Utility Scale Lithium-ion Battery Energy Storage System

Design Document–Part 4

Sddec24-18

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4.1 Introduction

4.1.1 Project Overview

Utility Scale Lithium-ion Battery Energy Storage System (BESS) stores excess energy from renewable energies or conventional power plants to charge up the large lithium-ion batteries with the intent to use the energy later, such as peak demand. Our client has specified that we will design a 25 MW, 4 hr system.

The system will have a 30-year life cycle and two augmentations throughout its lifetime. It will have a 10% build-over life (BOL), meaning it will be overbuilt at the beginning of its life, so it will still meet requirements at the end of its life as the batteries and inverter's capabilities degrade. We will be designing this system on a 15-acre plot of land in Ames, Iowa, but we are able to put it anywhere in the country by changing the transformers that connect our system to the electric grid.

4.2 Design Exploration

4.2.1 Design Decisions

We decided on a battery from BYD that has around 4700 kWh of energy and pairs well with the inverter we had chosen. We found that the 0.25C (4 hr charge/discharge) version of the battery worked best with the specifications we were given.

Using the specification sheet of the battery and the inverters, we decided we would need 22 batteries to meet our minimum energy needs. We rounded up to 24 so all inverters would have the same number of batteries, power, and energy output. Having an even number of batteries and inverters makes the design process simpler, as instructed by our client.

Another major design decision was the type of transformers we used for the system. There are two ways to cool transformers: liquid-based and air-based. Depending on what type we chose, we would need different fuses to follow safety guidelines. We ended up with a liquid-based transformer for our auxiliary power. While this type is far better at cooling the air-based transformer, it has many safety and environmental concerns. The oil would be detrimental to the environment if it were to leak, so we need to have a trough to catch any leaking oil. We also must be aware of the unlikely situation of the transformer's oil getting too hot and catching fire.

This means we will need two types of fuses to protect the downstream equipment: a current limiting fuse (CLF) and an expulsion fuse (EXF). The names of the fuses describe what they do. A current-limiting fuse will limit the current and open the circuit if the current exceeds the rated levels. The expulsion fuse is high-speed and will almost instantly explode when the requirements, such as lightning strikes, are met to protect from surges.

