Commissioning an Energy Storage System: Lessons Learned in the Field

September 7, 2022
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The Energy Storage Technology Advancement Partnership (ESTAP) is a US DOE-OE funded federal/state partnership project conducted under contract with Sandia National Laboratories.

ESTAP Key Activities:

1. Facilitate public/private partnerships to support joint federal/state energy storage demonstration project deployment

2. Disseminate information to stakeholders
   - ESTAP listserv >5,000 members
   - Webinars, conferences, information updates, surveys.

3. Support state energy storage efforts with technical, policy and program assistance
Thank You!

Dr. Imre Gyuk
Director, Energy Storage Research,
U.S. Department of Energy

Dan Borneo
Engineering Project/Program Lead,
Sandia National Laboratories
Webinar Speakers

**Dr. Imre Gyuk**
Director of Energy Storage Research, DOE Office of Electricity

**Dan Borneo**
Engineering Project/Program Lead, Sandia National Laboratories

**Dave Galarowicz**
Lead Engineer, Alliant Energy

**Clay Koplin**
CEO, Cordova Electric Cooperative

**Todd Olinsky-Paul**
Senior Project Director, Clean Energy States Alliance (moderator)
Commissioning an Energy Storage System: Lessons Learned from the Field

ESTAP Webinar Series
September 7, 2022

Presented By
Dan Borneo – Sandia
Susan Schoenung – Longitude 122 West
## Sandia team and 2021-22 DOE-OE Sponsored Projects

<table>
<thead>
<tr>
<th>State or Territory</th>
<th>Partner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska</td>
<td>Cordova Electrical Cooperative (CEC)</td>
</tr>
<tr>
<td>Alaska</td>
<td>Alaska Village Electrical Cooperative (AVEC)</td>
</tr>
<tr>
<td>Arizona (x3)</td>
<td>Navajo Tribal Utility Authority (NTUA)</td>
</tr>
<tr>
<td>Colorado</td>
<td>Poudre Valley Rural Electrical Association (PVREA)</td>
</tr>
<tr>
<td>Florida (x4)</td>
<td>Seminole Tribe</td>
</tr>
<tr>
<td>Hawaii</td>
<td>Natural Energy Laboratory of HI Authority (NELHA)</td>
</tr>
<tr>
<td>Iowa</td>
<td>Alliant Energy</td>
</tr>
<tr>
<td>New Mexico</td>
<td>Santa Fe Community College</td>
</tr>
<tr>
<td>New Mexico</td>
<td>Albuquerque Public Schools</td>
</tr>
</tbody>
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<tr>
<td>North Carolina</td>
<td>NC Electric Membership Corporation (NCEMC)</td>
</tr>
<tr>
<td>North Carolina</td>
<td>Ft. Bragg Sandhills Utility Services (SUS)</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>Villalba Municipality</td>
</tr>
<tr>
<td>South Dakota</td>
<td>Ellsworth AFB West River Electric Association (WREA)</td>
</tr>
<tr>
<td>Tennessee</td>
<td>Electric Power Board of Chattanooga (EPB)</td>
</tr>
<tr>
<td>Vermont</td>
<td>Green Mountain Power (GMP)</td>
</tr>
</tbody>
</table>
Energy storage system overview (ES is one Part of Whole)
Commissioning begins with RFP

**Construction Project Stages**

1. **Project Initiation**
2. **Project Development & Design**
3. **Procurement**
4. **Construction**
5. **Commissioning**
6. **Operations & Maintenance**

**Design/Construction Activities**

- Analysis, Application(s) and sizing
- Refine conceptual design with details for RFP, Include load profile and Sequence of Operation (SOO)
- Develop RFP with codes, standards, & specifications
- Site work, system installation, interconnection, Factory testing precedes installation
- Commissioning / acceptance testing checking that system meets specifications, SOO
- Project in-service

**Commissioning Activities**

- Applications lead to Sequence of Operation (SOO)
- Load Profile drives system performance need. SOO will drive commissioning activities, interconnection design and permitting
- Proposal to include commissioning plan, code requirements for safety, roles – one commissioning owner, warranty
- Testing at factory nice to have but hard to do:
  - Off shore manufacturing.
  - System components from different vendors meet at the job site
- One owner; Baseline measurements; Safety system checkout
- Collect operational data; track performance and capacity fade; Predictive tools - IR scan.
The Project Team includes

