Utility Scale Lithium-ion Energy Storage System

SDDEC24-18

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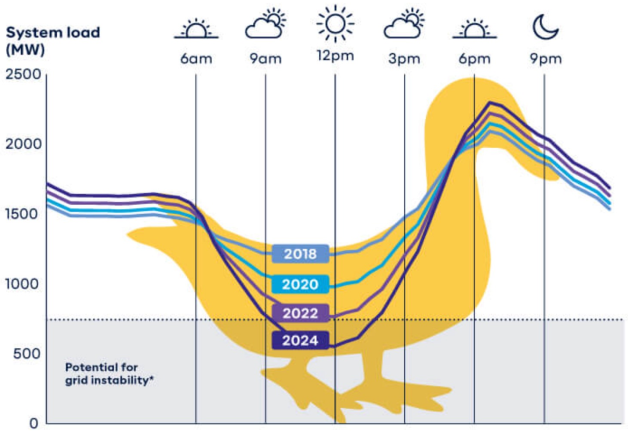
BURNS McDONNELL
IOWA STATE UNIVERSITY

Problem Statement

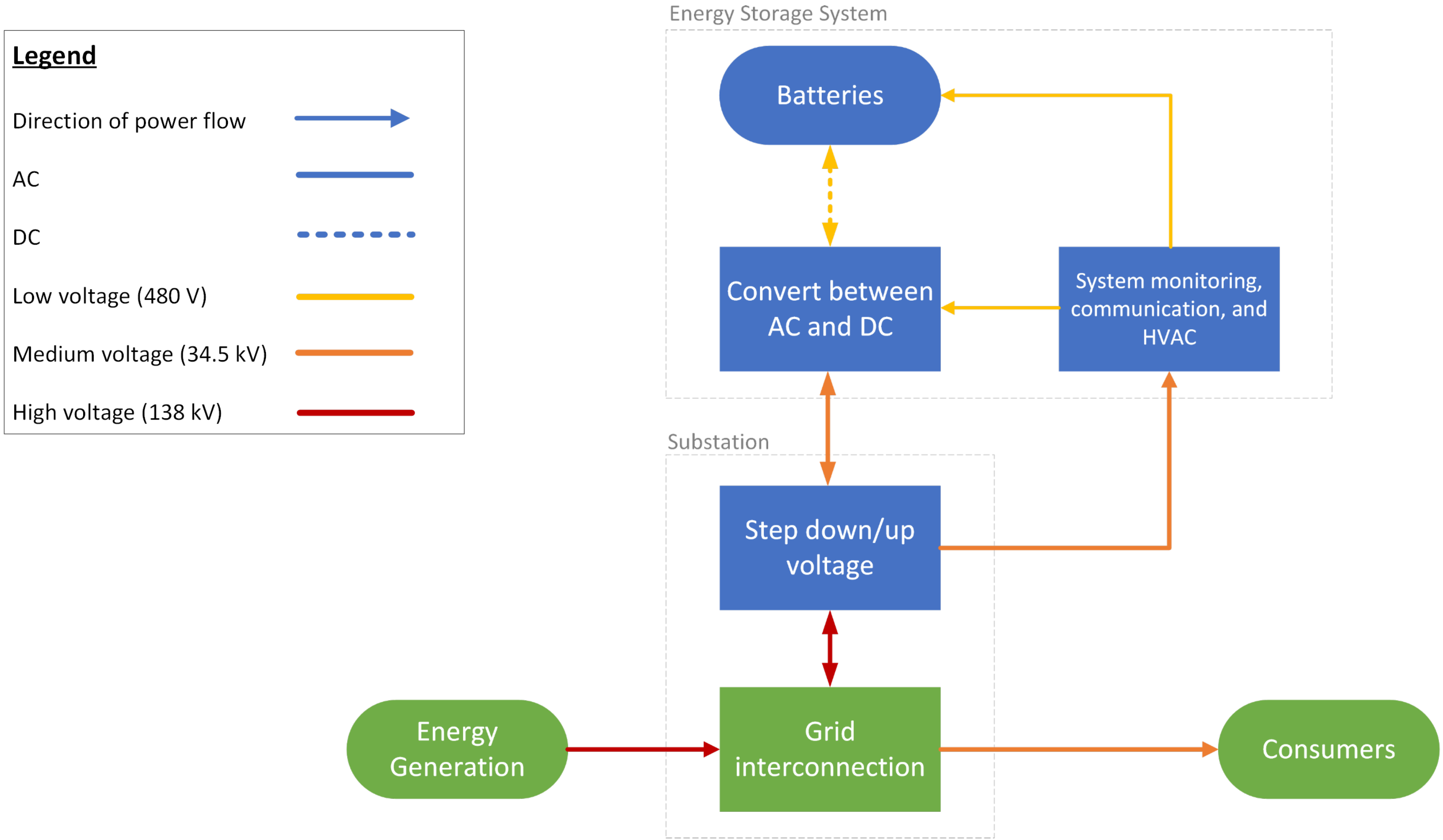
There are uncertainties with renewable energy generation that we cannot control.

