Energy Storage Feasibility

ENERJİSA ÜRETİM

Sabancı Üniversitesi — FACULTY OF ENGINEERING AND NATURAL SCIENCES

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ABSTRACT

Figure 1. Canakkale Wind Power Plant Turbines

The project was conducted with EnerjiSA Üretim with the purpose of helping them in their future plans. EnerjiSA Üretim is Turkey's largest electricity distribution and retail company. The main focus of the project was on their Çanakkale Wind Power Plant, which was established in 2011, and has an installed capacity of 30 MW with its 13 wind turbines. The main goal is to build a road map for future improvements in their energy storage systems. Throughout the span of this project we investigated the feasibility of different energy storage systems used in storing electricity.

To come up with a favorable storage system, we created a multi criteria decision model that consists of 8 different criteria that we have found to be crucial. For each technology, all the criteria values were researched and gathered to come up with a table. According to their respective values, for each technology, all the alternatives were given a score between 0 to 5, 0 being the worst and 5 being the best. After that step, each criterion was assigned a weight that was calculated by using AHP method to come up with a final total score. According to our findings, Li-ion battery systems were found to be the most favorable when the assigned weights are put into account. It must be noted that different weight assignments may change the favorable technology selection if the needs and desires of the firm changes.

OBJECTIVES

This project aims to develop a battery storage technology roadmap for EnerjiSA Üretim. The costs of battery technologies, such as grid-size of Li-ion batteries, have been falling, making them candidates for electricity storage in grids. Because these technologies still have very high capital costs, companies need to have a good understanding of their potential benefits as well as operational characteristics before making investment decisions.