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Project Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner</td>
<td>Programming, Financing, contracting and ownership strategies. Developer or Facility</td>
</tr>
<tr>
<td>Design Engineer</td>
<td>Design, Load profile, application(s), codes/standards/specifications, Procurement RFP, Inspection,</td>
</tr>
<tr>
<td>Utility</td>
<td>Interconnection authorization, Point of connection work</td>
</tr>
<tr>
<td>Site Construction team/installer</td>
<td>EHS / Site Safety Plans (SSP) and Safety Meetings, Site prep, permits, system delivery, Construction, all BoP</td>
</tr>
<tr>
<td>Vendor</td>
<td>Factory Witness Testing, Shop drawings, On-site connections, start-up, troubleshooting, Warranty</td>
</tr>
<tr>
<td>AHJ</td>
<td>Code adherence, Design verification</td>
</tr>
<tr>
<td><strong>System integrator, or Commissioning Agent</strong></td>
<td><strong>OWNS COMMISSIONING. Plan, Construction inspection, Operational Acceptance Testing (OAT), Integrated System Startup (S/U), Functional Acceptance Testing (FAT), shakedown, Training, as-builds, Commissioning Closeout</strong></td>
</tr>
<tr>
<td>Fire Department</td>
<td>Design review, Participate in training</td>
</tr>
</tbody>
</table>
Codes and Standards Related to Energy Storage Installations
(beware of new requirements)

Standards and Model Codes Hierarchy

BUILT ENVIRONMENT
- iCodes – IFC, IRC, IBC
- IEEE – C2, SCC 21
- NFPA 1, 5000

Complete ESS
- NFPA 855
- UL 9540
- ASME TES-1
- FM GLOBAL 5-33
- DNVGL GRIDSTOR
- NECA 416 & 417

INSTALLATION / APPLICATION
- NFPA 70
- IEEE C2
- IEEE 1547
- UL 9540 A
- IEEE 1635/ASHRAE 21
- IEEE 1679
- IEEE P1578

SYSTEM COMPONENTS
- UL 1973
- UL 1974
- UL 810A
- UL1741
- CSA 22.2 No. 340-201
- IEEE P2686
Acceptance Testing is the heart of Commissioning

Acceptance Testing of ES Components and Subsystems

Battery/DC Block:
- Rack, module, cell level data
  - Temperatures
- Calculated values
  - SOC, SOH

Power Conversion:
- Inverter data (individual & aggregate)
  - DC voltage, current
  - AC voltage, current, frequency, power factor
- Calculated values

Applications
- Utilize SOO

Balance of Plant (Environment, Safety Systems):
- Enclosure data:
  - Temperature, humidity
  - IR scan
- Local data
  - Outside temperature, humidity
- Fire Protection
  - Water and/or dry chem system status
  - Smoke/heat sensors
- Alarms
  - Faults, e-stops, door open, etc.
- Grid (Point of Connection – POC)
  - Voltage, current

Testing procedures
Lessons Learned (It always takes longer than you think)

- **Interconnection Request & Approval**
  - It can be a long process – start early, make contact with the Utility, follow through

- **BESS Siting (Location)**
  - Know your installation Standards/Codes consideration

- **Developing a RFP**
  - It is recommend that ‘best practice’ Codes/Standards are used in the RFP (specifically UL9540 2020 & NFPA 855 2020/IFC 2018 or 2021) no matter what Code year the State has adopted.
  - Load Profile and Application identification

- **Bid Analysis: Need to understand who is supplying which component of the BESS**
  - Who does what and who is in charge. In most cases there will be multiple vendors supplying different portions of the energy storage system which can lead to confusion about who is responsible for **acceptance testing** of individual components

- **Communications/Data Acquisition**
  - Collecting **ES data for monitoring** can be complex and scales in complexity with the size of the system, number of data points you have/want, frequency, etc. *Get an IT person on-board the project team.*
  - Cybersecurity of remote monitoring/data collection is a growing concern.
Lessons Learned (Continued)

- Training of operations and first responders
- IT / data collection – What to measure and does it work
- Fun Facts (unless you are there)

- Red hot bolts – Not torqued
- Failed Cables – Not meggered
- Breakers inadvertently tripping – Not coordinated properly
- Distribution Equipment Failure – Not installed correctly
- Over heating - Ventilation not sized correctly
- Water Leaks – Piping connections not tested
- Controls - Adequate testing procedure
- Application – Sequence of Operations (SOO) not well thought out
Questions that Bother Me So