The problem: There is a mismatch between peak energy demand and peak energy generation.

The Solution: To store excess energy in battery containers and release it when demand increases.



Duck Curve


Legend
Direction of power flow
AC
DC
Low voltage (480 V)
Medium voltage (34.5 kV)
High voltage (138 kV)
Energy Storage System
Batteries
Convert between AC and DC
System monitoring, communication, and HVAC
Substation
Step down/up voltage
Grid interconnection
Energy Generation
Consumers

Project Requirements

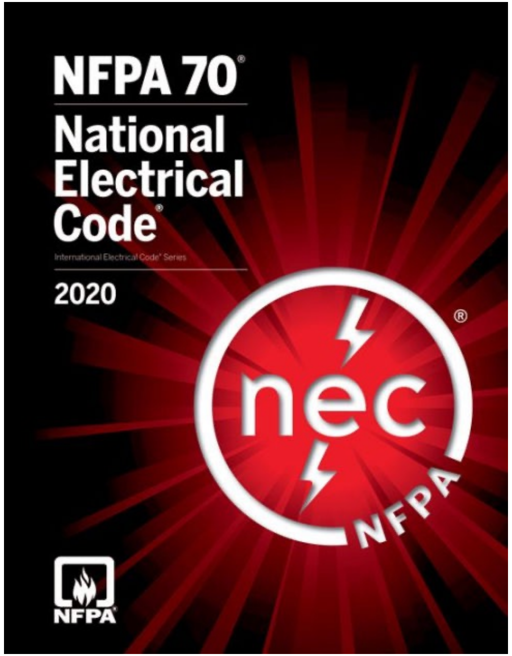
Functional Requirements

- Deliver 25 MW of power for 4 hours (100 MWh)
- Overbuild 10% BOL (Beginning of life)
- The system must be expandable to handle future needs

Battery Energy Storage System (BESS)

Non-functional Requirements

- On-site road dimensions
- Environmentally friendly components
- Components must function in our site's climate
- NEC (National Electric Code) 2020 standards
- Article 300, 310, 311



Non-technical Requirements

- Site location in Midwest
- 15 acres of land
- Near a distribution substation

Project Milestones

By December, we will have a 30% design for our BESS.

