Sandia National Laboratories

GRID RELIABILITY ENHANCEMENT USING ENERGY STORAGE SYSTEMS

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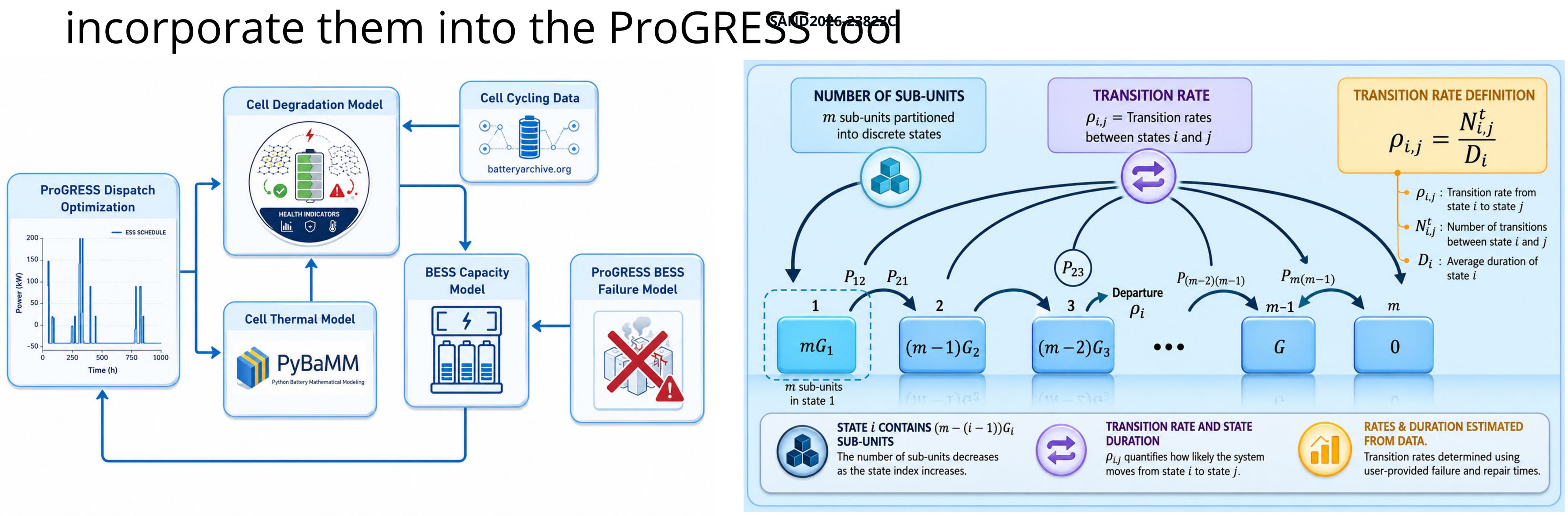
PROJECT PROFILE
Topic: Analytics & Tools| Vertical: Analytics
Strategic Pathway: Optimize
Project start and finish: FY24-FY26

