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Energy Storage for Peak Shaving in a Microgrid in the Context of Brazilian Time-of-Use Rate

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Key words: ***peak shaving; time-of-use rate; distributed generation; energy storage***

Table Contents

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Introduction

- Meeting time-varying demand, especially in peak periods, presents a key challenge to electric utility [1].
- Peak load shaving is a process of flattening the load curve by reducing the peak amount of load and shifting it to times of lower load consumption [2].
- Electricity storage can be used by end users to reduce their overall costs for electric service by reducing their demand during peak periods specified by the utility [4].
- The microgrid scenario with a commercial load profile is ideal for this application and also provides the integration with renewable energy sources.

Objective

Provide an overview of the application and Brazilian Scenario for DG and Storage

Detail the Simulink Model for Study and the BESS Control Strategy

Present the resultas and validate de financial savings with Homer Grid

Brazilian Scenario

- The micro and mini DG were regulated in Brazil in 2012 by ANEEL through Normative Resolution (REN) No. 482 [14]. Currently, the current regulatory model for DG is "net metering."
- The DG will increase yearly, so it is necessary to develop an analysis of applications to verify the opportunities, benefits, and risks of the implementation.
- Energy storage is a great ally to enable greater use of renewable energy sources.
- Batteries are one of the most cost-effective energy storage technologies available, with energy stored electrochemically [18] .

Brazilian Scenario

- Given the current regulatory framework and its perspectives, three possibilities of use can be seen for batteries in consumer units in the future, according to national planning.

  - ✓ Increased self-consumption of distributed microgeneration;
  - ✓ Change to the White Rate;
  - ✓ Replacement of diesel generation at the peak.

White Rate

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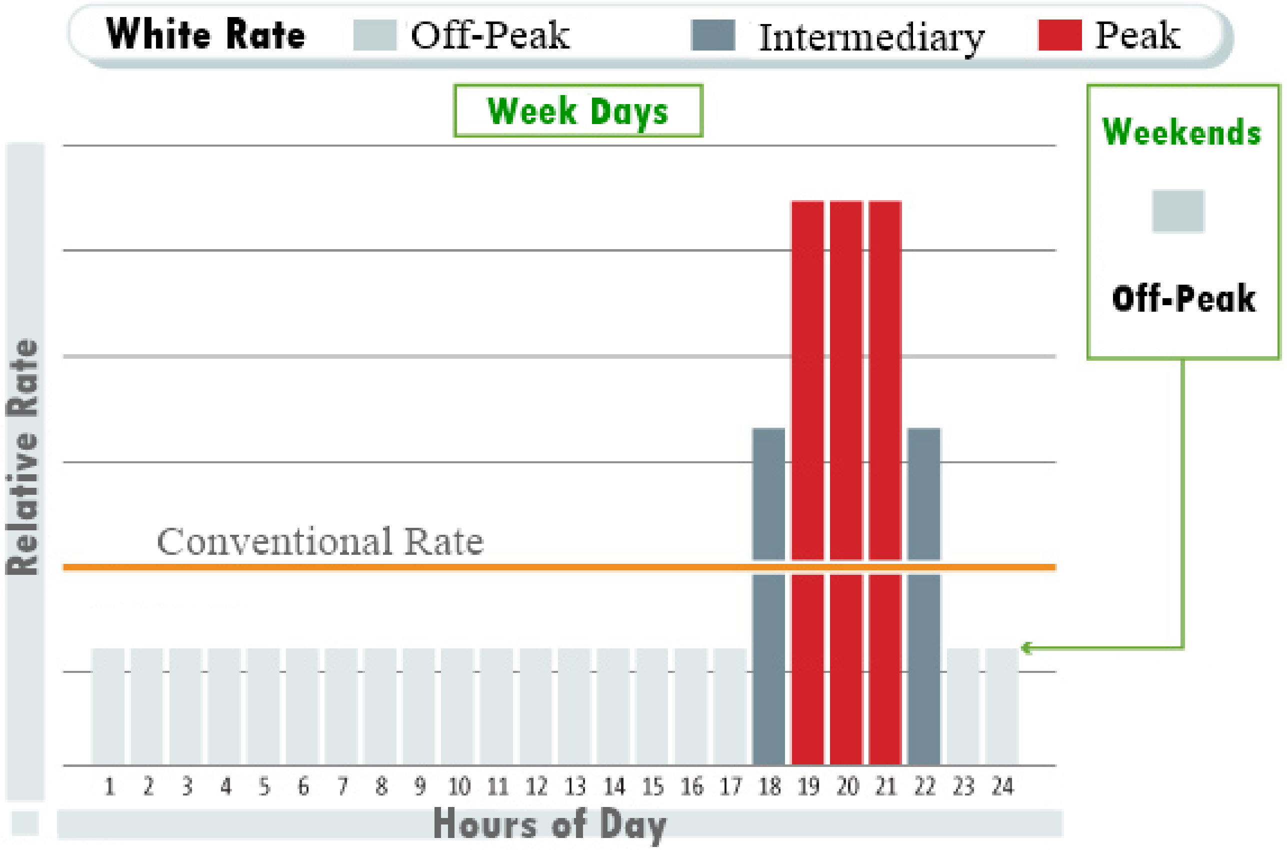