4.2.2 Ideation

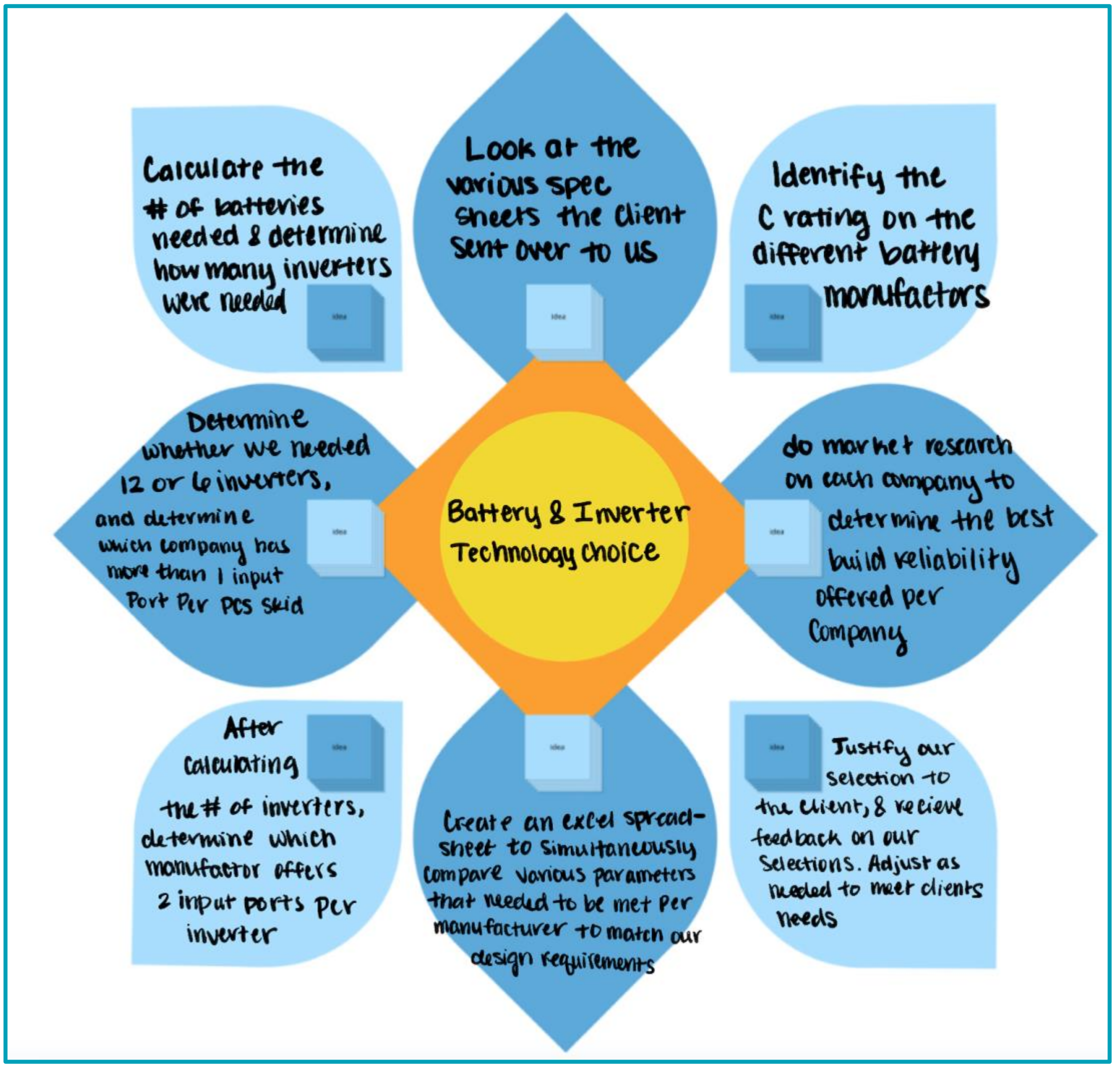

Figure 1: Lotus blossom used to determine the type of battery and inverter

When deciding on the technology we would use, we had to balance several of the pros and cons of the different manufacturers and types of batteries. We used a lotus blossom to figure out what was essential to the project and decided accordingly.

4.2.3 Decision-Making and Trade-Off

When deciding the type of battery and inverter, we used several methods to narrow the choices. First, several inverters and batteries would not go together because the battery's output voltage was not within the range of the inverters' input voltage. After eliminating many of the possible configurations because they are incompatible, we looked at the number of batteries it would take to reach the 100 MWh threshold. We eliminated several battery types due to needing well over 50 batteries. We decided on the four to six MWh range for the batteries; this led us to the BYD batteries, which all fell within this range. After we found the specific battery we wanted, it was a matter of balancing power and energy for each inverter.

4.3 Proposed Design

4.3.1 Overview

Burns and McDonnell need us to design a 25 MW/100 MWh battery energy storage system that will perform in a moderate climate. It needs to be 10% overbuilt to account for the degradation of the system over its 30-year life. It must also be upgrade-ready to account for the two augmentations it will sustain in its life.

The system will include three subsections: the inverters, the batteries, and the auxiliary power. The main power transformer and the substation are located offsite at a nearby substation. The batteries can convert electrical energy into chemical energy and back to electrical energy when needed. The batteries operate in direct current (DC), but the grid operates in alternating current (AC). This difference in current is what the inverter is for. They are able to convert between alternating and direct current. Moving energy from the batteries to the electric grid will change the direct current into alternating current. The last subsection is the auxiliary power, where all the monitoring equipment is located. Auxiliary power also provides power to the cooling systems of the batteries and the inverters.

For power to be at the correct voltage when entering or leaving our BESS, we need a transformer to take the very high grid voltage and lower it to the voltage we are using; we need a main power transformer.