• Who leads Commissioning and how to identify/request in RFP
• What if Equipment is delayed?
• Which State and Federal codes/Standards need to be followed
• What’s an interconnection agreement?
• How long will the battery realistically last?
• Predictive measurements of battery to indicate performance?
• Given today’s economic environment how realistic are the cost and delivery estimates?
Conclusions

• Commissioning can be described as PAYING ATTENTION to the DETAILS
• Energy Storage resources available online
• SNL and EPRI developing updated commissioning guide for year-end release
Thank you

This work is funded by the DOE OE Stationary Energy Storage program, directed by Dr. Imre Gyuk.

Daniel Borneo dborne@sandia.gov
Great project, but...

Decorah Battery System Design

- 2.5 MW, 2.9 MWH system

  - Larger power rating → more flexibility
    - Voltage managed with reactive power (Vars)
    - Power Flows managed with real power (Watts)

- Samsung / Sungrow Integrated Solution from EnelX
  - Lithium Ion (NMC Chemistry)

Commissioning delayed by difficult access to vendors for data...
Decorah Battery Project

Alliant Energy, with EnelX (integrator) and Samsung-Sungrow (Mfr)

Location: Leased Land in City Park - Decorah, IA

What: NMC Li-Ion Battery, 2.5 MW, 2.9 MWH

Why: Increasing Hosting Capacity (Ability to Accommodate DG)

When:
- RFP issued: Spring 2019
- Contract placed: Fall 2019
- Installation complete: Summer 2021
- Commissioning complete: June 2021
  - Pending Field Certification
  - Pending Final Fire System Testing

How much:
- Total Estimated cost: $2.9 MM
- DOE Cost share (equipment only): $250,000
Module Installation

Visual Screening
Decorah Commissioning
Post Manufacture Certification

• Corrected labeling of devices and container
• Field certification
  – Long lead times for scheduling of inspectors (>3 months)
  – In progress for water ingress testing
Site Commissioning Actions Taken

- Implemented non-zero power setpoint to minimizing open / close cycles on the DC contactors
- Encountered frequent battery fans failures, which have been replaced
- Animal ingress was addressed early in the design process and has not posed an issue.
- Implemented automated alarms and e-mail notification for loss of communications and availability
Site Commissioning Improvements (1)

- Ensure that EMS can issue reset commands to the BMS / PCS remotely as allowed by BMS manufacturer
- Coordinate with EMS manufacturer to integrate aftermarket off-gas detection systems
- Verify connectivity and system functionality in advance of system performance testing.
Site Commissioning Improvements (2)

• Request commissioning checklist/plan to review and provide feedback
  – Should test operational processes including starts/stops/alarm resets/setpoint tracking
• Test alarms from the field through to SCADA
QUESTIONS?
Dave Galarowicz, P.E.

- Dave Galarowicz has spent 13 years in the utility sector. He has worked extensively in power generation and fossil units in both engineering and operations roles. He is currently working on pilot scale projects, deploying new technologies to evaluate their value and potential to integrate into the Alliant Energy system.
Orca Power Plant
10.8 MW Diesel Control Center, CEC

Humpback Creek Hydroelectric Plant
1250kW (2 x 500 kW + 1 x 250 kW)
17,000 foot UG and submarine transmission line

Power Creek Hydroelectric
6278kW (2 x 3124 kW)
25 kV transmission ties to Eyak Substation, Inflatable dam

City of Cordova
1,566 customers
18MW
One Substation
78mi UG distribution lines

Battery Energy Storage System
1 MW 1MWh
ABB/SAFT at Eyak Substation

Cordova Electrical Grid
Procurement – Start in the Right Place
(Dr. Imre Gyuk  Director of Energy Storage Research  Office of Electricity)

- US DEPT OF ENERGY-SANDIA-ACEP INITIAL MODELLING TO RIGHT-SIZE
- SANDIA AND NRECA – DRAFT SPECS AND PROCUREMENT DOCS
- CEC INTERNAL SPECS AND INTEGRATION - USE CASE!
- SHARE FINAL DOCS BACK TO NRECA AND SANDIA FOR TRANSFER
- CRITICAL; MEETING OF THE MINDS WITH SAFT/ABB
A little more detail: Commissioning Planning

- Manufacturers have standard commissioning plans and protocols.
- Structure your commissioning around your use case and integration.
  - Communications integration – compatible protocols, handshaking, etc.
  - Controls integration – serial vs. parallel comms (Modbus TCP vs. Modbus RTU)
  - Operational integration – “bumpless” state change, ramp rates, mode transfers.

