Taps

Many BESS sites are now integrating auxiliary loads in the low voltage primary power design by using dedicated taps within the equipment. These taps are typically included in the inverter AC bus or within the secondary cabinet of the BESS transformers.

Advantages

- Modular design can be repeated across site
- Additional medium voltage transformers not required
- Eliminate need for auxiliary power panels
- Localized control of auxiliary power relative to specific BESS units
- Reduced conductor length

Disadvantages

- Potential need for transformers depending on auxiliary power voltage
- Changes to auxiliary design or requirements directly impact primary power system
- Approval of tap addition may be required from manufacturer

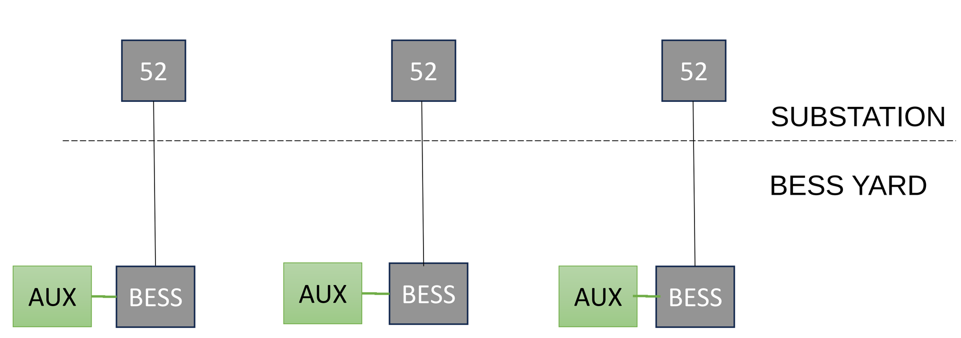

Figure 4
Block Diagram Schematic for auxiliary loads being fed from the onsite BESS equipment

RACEWAY DESIGN

In all electrical power systems, selecting and designing an appropriate raceway can lead to either cost savings and a smooth construction process or headaches for all stakeholders. The unique energy density of BESS facilities requires designers to explore multiple raceway options including Above Ground, Duct Bank, and Direct Buried.

Definitions

Above Ground
Typically, a cable tray or cable bus. A rigid structural system used to support and secure cables. Can be installed above or at finish grade level.

Duct Bank
Underground electrical conduits that provide a pathway for cables. Typically, conduits are installed and buried first and then cables are pulled through and terminated on equipment.

Direct Buried
Raceway containing direct burial rated cable installed directly in the earth without any conduit. All cables must be installed prior to landing equipment. Conduit sweeps often installed for entry through equipment pads.

Comparison

Category	Description
Constructability	Ease or complications of construction in terms of labor, time, and materials
Cost	Expenses associated with manufacturing, procurement, and installation
Conductor Size	Typical size of conductors permitted within raceway
Risk	Probability of consequences (e.g. failure, damage)
Lead Time	Time required for procurement
Integration	Ability to be incorporated into design with other equipment

Table 1
Comparison Table for Raceway Types and Impact on Project Delivery

Raceway Type	Constructability	Cost	Conductor Size	Risk	Lead Time	Integration
Above Ground		$$$				
Duct Bank		$$				
Direct Buried		$				