This semester

- Major equipment models
- Site layout
- One-line
- Cable sizing

Next semester

- Design system in ETAP
- Short circuit analysis
- Load flow analysis
- Cable thermal analysis

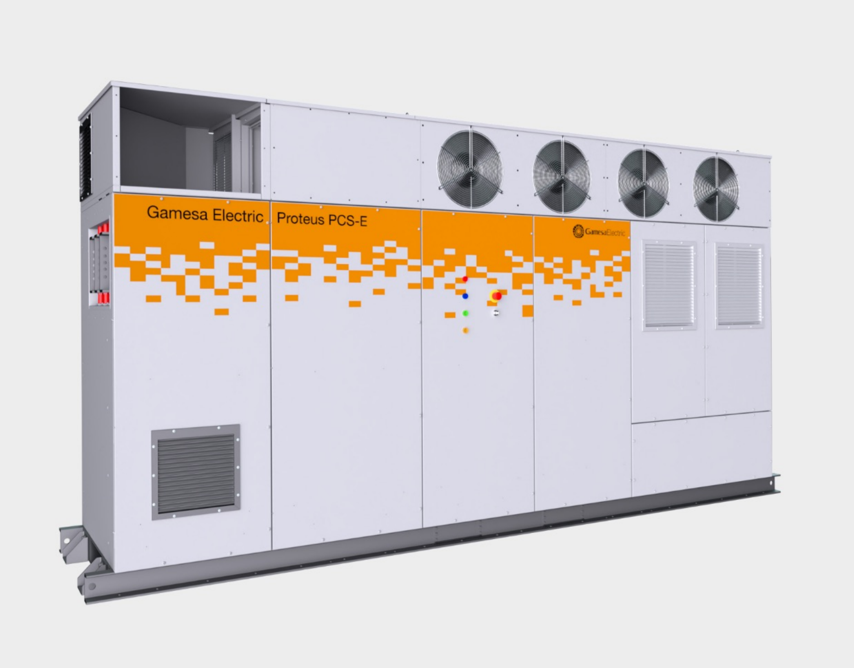
BESS Subsystems

Battery Containers

Manufacturer	BYD
Capacity	4946 KWH
Discharge C-rate	0.25 C
Output Voltage	1081 - 1497 V
Ambient Temp Rating	-30° to 55° C

Power Conversion System (PCS)

Manufacturer	Gamesa
AC Output Power	4607 KVA
DC Input Voltage	1075 – 1500 V
AC Output Voltage	User defined
Ambient Temp Rating	-20° to 60° C



Auxiliary Power System

- Powers cooling system in batteries and inverters
- System monitoring and communication

Main system components:

- Transformer
- Switchboards
- Breakers and aux power cabinet

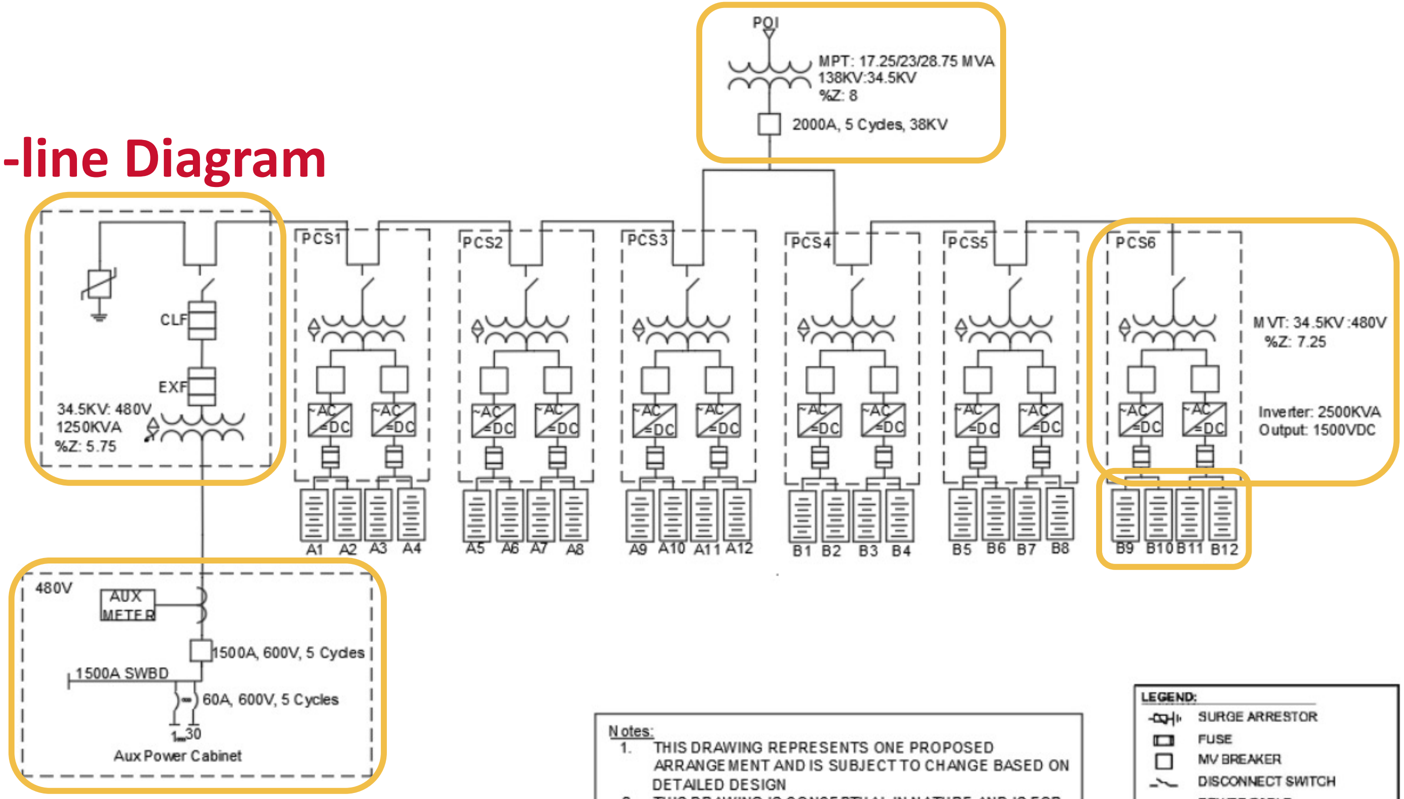
Switchboard

BESS Design

Site Layout

- Installation manuals for battery container and PCS
- Road width and turn radii
- Industry standards

One-line Diagram



Equipment List		Quantity
1.	Siemens Gamesa Electric Proteus PCS 4600E	6
2.	Main Power Transformer 17.25/23/28.75 138KV:34.5KV %Z:8	1
3.	Auxiliary Power Transformer 1250KVA 34.5KV:480V %Z:5.75	1
4.	BYD MC10C-B5365-U-R4M01	24

Notes:

1. THIS DRAWING REPRESENTS ONE PROPOSED ARRANGEMENT AND IS SUBJECT TO CHANGE BASED ON DETAILED DESIGN
2. THIS DRAWING IS CONCEPTUAL IN NATURE AND IS FOR PLANNING PURPOSES ONLY. IT IS NOT FOR PROCUREMENT, DESIGN, OR CONSTRUCTION.
3. POWER EXPORT AT INVERTERS WILL BE CONTROLLED BY ENERGY MANAGEMENT SYSTEM TO MEET REAL AND REACTIVE POWER REQUIREMENTS AT POI
4. MAIN POWER TRANSFORMER WILL BE FILLED WITH SR3 OIL FOR ENVIRONMENTAL SAFETY

LEGEND:

- SURGE ARRESTOR
- FUSE
- MV BREAKER
- DISCONNECT SWITCH
- POWER CABLE
- CIRCUIT BREAKER
- POWER TRANSFORMER
- INVERTER
- LI-ION BESS ENCLOSURE