Battery – Power Converter – CEC SCADA system handshaking
<table>
<thead>
<tr>
<th>Customer Site Acceptance Steps</th>
<th>Notes</th>
<th>Date Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Verify that there are no mechanical defects or physical damage from factory or shipping</td>
<td>Fire Alarm on the Battery was damaged and the air conditioner was dented</td>
<td>8/17/2019</td>
</tr>
<tr>
<td>2 Verify all the components that we ordered are present and in good condition</td>
<td>Invintoried upstream at ORCA</td>
<td>8/24/19</td>
</tr>
<tr>
<td>Power up station service devices (lights, Fans, Fire system, Etc) and ensure they all are working properly</td>
<td>The air conditioner on the battery needed troubleshooting and repair, this was completed by Ed on 6/10/10.</td>
<td>6/10/10</td>
</tr>
<tr>
<td>3 Verify that fire alarm bypass is working i.e. test it during fire suppression test</td>
<td>NOT A BYPASS NEED TO VERIFY OPERATION WHEN FIRE ALARM CONTRACTOR IS HERE</td>
<td>0/10/2019</td>
</tr>
<tr>
<td>4 Verify that transformer alarms are paralleled onto EYAK PLC I/O card</td>
<td>They are not. THEY ARE POLLED BY PWRC OVER TCP FROM ABB AND DISPLAYED ON SAF/ABB DETAIL PAGE</td>
<td>Week of 8/18/2019</td>
</tr>
<tr>
<td>5 ABB, CEC and SAFT to complete their site integration work</td>
<td>Abb still needs to implement final iteration of soc limit ramping to 0. Emailled after second commissioning trip.</td>
<td>Week of 8/18/2019</td>
</tr>
</tbody>
</table>

**Follow through, follow through, follow through…**

### Power up control comm devices and ensure they all are working properly

A control relay in the PCS e-stop string was faulty upon startup and had to be replaced. This was done by Nate and Isak on 6/6/19. Some Ribbon cables from the master PCS controller to the inverters were not working these were replaced by Nate and Isak and Allen on 6/8-7/19. The MB/MV was faulty and needed reprogramming. This was done by Ed on 6/8/19 and 6/10/19. The vacuum alarm on the main stepup transformer is faulty and needs to be repaired or replaced. The master control in the PCS is faulty and needs to be repaired or replaced. The modbus rtu communication from ABB Plc to the CEC Plc is very slow (about 1-3 seconds between good reads) and needs to be repaired. The ABB Plc would not communicate at all without using two stop bits. The setting should be one stop bit. This needs to be repaired. Sometimes the modbus rtu communication to and from the CEC Plc and ABB Plc will just stop, this needs to be repaired.

### Power up control comm devices and ensure they all are working properly

#### 4-1 Verify Communication settings (i.e., programmable switch settings)

#### 4-2 Verify Communication is working between all CEC, ABB, SAFT devices.

#### 4-3 Verify ramp rates of 10kw/5/sec for all configurable settings

#### 4-4 Verify that 10 second trip on loss of comms is disabled, i.e., let the battery ramp when dead or full

#### 4-5 Get modbus alarm register details from saft and abb

#### 4-6 Additional verifications before CEC ties to their grid...

#### 4-7 Get modbus rtu communication details from CEC tie to their grid... (Continue)

#### 4-8 ABB, SAFT team to manually test register each in PCS

#### 4-9 Tie BESS to CEC Buss through fused disconnects

### Verify all comm interface registers from Pcs to EYAK are correct

### Verify all comm interface registers from EYAK to Pcs are correct

### Tie to grid

<table>
<thead>
<tr>
<th>Run system locally from Pcs hmi. Verify each mode, and each setpoint, and confirm it is seen on CEC hmi.</th>
<th>What to do with the system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode Requested = Off</td>
<td>Nothing</td>
</tr>
<tr>
<td>2=Cell(Baseload)</td>
<td></td>
</tr>
<tr>
<td>Charge/Discharge Setpt (-1000 to 1000), Positive = Discharging, Negative = Charging</td>
<td></td>
</tr>
<tr>
<td>Kvar Setpt (-1000 to 1000) pos = inductive, neg = capacitive</td>
<td></td>
</tr>
<tr>
<td>Voltage Setpt: 7000 - 7000</td>
<td></td>
</tr>
<tr>
<td>Frequency Setpt: 5500 to 6100</td>
<td></td>
</tr>
<tr>
<td>Put the BAT in off mode on the panel and look at Scada and see if it registers.</td>
<td></td>
</tr>
<tr>
<td>14-14 = stop do nothing. This troubleshoot and fix it.</td>
<td></td>
</tr>
</tbody>
</table>
Meeting of Minds
(highly recommended)