PROJECT DETAILS

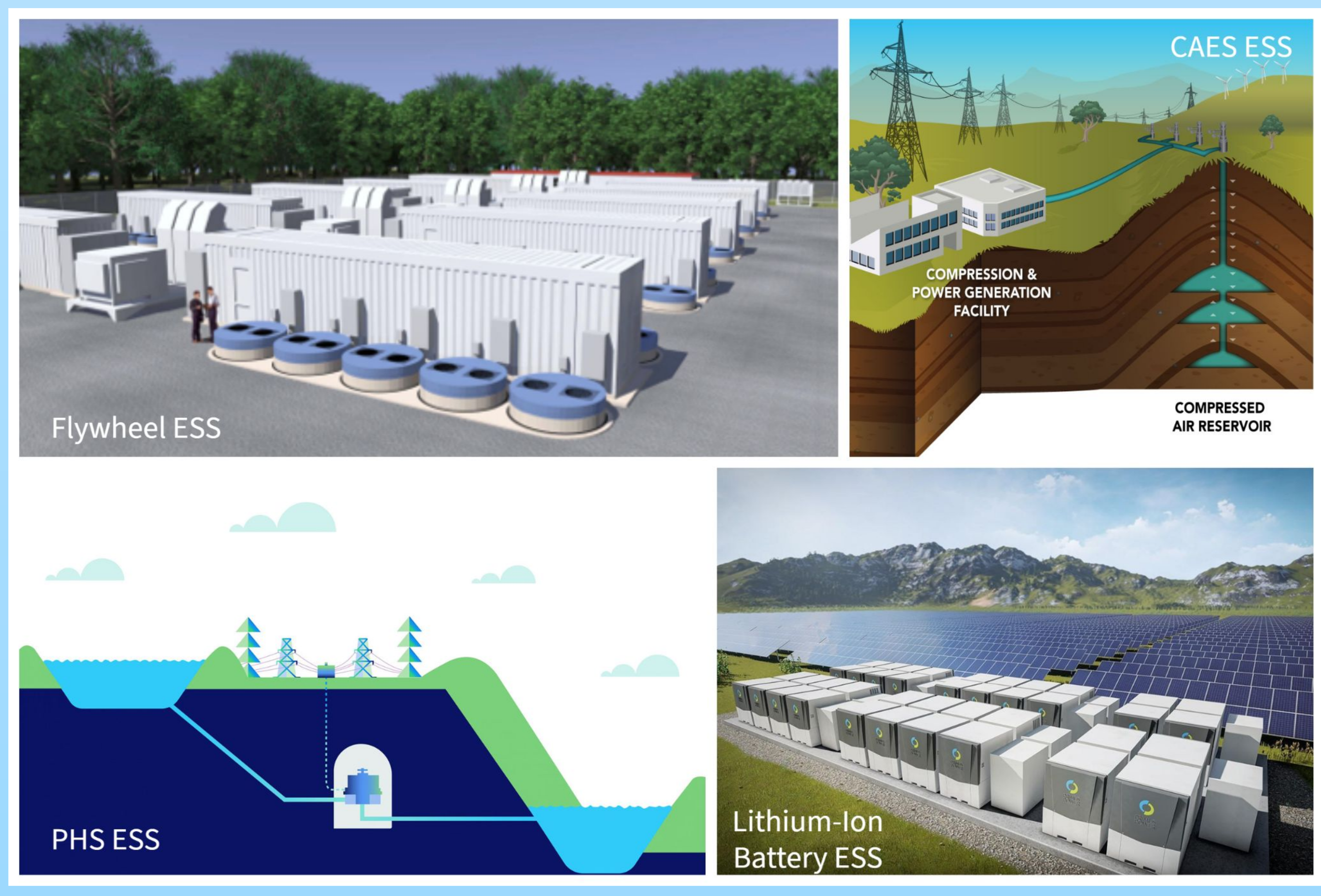

Figure 2. Some of the Energy Storage Technologies Considered In This Project

The main purpose of energy storage systems is to store the generated energy and use it whenever it is necessary. Energy storage systems benefit the company in many ways. Firstly, renewable energies have unsteady natures causing fluctuations in the generated energy output, which might cause hardships while trying to meet the demand. Energy storage systems could help to smooth these fluctuations resulting in reducing the unmet demand. Second most important aspect of energy storage systems is peak shaving. Since demand fluctuates daily and even at every moment of time, peak to valley differences occur during the day. As a result, peak shaving and load leveling are required to store created power and provide vacant power during peak loads. (Chen, T., et al., 2020)

PROJECT DETAILS 2

Table 1. Technology Alternatives Score Table

	Li-ion	NaS Battery	Lead Acid Battery	Redox Flow	Compressed Air	Flywheel	PHS
Storage Capacity	5.00	5.00	5.00	5.00	5.00	0.00	5.00
Response Time	5.00	5.00	5.00	3.00	2.00	4.00	4.00
Cycle Time/ Life Time	4.00	3.00	2.00	4.00	4.00	4.00	5.00
Risk and Safety	2.50	1.50	1.50	3.50	3.50	3.50	3.50
Energy Efficiency	5.00	2.00	2.00	2.00	1.00	5.00	2.00
Investment Costs	5.00	3.49	2.75	3.25	4.79	4.26	0.00
Ease of Installation	5.00	5.00	5.00	3.33	0.00	3.33	0.00
Tech Maturity	5.00	4.00	5.00	5.00	5.00	5.00	5.00
Total Score with Weights	4.75	3.23	2.95	3.02	2.81	4.26	2.11
%	0.95	0.65	0.59	0.60	0.56	0.85	0.42

The project was successfully completed using multicriteria decision making. Battery types and energy storage systems were evaluated on 8 main criteria: Storage Capacity, Response time, Cycle Time/ Life Time, Risk and Safety, Energy Efficiency, Investment Costs, Ease of Installation and Tech Maturity.(Barin, A., et al., 2011) While making these evaluations, many different sources and real-life examples were used, list of other sources can be found in the references part of this poster. Through this study; lead acid, sodium sulfide, li-ion, redox flow batteries, pumped hydro, flywheel and compressed air energy storage systems were compared.

Table 2. Criteria Weight Distribution

Criteria	Weights
Storage Capacity	0.02
Response Time	0.14
Cycle Time/ Life Time	0.09
Risk and Safety	0.06
Energy Efficiency	0.30
Investment Costs	0.29
Ease of Installation	0.06
Tech Maturity	0.03
Total Score	1.00

The criteria and energy storage technology alternatives were organized into an AHP hierarchy, which is then utilized to build the pairwise comparison matrix. The weights of the criteria were estimated for this. This was accomplished by the measurement of AHP. After forming a pairwise comparison matrix, we went on to calculate the weights for each criteria. We examined if the formed matrix was inconsistent or not. After examination, we concluded that the ratings were transitive but they were not numerically consistent. Therefore the pairwise comparison matrix was inconsistent, and to calculate the weights of the inconsistent matrix geometric mean method was selected. As the first step of the method, we normalized each column. Since our matrix was 8x8, it was challenging to normalize columns one by one by hand. Therefore we wrote a python code to normalize the matrix using scikit-learn library.