SOURCE: ANEEL

White Rate	Rate Value (US$/kWh)	Class
Off-Peak	0.1370875	Non-residential
Intermediary Peak	0.188515 0.2827075	Non-residential Non-residential

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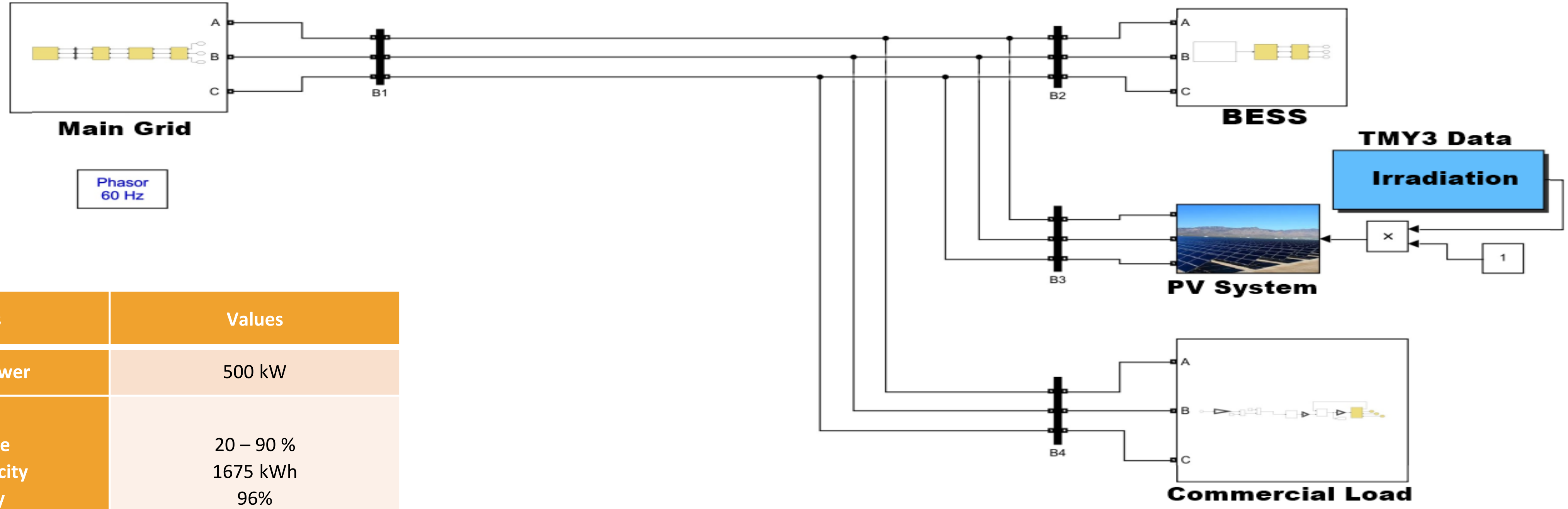
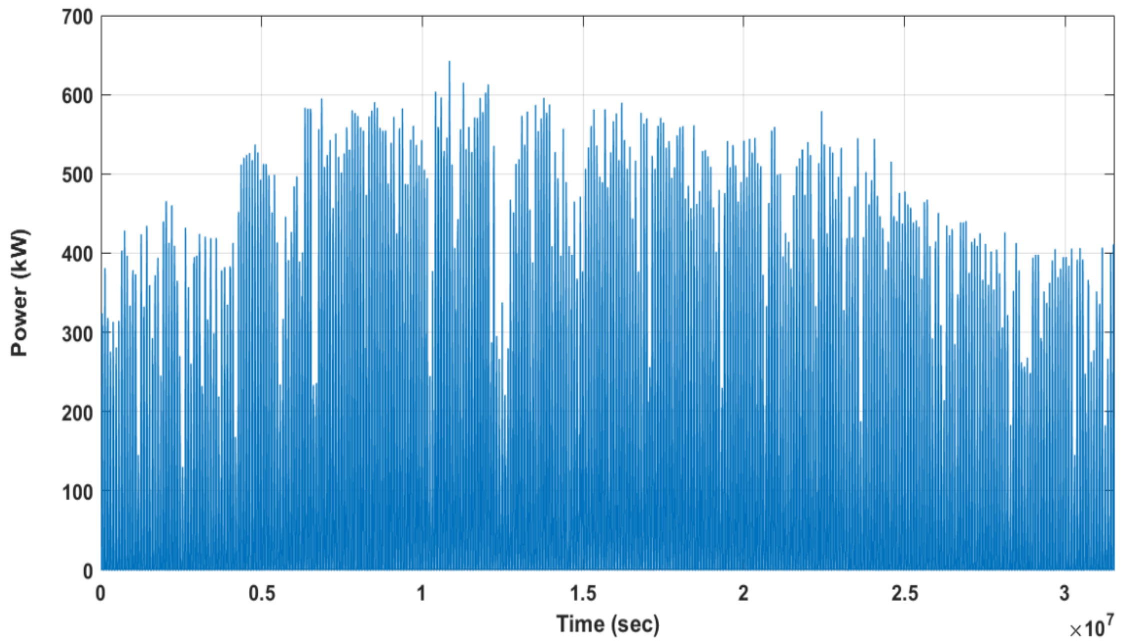
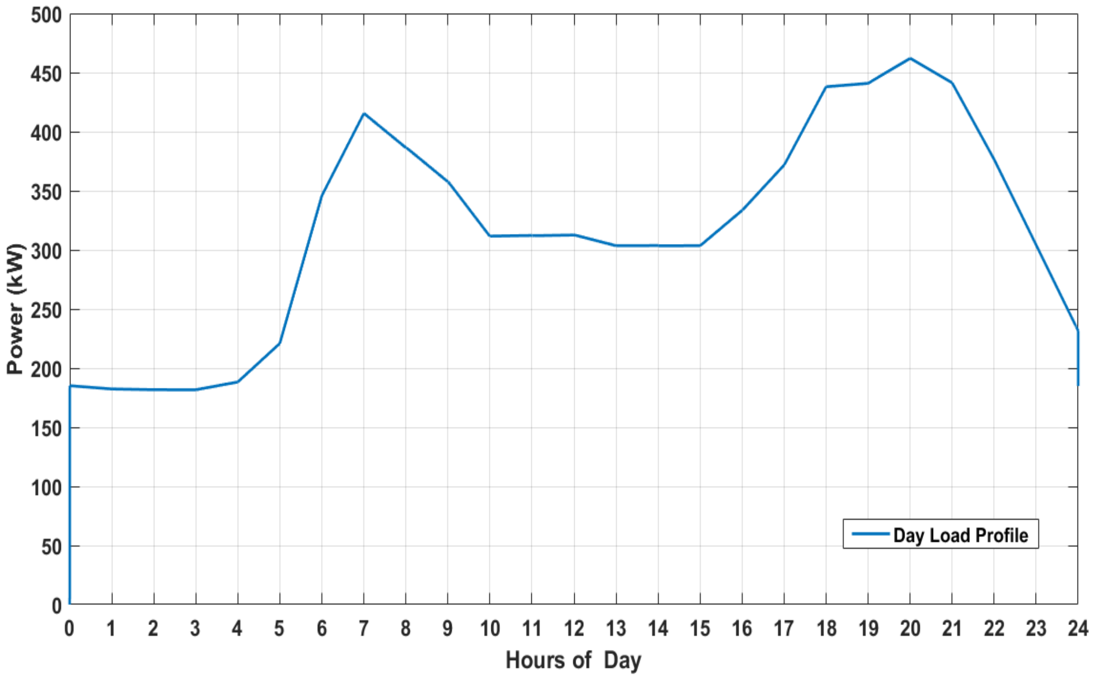
Microgrid Components and Simulation



