Storage Requirements of Integrated Clean Power Generation Systems for Load Following

U.S.NRC
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Western Carolina University
School of Engineering + Technology

Problem Statement

Renewable energy is synonymous with variability. Creating integrated power systems which use multiple generation sources can aid in overcoming this intermittency. The proposed power system utilizes wind and solar with nuclear reactors and battery storage devices to ensure that renewables are optimized, and reliability is maintained. Battery storage devices are the costliest component and should be minimized to incentivize the adoption of these clean integrated power systems.

Objectives/Scope

- Model an integrated power system using NuScale Small Modular Reactors (SMR), solar, and wind farms , with a load following battery storage system.
- Perform an optimization to determine the sizes of generations sites which will result in the smallest battery capacity for a given data profile.

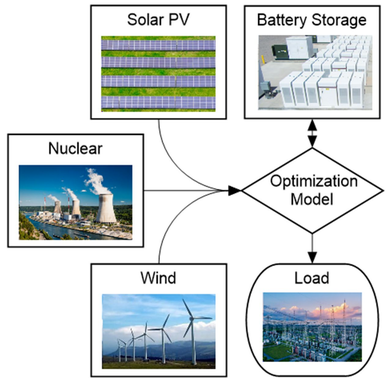

Figure 1: General Concept

- Develop a cost analysis to explore the relationship between battery, nuclear capacities, and cost within a power system.

Methodology

Data Collection

- Load data [MW]: provided by regional utilities in 5-min intervals over three 1-week periods
- Solar irradiance [W/m^2]: collected via the Physical Solar Model (PSM v3) online tool.
- Wind speed [m/s]: collected via the Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) reanalysis dataset. Raw wind speed is associated with the specific power output via the chosen wind turbine's (GE 2.5xl) power curve data.

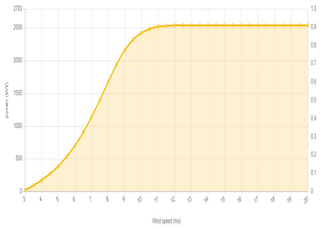

Figure 2: GE 2.5xl power curve

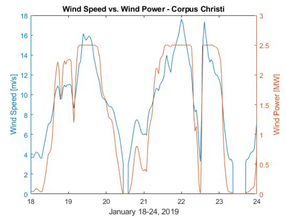

Figure 3: Wind Speed to Wind Power

Optimization

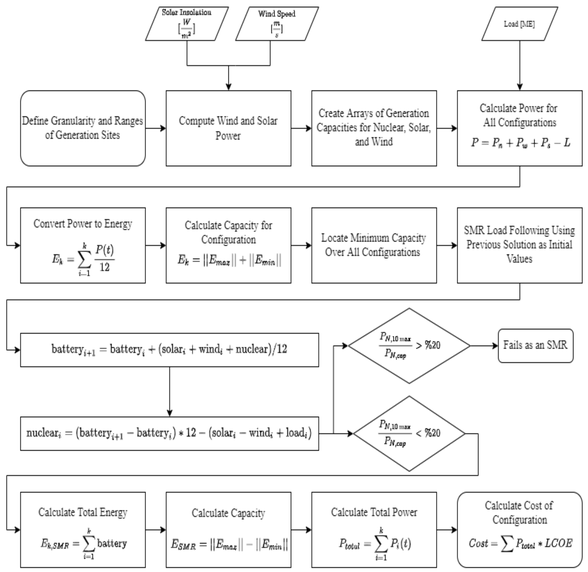

Figure 4: Optimization Flow Chart

Results

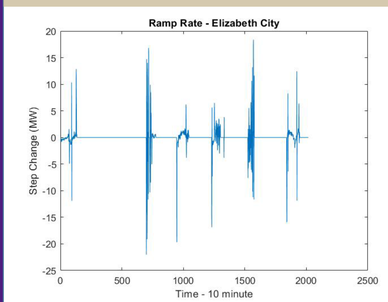

Figure 5: Ramp Rate Check

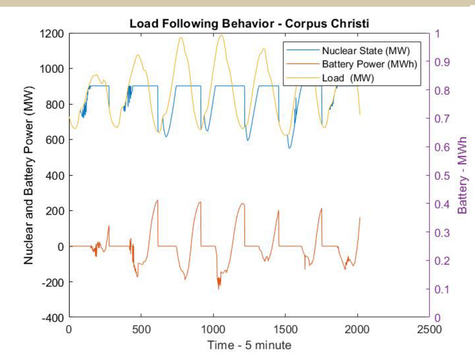

Figure 6: Nuclear State vs Battery State vs Load

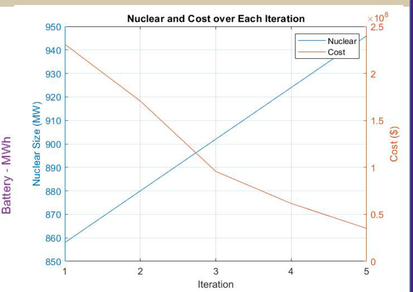

Figure 7: Nuclear Size vs Cost

Location	Population	Solar (MW)	Wind (MW)	Nuclear (MW)	Battery Size (MWh)	Average Load (MW)
Dobson	1646	0	10	0	218	3.72
Elizabeth City	17,629	30	10	22	422	39.7
Corpus Christi	325,780	180	0	858	1682	1228
Midland	138,549	220	140	1012	209	1056

Table 1: Summary of Optimization Results

Cost Analysis

City	Period (2019)	Max Power (MW)	Min Capacity (MWh)	Battery Hour Rating	Battery Cost (In Million Dollars)
Dobson	January	16.7	218	10	77.0
	April	7.7	107	10	38.2
	August	5.6	92	10	32.6
Elizabeth City	January	39.0	244	6	90.0
	April	16.1	156	10	55.5
	August	24.4	168	6	62.0

Table 2: Battery Cost Analysis

- Battery cost was estimated via Pacific Northwest National Laboratory (PNNL) [1].
- Price per MWh for solar and wind was found using the System Advisory Model (SAM).
- Price per MWh for nuclear was given in the NuScale SMR marketing publication [2]

Summary

- Allowing the SMRs to bypass steam when demands were low, reduced the overall battery capacity needs.
- The minimum battery capacity resulted in the lowest overall system cost for all cases.
- Not all results passed the required surplus and ramping tests.

References

[1] K. Mongird, V. Viswanathan, J. Alam, et al, "2020 Grid Energy Storage Technology Cost and Performance Assessment," Pacific Northwest National Laboratory, Richland, WA, USA, DOE/PA-0204, 2020.

[2] "NuScale SMR Technology: An Ideal Solution for Repurposing U.S. Coal Plant Infrastructure and Revitalizing Communities," NuScale Power, LLC, Corvallis, Oregon, USA, 2021.

Team & Acknowledgements

- Sponsor: Dr. Karayaka
- Team Members: Faisal Alrumman (EE), Lindsey McGregor (ME), and Lyle Pressley (EE), with special thanks to John Kiger (EE) for his contributions.

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