- High level discussion between project partners and vendors to carefully articulate the use case, the operating environment, the operating modes and purpose. The discussion pushes on the applications and capabilities of individual components in various operating modes and environments and discusses weather electrical system dynamics, communications, controls, handshaking with SCADA / automation system. All should leave with a clear pictures of the application and a working list of items to test or confirm for the application to minimize the inevitable challenges during installation, commissioning, and operation.
INSTALLATION / COMMISSIONING

July 2019 – Manual Operations Commence
TIMELINES

- 2007 – CEC System Loads Exceed Hydro Capacity and diesel peaking creates a “valley of death”
- 2012 – CEC partners with ACEP and recognizes the benefits of energy storage to CEC Grid
- 2015-16 ACEP Approaches Dr. Gyuk with CEC use case/opportunity and rich CEC data set
- 2016 Dr. Gyuk initiates phase 1 modelling of CEC energy storage via Sandia Laboratories
- 2017 Modelling and analysis indicates a right-sized, right-located Lithium Ion solution for CEC
- 2018 Dr. Gyuk sponsors phase 2 specification and procurement of BESS
- October 2018 CEC BESS Ordered
- May 2019 BESS arrives on site
- June 2019 BESS Installed
- July 2019 BESS Operational
- November 2019 Fully integrated and automated saves $10,000 over 2-day Thanksgiving Holiday
- November CEC achieves 94% hydro crushing all previous records
- December 2019 CEC achieves 86% hydro crushing all previous records
- April 2020 CEC goes 100% hydro 3 weeks early and starts automated electric boiler heating
- 2021: Saved 50,000 gallons of diesel directly with BESS 14,000 gallons indirectly with e-boiler
- 2022: Delivering more hydro upgraded diesel heat loops to save 25,000 gallons with e-boiler
- 2022: New valves unleashed more hydro; extending heat loops and EV charging with excess hydro
RIBBON CUTTING
June 7 2019
CEC BESS Commissioning – Takeaways

- Conduct a meeting of minds and document functional items – project teams can change
- Understand the ecosystem – a microgrid does not have an infinite bus / fault current
- Make sure vendors close the gap between sales staff and field installers
- Details matter – bumpless switching between power converter modes was/is challenging
- Pay attention to alarms – lots of internal alarms may have value to vendor but not the client
- Pay close attention to warranties and PMs – a big challenge in Alaska and a work in progress

We just started full battery operations 2 weeks ago
Questions?
Webinar Speakers – Q&A

• Dr. Imre Gyuk, Director of Energy Storage Research, Office of Electricity, US Department of Energy
• Dan Borneo, Engineering Project/Program Lead, Sandia National Laboratories
• Dave Galarowicz, Lead Engineer, Alliant Energy
• Clay Koplin, CEO, Cordova Electric Cooperative
• Todd Olinsky-Paul, Senior Project Director, Clean Energy States Alliance (moderator)
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Dr. Imre Gyuk  
US DOE-OE  
imre.gyuk@hq.doe.gov

Dan Borneo  
Sandia National Laboratories  
drborne@sandia.gov

Todd Olinsky-Paul  
Clean Energy States Alliance  
todd@cleanegroup.org

ESTAP Website: https://cesa.org/projects/energy-storage-technology-advancement-partnership/

ESTAP Webinar Archive: https://cesa.org/projects/energy-storage-technology-advancement-partnership/webinars/
Upcoming Webinar

Advancing Solar for Manufactured Homes through Community Solar

Wednesday, September 14, 2-3pm ET

Panelists will share more information about how community solar can be used to bring the benefits of solar to manufactured homes; how to engage with the U.S. Department of Energy’s National Community Solar Partnership; and successful examples of community solar projects that have benefitted manufactured homes and communities.

Read more and register at: www.cesa.org/webinars