PROBLEM

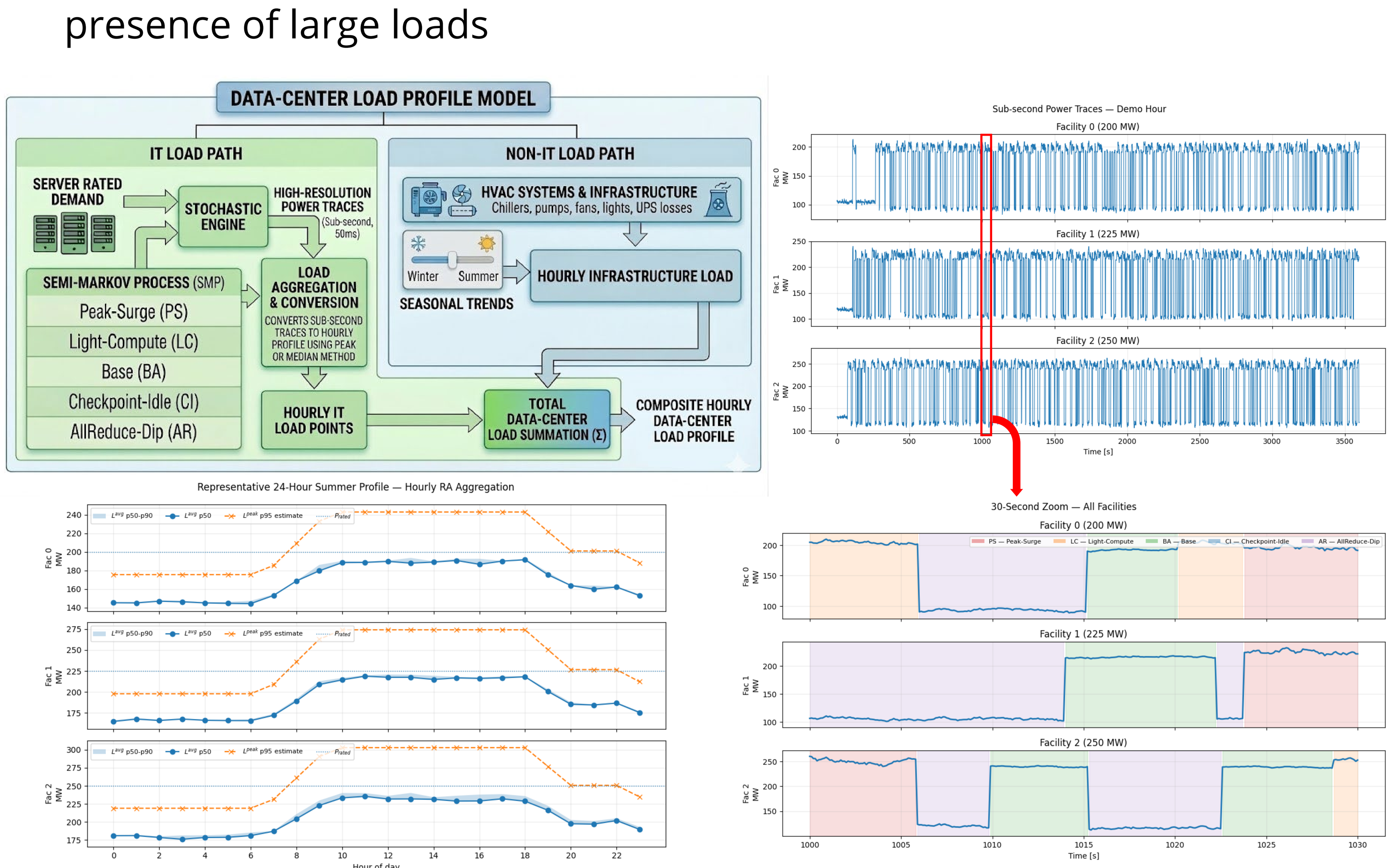
- **Problem:** While **energy storage systems (ESS)** are widely deployed for **grid reliability applications,** realistic and detailed ESS models are not typically used while analyzing grid reliability
- **Motivation:** There is a critical need to develop and integrate **state-of-the-art ESS models** into grid planning and reliability assessment frameworks to accurately quantify their contribution toward building a **reliable, resilient, and affordable** future power grid.
- **Current Practice:** Most existing reliability evaluation frameworks employ **simplified models** that do not fully represent the operational behavior, degradation, and failure characteristics of ESS

APPROACH

- Develop and maintain open-source **grid reliability assessment** tool that integrates **state-of-the-art ESS models** — *Probabilistic Grid Reliability Analysis with Energy Storage Systems (ProGRESS)*
- Develop state-of-the-art battery **degradation** and **failure** models and incorporate them into the ProGRESS tool