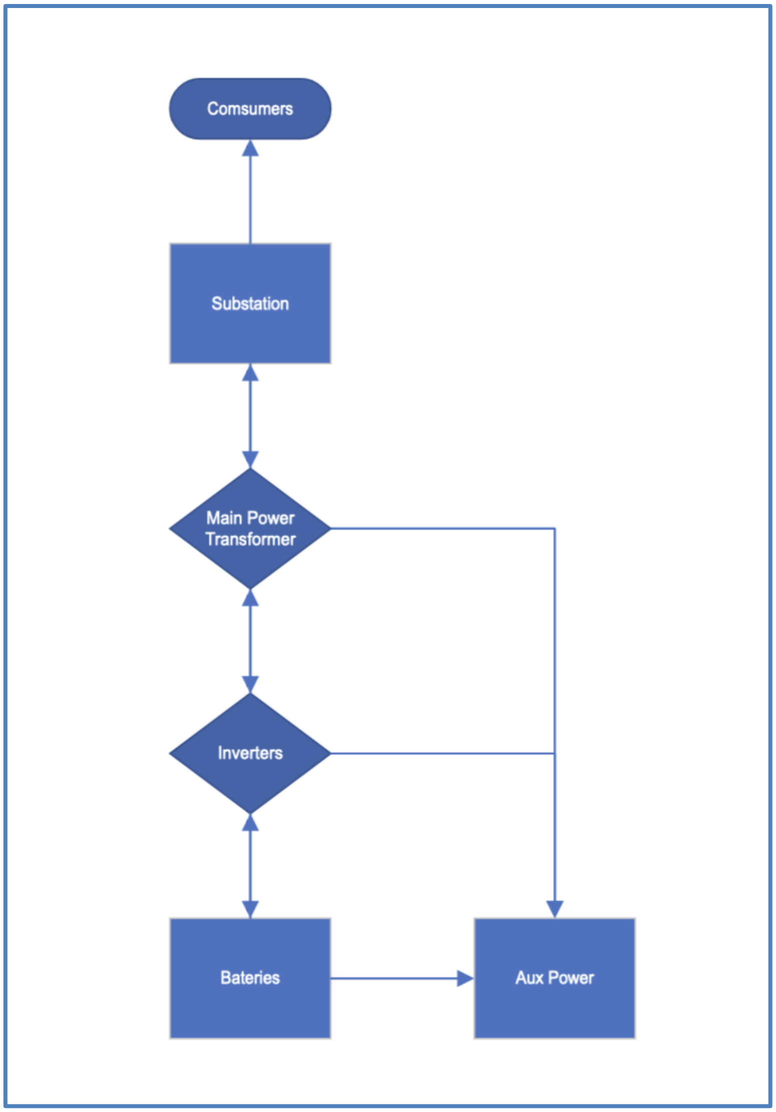

Figure 2: Overview of the battery storage system

4.3.2 Detailed Design and Visual(s)

One of the most essential parts when designing a battery energy storage system is the electrical connections between components. This concept is illustrated with a one-line diagram. The one-line diagram includes every connection, from the substation to the main power transformer, the inverters, the batteries, and the auxiliary power. It also reveals important information, such as the transformers' substation voltage and voltage ratios.

