SIMULATION AND EVALUATION OF A LITHIUM-ION BATTERY STORAGE SYSTEM ASSOCIATED WITH PHOTOVOLTAIC GENERATION TO MEET LOCAL DEMAND

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ABSTRACT

Photovoltaic systems and energy storage have proven to be promising solutions for the management and generation of electrical energy, especially in low-voltage units. This work aimed to evaluate the impacts of implementing a photovoltaic system combined with a lithium-ion battery system at the School of Engineering of the Federal University of Goiás. Simulations will be conducted using the Hybrid Optimization of Multiple Energy Resources (HOMER) software. In this environment, simulations of the installations of the same generation set and battery system were carried out to evaluate the results in different applications and identify the benefits that the consumer received in the proposed scenarios. The following scenarios were evaluated: an increase in solar generation without the battery system and an increase in solar generation with the battery system. From this analysis, it is expected to measure the gains from adding batteries to photovoltaic systems installed in low voltage (LV), which are responsible for the significant growth of microgeneration in recent years.

Keywords: Battery Systems; Economic Feasibility; Homer; Photovoltaic Systems.

INTRODUCTION

The growing need for sustainability and energy efficiency has driven all types of energy consumers to rethink their energy generation and storage strategies. In this context, the analysis of Energy Storage Technologies (EST) becomes essential to ensure the stability of energy supply and meet the variable demands of the market. This article aims to show a simulation of the use of an integrated system combining Photovoltaic and lithium battery storage. The adoption of effective storage systems not only improves operational resilience but also promotes the integration of renewable sources, allowing for a more efficient use of generated energy.

The article discuss various energy storage technologies and methods in the industry, highlighting the importance of these techniques for the efficiency and stability of energy supply. In the automotive industry context, the agile development of production technologies for energy storage systems is crucial due to rapid technological evolution. In this scenario, agile project management methods such as Scrum and Extreme Programming are effective for the pre-development of hardware, improving complexity management and communication [1].

Among the various energy storage technologies available, lithium-ion batteries stand out for their high energy density and efficiency, being widely used in various sectors. However, other alternatives, such as thermal storage, compressed air storage, and hydrogen, also have significant potential. Each of these technologies has unique characteristics that meet specific industrial needs, such as reducing operational costs, energy arbitrage, and ensuring backup in emergency situations [2,3].

Furthermore, the analysis of hybrid solutions, which combine different forms of storage, has shown additional benefits in terms of flexibility and efficiency. For example, the combination of electrical and thermal storage systems not only optimizes energy use but also contributes to the sustainability of industrial operations. This integrated approach allows industries to better manage their energy resources, aligning with efficiency and emission reduction goals [4,6].

Recent technological advances make energy storage solutions more economically viable, reducing costs and increasing accessibility. The concept of cloud energy storage, for example, offers an innovative alternative by enabling shared access to large-scale storage resources. This approach not only promotes economies of scale but also allows for more efficient energy resource management.

MATERIALS AND METHODS

Based on the loads measured in block B of the School of Electrical Engineering at the Federal University of Goiás, Figure 1, a photovoltaic system and a battery energy storage system (BESS), were designed to meet these loads. Figure 2 presents all the load curves, including the energy consumption from the grid. The sizing was carried out using HOMER software for economic feasibility analysis with current market values. The system was sized by software with the following parameters, table 1: Photovoltaic system of 100kWp, the energy storage system in batteries, designed with 52 batteries of 48V and 183.56 kWh and an autonomy of approximately 8 hours.

The economic feasibility analysis was conducted based on a case study of a Group A consumer under the green tariff. The criteria for the analysis included specific electricity rates and demand charges as follows: an off-peak electricity rate of R$ 0.34 per kWh, applicable during the periods from 00:00 to 18:00 and from 21:00 to 00:00, and a peak electricity rate of R$ 1.99 per kWh, applicable from 18:00 to 21:00. Additionally, the contracted demand charge considered in the simulation was R$ 25.22 per kW. These rates were integral in determining the overall economic viability of the proposed energy solutions. Economic feasibility analysis is a important method for evaluating the viability of projects by considering the present value of all associated costs, charges, and investments alongside the expected revenues over time, allowing stakeholders to assess the long-term financial implications of adopting different energy solutions.