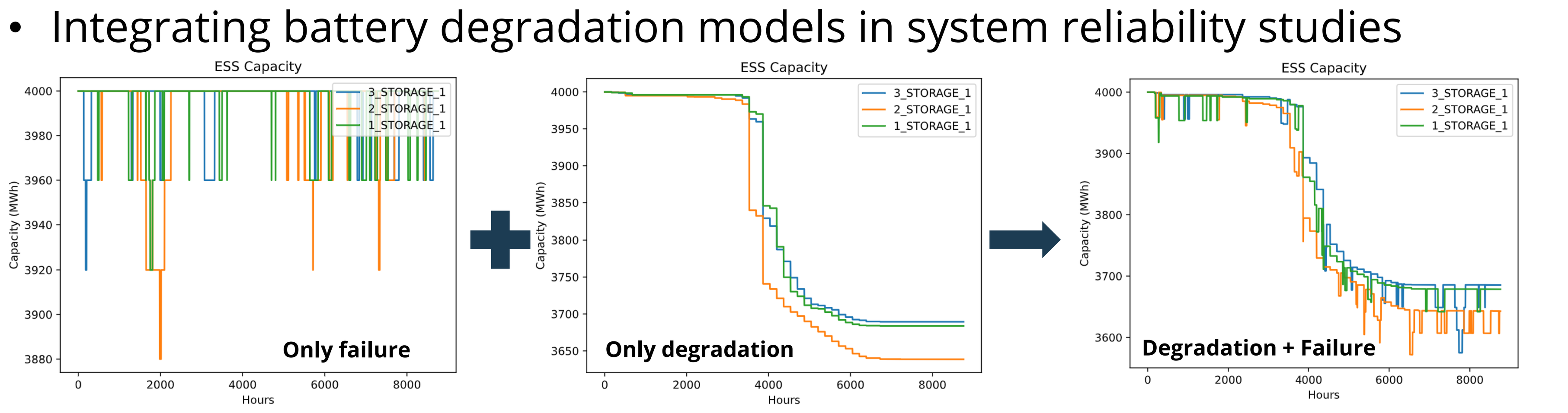
- Modify ProGRESS tool such that different types of **ESS operational models** can be integrated: reliability mode, economic dispatch mode, ESS application stacking mode
- Develop **large load (AI data center) models** and study their impact on grid reliability; **site and size ESS** to improve system reliability in presence of large loads



RESULTS

progress

- Integrating battery degradation models in system reliability studies



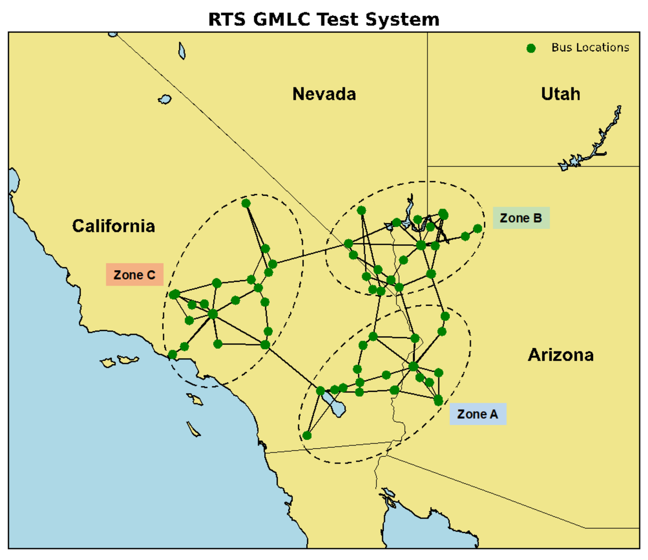
Simulation Parameters:

- **Spatial fidelity:** Zonal
- **BESS details:** 1000 MW, 4-hr BESS in each zone,
- **Failure parameters:** Each BESS has 100 sub-units, each with MTTF of 500 hrs. and MTTR of 48 hrs.
- **Operation mode:** Economic dispatch
- **Chemistries tested:** LFP, NMC
- **Samples:** 20,000

Chemistries	LOLE (days/year)	LOLF (events/year)	EUE (MWh/yr)
No degradation no failure	1.218	2.12	3884
No degradation only failure	1.232	2.15	3912
Degradation only: LFP	1.237	2.14	3913
Degradation only: NMC	1.566	2.45	4857
NMC degradation + failures	1.583	2.45	4877

***Table 1.** Reliability indices with different battery chemistries.*

- ESS required to maintain reliability in presence of data center (DC) load



No.	Size (MW)	Location (Bus, Zone)
1	200	Anna (11), A
2	230	Bardeen (35), B
3	250	Cary (59), C

***Table 2.** Large load sizes and locations*

```
=== TOTAL OUTAGE HOURS =
Rank    Bus     Hours
1       Baker   4003.0
2       Carew   2758.0
3       Adams   1335.0

=== AVERAGE OUTAGE MAGNITUDE
Rank    Bus     Average
1       Baker   112.7704
3       Carew   107.8146
18      Adams   52.2001
```