Cable Schedule

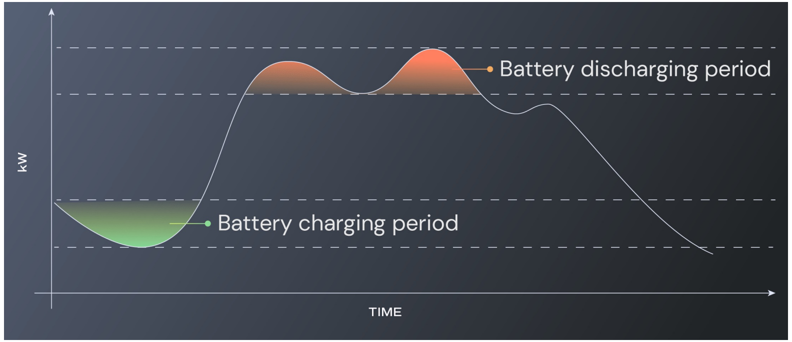
- Cable ID
- Current Flow
- From/to
- Description
- Conductor Size
- Cable Length
- Conductors per phase
- Quantity
- Raceway Length

Cable ID	Current flow	From	To	Description	Conductor Size	Length	Conductors per phase	Qty	Raceway Length
1	20.92 A	Surge Arrestor	PCS1	Fuse/ Surge Arrestor	6 AWG	45.57 ft	1	3	29.57 ft
2	103.66A	PCS1	PCS2	PCS1	4 AWG	53.02 ft	1	3	37.02 ft
3	186.39A	PCS2	PCS3	PCS2	1/0 Kcmil	53.02 ft	1	3	37.02 ft
4	269.13A	PCS3	Substation Breaker	PCS3	4/0 Kcmil	53.02ft	1	3	37.02 ft
5	258.67A	Substaion Breaker	Substation Breaker	Home run 1	4/0 Kcmil	572.05 ft	1	3	556.05 ft
6	258.67A	Substation Breaker	PCS4	Home run 2	4/0 Kcmil	563.99 ft	1	3	547.99 ft
7	248.21A	PCS4	PCS5	PCS4	4/0 Kcmil	53.02 ft	1	3	37.02 ft
8	165.47A	PCS5	PCS6	PCS5	1 AWG	53.02 ft	1	3	37.02 ft
9	82.74A	PCS6	PCS6	PCS6	6 AWG	53.02 ft	1	3	37.02 ft
10	1274A	Inverter	Battery B12	DC Battery B12	500 Kcmil	30.86 ft	4	4	16.86 ft
11	1274A	Inverter	Battery B11	DC Battery B11	500 Kcmil	74.19 ft	4	4	60.19 ft
12	1274A	Inverter	Battery B10	DC Battery B10	500 Kcmil	72.62 ft	4	4	58.62 ft
13	1274A	Inverter	Battery B09	DC Battery B09	500 Kcmil	24.03 ft	4	4	10.03 ft
14	1274A	Inverter	Battery B08	DC Battery B08	500 Kcmil	30.86 ft	4	4	16.86 ft
15	1274A	Inverter	Battery B07	DC Battery B07	500 Kcmil	74.19 ft	4	4	60.19 ft
16	1274A	Inverter	Battery B06	DC Battery B06	500 Kcmil	72.62 ft	4	4	58.62 ft
17	1274A	Inverter	Battery B05	DC Battery B05	500 Kcmil	24.03 ft	4	4	10.03 ft
18	1274A	Inverter	Battery B04	DC Battery B04	500 Kcmil	30.86 ft	4	4	16.86 ft
19	1274A	Inverter	Battery B03	DC battery B03	500 Kcmil	74.19 ft	4	4	60.19 ft
20	1274A	Inverter	Battery B02	DC Battery B02	500 Kcmil	72.62 ft	4	4	58.62 ft
21	1274A	Inverter	Battery B01	DC Battery B01	500 Kcmil	24.03 ft	4	4	10.03 ft
22	1274A	Inverter	Battery A12	DC Battery A12	500 Kcmil	30.86 ft	4	4	16.86 ft
23	1274A	Inverter	Battery A11	DC Battery A11	500 Kcmil	74.19 ft	4	4	60.19 ft
24	1274A	Inverter	Battery A10	DC Battery A10	500 Kcmil	72.62 ft	4	4	58.62 ft
25	1274A	Inverter	Battery A09	DC Battery A09	500 Kcmil	24.03 ft	4	4	10.03 ft
26	1274A	Inverter	Battery A08	DC Battery A08	500 Kcmil	30.86 ft	4	4	16.86 ft
27	1274A	Inverter	Battery A07	DC Battery A07	500 Kcmil	74.19 ft	4	4	60.19 ft
28	1274A	Inverter	Battery A06	DC Battery A06	500 Kcmil	72.62 ft	4	4	58.62 ft
29	1274A	Inverter	Battery A05	DC Battery A05	500 Kcmil	24.03 ft	4	4	10.03 ft
30	1274A	Inverter	Battery A04	DC Battery A04	500 Kcmil	30.86 ft	4	4	16.86 ft
31	1274A	Inverter	Battery A03	DC Battery A03	500 Kcmil	74.19 ft	4	4	60.19 ft
32	1274A	Inverter	Battery A02	DC Battery A02	500 Kcmil	72.62 ft	4	4	58.62 ft
33	1274A	Inverter	Battery A01	DC Battery A01	500 Kcmil	24.03 ft	4	4	10.03 ft
34	1820A	Aux Transformer	Aux Equipment pad	Auxilary Equipment pad	1000 Kcmil	40 ft	4	1	24 ft