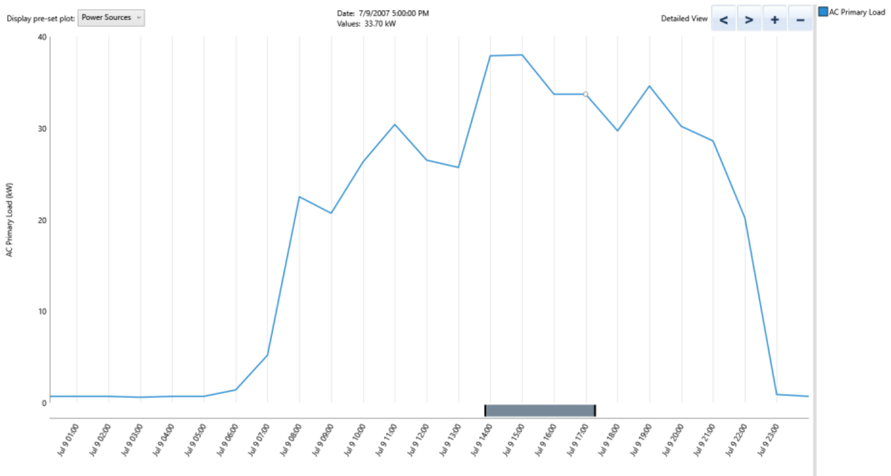


Figure 1. AC Primary Load

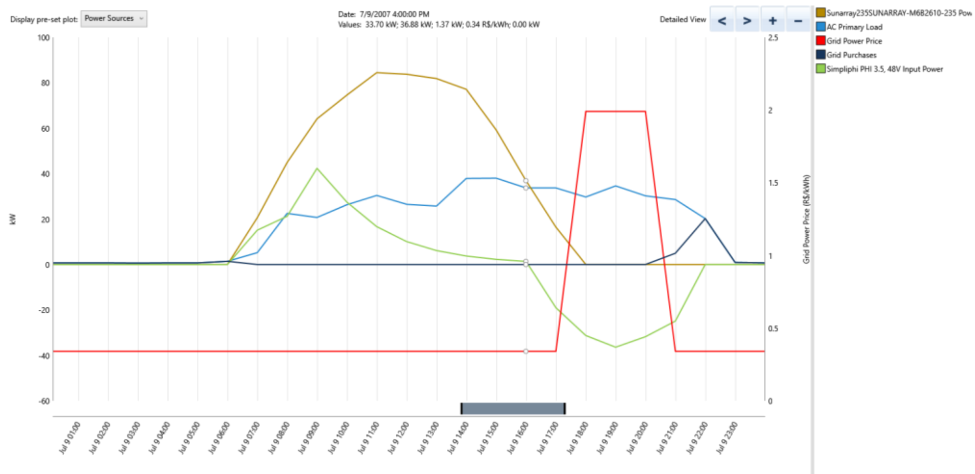


Figure 2. All Charges

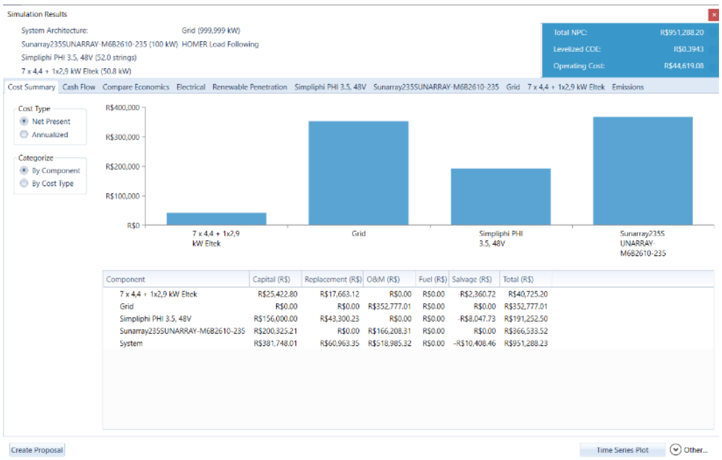
Component	Power
GRID	∞
PV	100 kWp
BESS	52 X 3.53 kWh
Conversor	50.8 kW

Table 1. Simulation Settings

RESULTS AND DISCUSSION

Based on the simulations conducted, the photovoltaic system has been sized at 100 kW of peak power, serving to offset consumption for a large part of the day. When its generation decreases, the energy storage system in batteries, designed with 52 batteries of 48V and 183.56 kWh and an autonomy of approximately 8 hours, charged by the photovoltaic system, takes over the load, generating the following results, table 1.