***Table 3.** Bus statistics w. DC load*

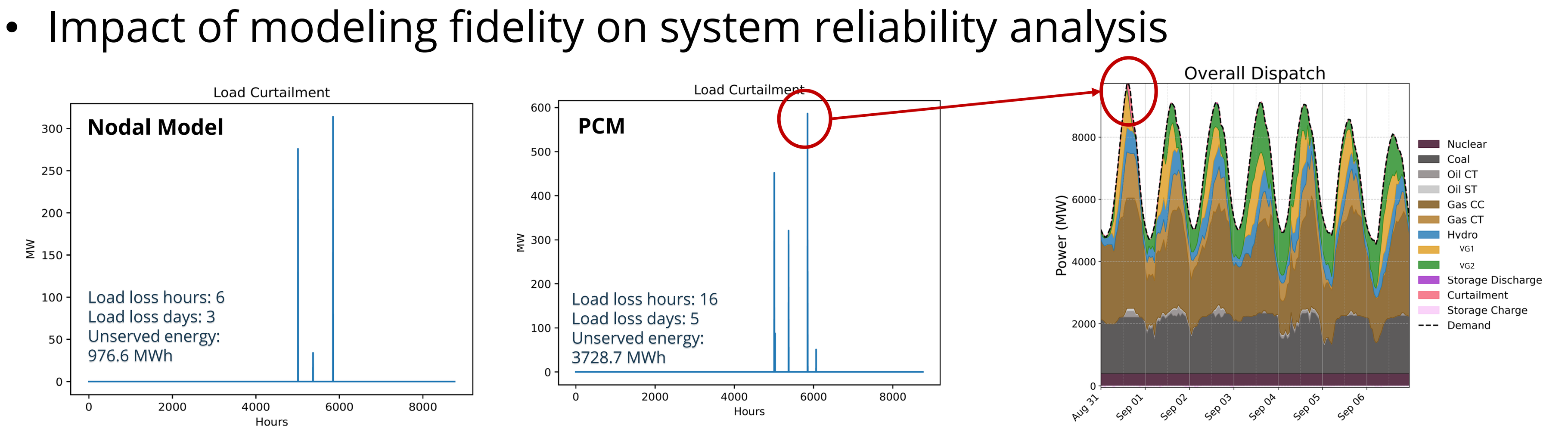
Capacity (MW)	Duration (hr.)	Location (Bus)
60	4, 8	Adams (2)
115	4, 8	Baker (31)
110	4, 8	Carew (55)

***Table 4.** ESS added to maintain reliability with large load*

Case	LOLE (days/year)	MDT (hours)	EUE (MWh/yr)
Base	0.26	0.87	38.37
DC w/o ESS	2.55	2.78	1839.93
DC w. ESS 4-hr	0.73	1.54	699.01
DC w. ESS 8-hr	0.70	1.25	424.64

***Table 5.** System reliability metrics (detailed nodal network model) with DC load and ESS addition*

- Impact of modeling fidelity on system reliability analysis



CONCLUSIONS & IMPACT

- **ProGRESS 2.0 released**: Latest version has battery degradation models, new operation modes, large load models, along with bug fixes, detailed results analysis options, and usability improvements
- **2.9k+ downloads** from GitHub and pypi repositories
- Paper presented at *IEEE EESAT 2026*
- ProGRESS allows stakeholders including *utilities, system planners, operators, regulators, and researchers* to plan for an **affordable** and **reliable** power grid with **state-of-the-art energy storage models**
- Cutting-edge **ESS operation, degradation, and failure models** allow stakeholders to accurately quantify contribution of ESS toward enhancing system reliability
- **Integration with other grid planning tools** like *QuESt Planning* and *QuESt PCM* using *QuESt Workspace* for comprehensive grid planning options

FUTURE DIRECTIONS

- Model *cell-to-cell variation* and *impact of battery topology* on capacity degradation of large systems to capture more accurate ESS contribution to system reliability
- Develop and integrate scenario reduction techniques to the ProGRESS tool for faster evaluation of system reliability in presence of ESS
- Develop novel AI-powered coordination techniques between ProGRESS and other grid planning tools for a more efficient grid planning process

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