Market and Users

Market Research and Demand

- Allows for renewable energy integration
- Improves grid reliability
- Peak shaving
- Back-up power
- Very expensive



Users

The residents of Ames

- Grid reliability, environmental, and financial concerns

The construction and maintenance teams

- Work on a well-organized, safe, and efficient site

The local utility

- Easily monitor the power it is drawing and generating

Risks and Mitigation

Risk	Mitigation
Calculations for number of batteries, inverters, and cable sizing may not be completely accurate.	Review calculations step by step with the team at Burns & McDonnell and our faculty advisor.
Drawings made for the site layout and one line diagram may not follow National Electric Code (NEC).	1. Research concepts online 2. Review NEC documents and installation manuals 3. Receive feedback from Burns & McDonnell

Responsibilities and Contributions - Oksana

Role: Team Leader

- Responsible for keeping team on task and providing reminders for upcoming deadlines

Tasks completed

- Calculations to determine the number of batteries and inverters
- Researched the battery installation manual to determine battery spacings for site layout
- Calculated cable ampacities and determining the conductor size by reviewing the NEC
- Cable schedule report
- Cable sizing report for client

Responsibilities and Contributions - Sarah

Role: Organizer

- Responsible for revising and finalizing all our reports and documents

Tasks Completed

- Comparison of specs for battery and inverter technologies
- Calculations for one-line diagram
- Sketch of one-line diagram
- Technical documentation for one-line diagram

Responsibilities and Contributions - James

Role: Documenter

- Responsible for submission of our reports and creation of notes for clients

Tasks Completed

- Comparison of specs for battery technologies
- Completed of one-line diagram design in AutoCAD
- Technical documentation for one-line diagram
- Technical documentation for equipment selection

Responsibilities and Contributions - Cole

Role: Communications Lead

- Scheduled meetings and talked with the client

Tasks Completed

- Organized and set up Microsoft Teams for meeting with the client
- Created site layout in AutoCAD
- Sized cable lengths in AutoCAD site layout
- Technical documentation for site layout

Plan for Next Semester

Run tests and simulations

- Integrate system into ETAP software
- Short-circuit analysis
- Load flow analysis
- Cable Thermal Analysis

These tests will be used to determine the overall safety and reliability of the system

After completing simulations

- Resize conductors after depending on results from short-circuit analysis
- Add communication and grounding cables

Q&A