The simulated economic viability shows that the average cost of kWh when using only the grid is R$ 0.756, while with the photovoltaic system it drops to R$ 0.506, and with the BESS it decreases even further to R$ 0.394. These values are calculated considering the investment needed to purchase and install the mentioned systems, and the differences in these values are shown in Figure 4.



Component	Capital (R$)	Replacement (R$)	O&M (R$)	Fuel (R$)	Salvage (R$)	Total (R$)
7 x 4,4 + 1x2,9 kW Eltek	R$25,422.80	R$17,663.12	R$0.00	R$0.00	-R$2,360.72	R$40,725.20
Grid	R$0.00	R$0.00	R$352,777.01	R$0.00	R$0.00	R$352,777.01
Simpliphi PHI 3.5, 48V	R$156,000.00	R$43,300.23	R$0.00	R$0.00	-R$8,047.73	R$191,252.50
Sunarray235SUNARRAY-M6B2610-235	R$200,325.21	R$0.00	R$166,208.31	R$0.00	R$0.00	R$366,533.52
System	R$381,748.01	R$60,963.35	R$518,985.32	R$0.00	-R$10,408.46	R$951,288.23

Figure 4. Simulations Values

The analysis of the graphs presented in Figure 2 reveals the operating curve of the BESS. The green line represents the BESS power, with positive values indicating charging and negative values indicating discharging. The red line depicts the energy tariff at different times of the day. From the graphs, it is evident that the BESS charges during periods when energy is less expensive and discharges during peak times when the energy tariff is higher. Additionally, Figure 2 shows load shifting, where energy is stored during periods of solar incidence and used during periods with higher tariffs. This strategic operation optimizes cost savings by leveraging the BESS to reduce energy expenses during peak tariff hours.

CONCLUSION

The analysis of energy storage technologies and methods associated with photovoltaic generation reveals a promising and multifaceted scenario, where the adoption of these systems proves crucial for operational efficiency and sustainability. The discussed solution demonstrates not only its sustainable viability but also its potential to meet the growing demands for flexibility and reliability in energy supply.

Therefore, this study reinforces the importance of continuing research and investment in energy storage technologies associated with photovoltaic systems. The pursuit of solutions that integrate economic and environmental efficiency will be decisive for the future, enabling a competitive and sustainable positioning in the global market.

ACKNOWLEDGMENT

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REFERENCES

[1] Hilt M.J., Wagner D., Osterlehner V., Kampker A. Agile predevelopment of production technologies for electric energy storage systems – a case study in the automotive industry, Procedia CIRP, 2016, 50, 88-93, doi: 10.1016/j.procir.2016.04.189.

[2] Borba, A. T. A., Santos, A. A. B., Melo, T. R. Análise de viabilidade técnica e econômica de um sistema de geração híbrido com armazenamento: Estudo de caso de Casa Nova - Bahia, Centro Universitário SENAI CIMATEC, 2024, 105 f., Available in: http://repositoriosenaiba.fieb.org.br/handle/fieb/1847.

[3] Cardoso, J. J., Vieira, V. M. Análise de viabilidade técnica-financeira da inserção de geração fotovoltaica com armazenamento de energia em uma indústria de movimentação de containeres. Universidade Salvador, 2021. Available in: http://tede.unifacs.br/tede/handle/tede/771

[4] Botezeli, L. K., Goehring, R. N., Canha, L. N., & Almeida, D. T. Análise do Investimento Industrial em Energia Solar Fotovoltaica e Armazenamento de Energia – Estudo de caso da Bruning Tecnometal. Sociedade Brasileira de Automática (SBA) IX Simpósio Brasileiro de Sistemas Elétricos - SBSE 2022, 2022, 10 a 13 de julho de 2022, 1739-1745. DOI: 10.20906/sbse.v2i1.3111.

[5] Corrêa JR. Armazenamento de energia na indústria. PPGEP - UTFPR. 2024; 1(1): 1-8. Available in: https://aprepro.org.br/conbrepro/2021/anais/arquivos/09272021_180947_615233574c468.pdf.

[6] Sun L., Qiu J., Han X., Yin X., Dong Z. Y. Capacity and energy sharing platform with hybrid energy storage system: An example of hospitality industry, Applied Energy, 2020, 280, 115897, https://doi.org/10.1016/j.apenergy.2020.115897