As the second step of the method, after normalizing each column, we calculated the geometric mean for each row. The geometric mean of a row gives the weight for the criteria related to that row.

CONCLUSIONS

When all energy storage technologies were investigated under the chosen criteria and their priorities among each other, we observed that the optimal technology was Li-Ion batteries. Li-ion batteries have higher response rates, higher energy efficiencies, high technical maturity and less costs when compared with other technologies that made it stand out. Throughout our investigation, we have come across many global real life examples of these energy storage systems in use, thus we used those findings in our investigations. We encountered some limitations while we searched for real life examples in Turkey due to lack of resources on this matter. However, on the basis of our findings EnerjiSA Üretim can decide on a suitable energy storage technology that would fulfill their needs.

REFERENCES

- *Advanced Energy Storage Technologies*. Energy Storage Association. (2020, September 24). Retrieved May 29, 2022, from https://energystorage.org/why-energy-storage/technologies/
- Battery pack prices fall to an average of $132/kwh, but rising commodity prices start to bite. BloombergNEF. (2021, November 26). Retrieved April 17, 2022, from https://about.bnef.com/blog/battery-pack-prices-fall-to-an-average-of-132-kwh-but-rising-commodity-prices-start-to-bite/
- Chen, T., Jin, Y., Lv, H. *et al.* Applications of Lithium-Ion Batteries in Grid-Scale Energy Storage Systems. *Trans. Tianjin Univ.* **26,** 208–217 (2020). https://doi.org/10.1007/s12209-020-00236-w
- *Compressed Air Energy Storage (CAES)*. Energy Storage Association. (2021, April 7). Retrieved April 17, 2022, from https://energystorage.org/why-energy-storage/technologies/compressed-air-energy-storage-caes/
- *Compressed Air Energy Storage*. Compressed air energy storage - Energy Education. (n.d.). Retrieved April 17, 2022, from https://energyeducation.ca/encyclopedia/Compressed_air_energy_storage
- Energy Storage Cost and Performance Database. (2020). Retrieved April 17, 2022, from https://www.pnnl.gov/ESGC-cost-performance
- ENERJİ GÖRÜNÜMÜ. (n.d.). [online] Available at: https://www.tskb.com.tr/i/assets/document/pdf/enerji-sektor-gorunumu-2020.pdf.
- Girschik, J., Kopietz, L., Joemann, M., Grevé, A. and Doetsch, C. (2021), Redox Flow Batteries: Stationary Energy Storages with Potential. Chemie Ingenieur Technik, 93: 523-533. Retrieved April 17, 2022, from https://onlinelibrary.wiley.com/doi/full/10.1002/cite.202100001
- Innovation Insights Brief | | 2020 FIVE STEPS TO ENERGY STORAGE In collaboration with the California Independent System Operator (CAISO). (n.d.). [online] Available at: https://www.worldenergy.org/assets/downloads/Five_steps_to_energy_storage_v301.pdf.
- *Lead acid battery*. Lead Acid Battery - an overview | ScienceDirect Topics. (n.d.). Retrieved April 17, 2022, from https://www.sciencedirect.com/topics/engineering/lead-acid-battery
- *NAS Batteries*. NGK. (n.d.). Retrieved April 17, 2022, from https://www.ngk-insulators.com/en/product/nas.html
- Qie, X., Zhang, R., Hu, Y., Sun, X., & Chen, X. (2021). A multi-criteria decision-making approach for Energy Storage Technology selection based on demand. *Energies*, *14*(20), 6592. https://doi.org/10.3390/en14206592
- Sheffield, U. of. (2017, June 2). *News archive*. Europe's largest hybrid flywheel battery project to help grid respond to energy demand - Archive - News archive - The University of Sheffield. Retrieved April 17, 2022, from https://www.sheffield.ac.uk/news/nr/flywheel-europe-energy-1.704921
- Zhang, X., Qin, C. (C., Loth, E., Xu, Y., Zhou, X., & Chen, H. (2021, September 23). *Arbitrage analysis for different energy storage technologies and strategies*. Energy Reports. Retrieved May 29, 2022, from https://www.sciencedirect.com/science/article/pii/S2352484721008143
- Barin, A., Canha, L. N., Abaide, A. R., Magnago, K. F., Wottrich, B., & Machado, R. Q. (2011). Multiple criteria analysis for energy storage selection. Energy and Power Engineering, 3(04), 557.