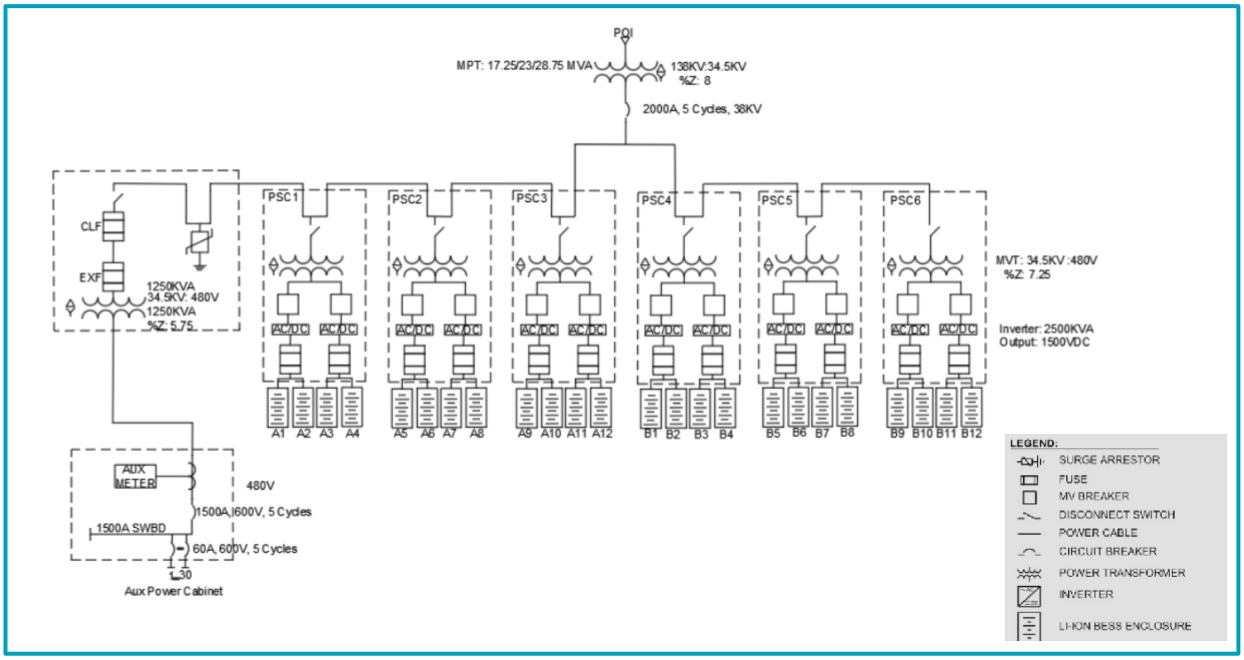

Figure 3: One-line drawing

Figure 3 shows the interconnection of the major equipment that will be used to design the BESS. The purpose of this diagram is to depict an overview of where each component will connect and the substation. This image will depict a three-phase cable as one cable for simplicity.

4.3.3 Functionality

This system is intended to reduce the energy demand from power plants during peak demand. This is achieved by charging the batteries when energy demand is low, which could be during the night or hours before the hottest time of the day in summer. The system will then discharge when demand is highest, such as 2 p.m. in the middle of August when air conditioning systems run as hard as possible.

What this accomplishes is more consistent energy prices throughout the day. When the grid's energy storage is high enough, it can reduce the need for additional power plants whose power only needs a couple of days throughout the year when demand is highest.

4.3.4 Areas of Concern and Development

Since we work very closely with Burns and McDonnell and meet weekly, we do not stray far from the intended end product they have in mind. If the Burns and McDonnell team comes across a problem with our actions, they will explain what we are doing wrong and guide us in the correct direction. We still have ample freedom in how we complete the project; if there are multiple ways of doing something, we have the freedom to choose as long as it works.

4.4 Technology Considerations

We are using many recent technologies that are rising in popularity, such as large lithium-ion battery containers and DC-to-AC inverters. These two technologies go together very well. They have many advantages and disadvantages compared to not storing energy. One advantage is that you can get away with smaller fossil fuel plants because you can charge the batteries during low demand and discharge the batteries when the demand peaks. Another advantage is smoothing the cost of energy throughout the day. The last significant advantage is allowing renewable energy to become more readily available during dark or windless days.

Some disadvantages include having a significant portion of the energy cost devoted to energy storage instead of focusing purely on production. Having an energy storage system raises the cost of energy due to imperfect efficiency, maintenance, and

4.5 Design Analysis

Since we started working with Burns and McDonnell on the battery energy storage system, we have completed many steps of the process. We have decided on the system's size and location. We found that a BESS of this size would fit well in Ames. We then found a location in south Ames close to a substation with some unoccupied land.

After finding a location, we needed to determine what components we would use. We were given a list of possible batteries and inverters that Burns and McDonnell have used in the past. We found the batteries and inverters that worked well and gave our justifications to the team at Burns and McDonnell, and they agreed with our reasoning.

Once we know what components we will use, we need to draw them in AutoCAD. We used a version of AutoCAD that allows us to overlay our site on top of maps to see what this will look like at our location.

The next thing we worked on was the one-line drawing. The one-line helps everyone who looks at the system understand what we're working on. Comparing our progress to a one-line that is complete showed us what we were missing and what we could improve upon.

One of the last major parts of the design part is the cable schedule. The cable schedule will tell us everything we need to know about the cabling, including the size of the cable, the length of the cable, how many cables we need, and the maximum temperature of the cable.

The following steps for our design include testing. This will be done with some software called ETAPs. This simulation software will tell us whether or not we have done all of our math correctly. It will also help us find ways to increase our system's safety and efficiency and ensure compliance.