Features	Values
Nominal Power	500 kW
SOC Range Rated Capacity Efficiency	20 – 90 % 1675 kWh 96%

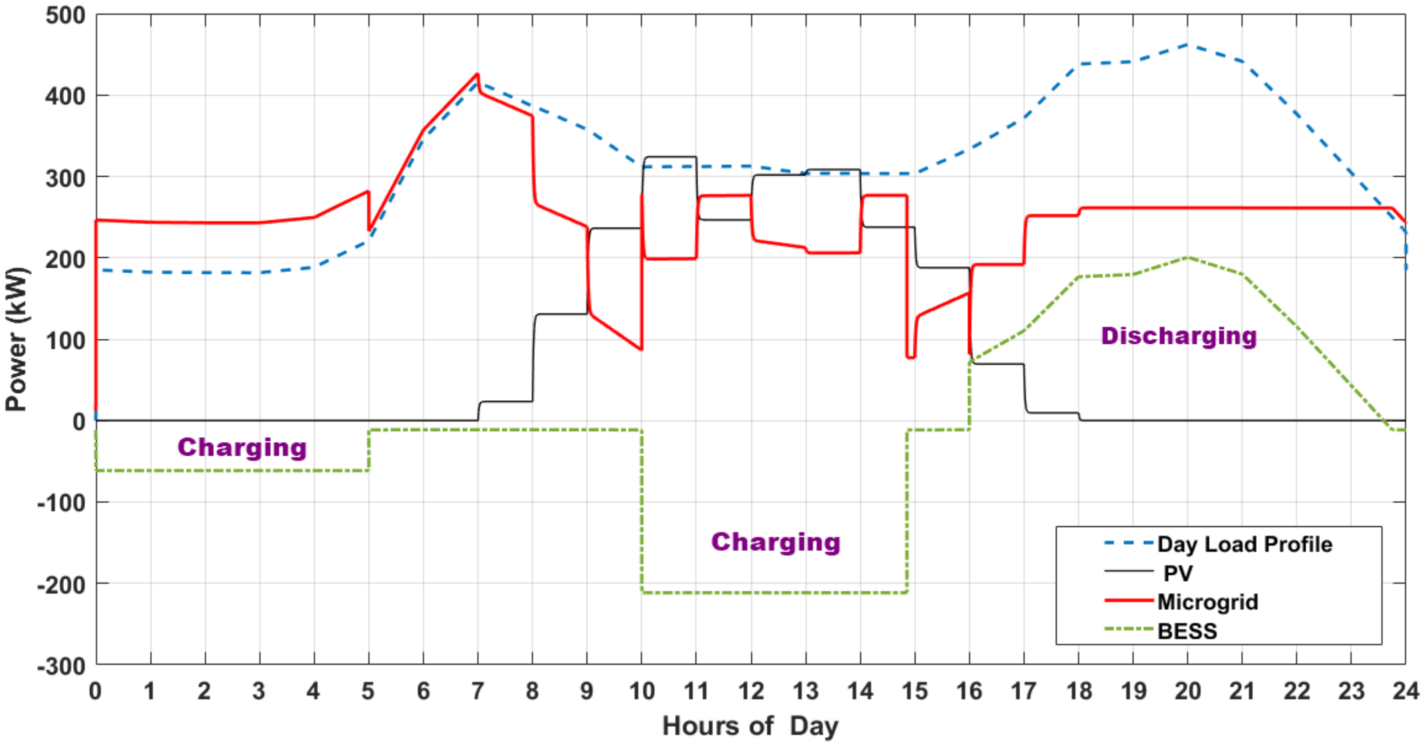
Microgrid Components and Simulation



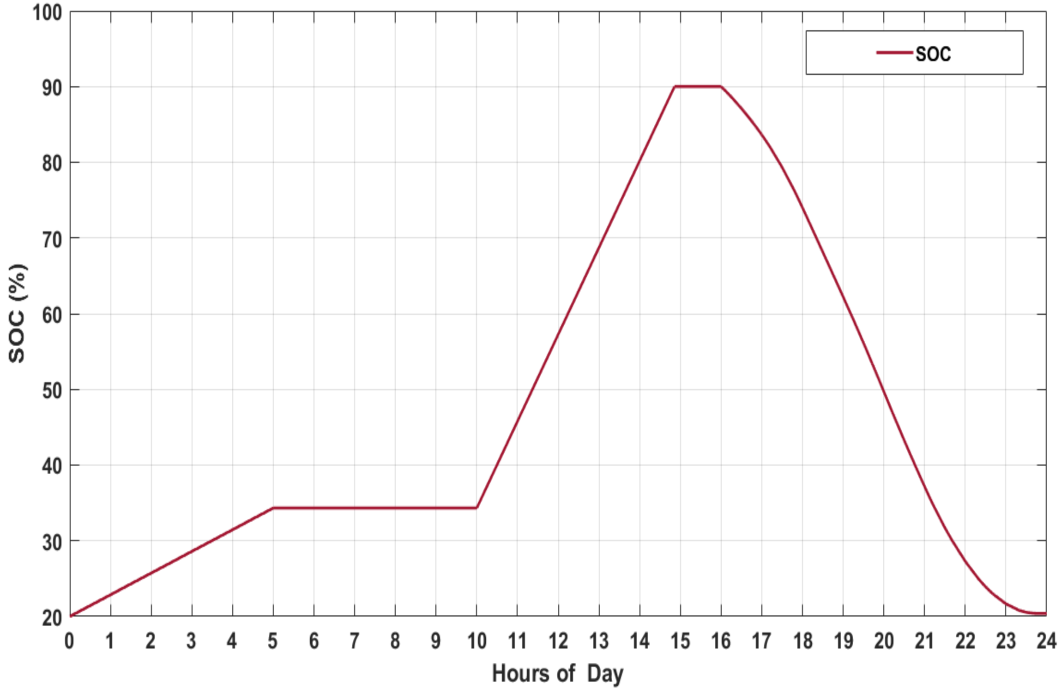


The nominal generation of this PV farm is 645 kilowatts (kWp)

Results

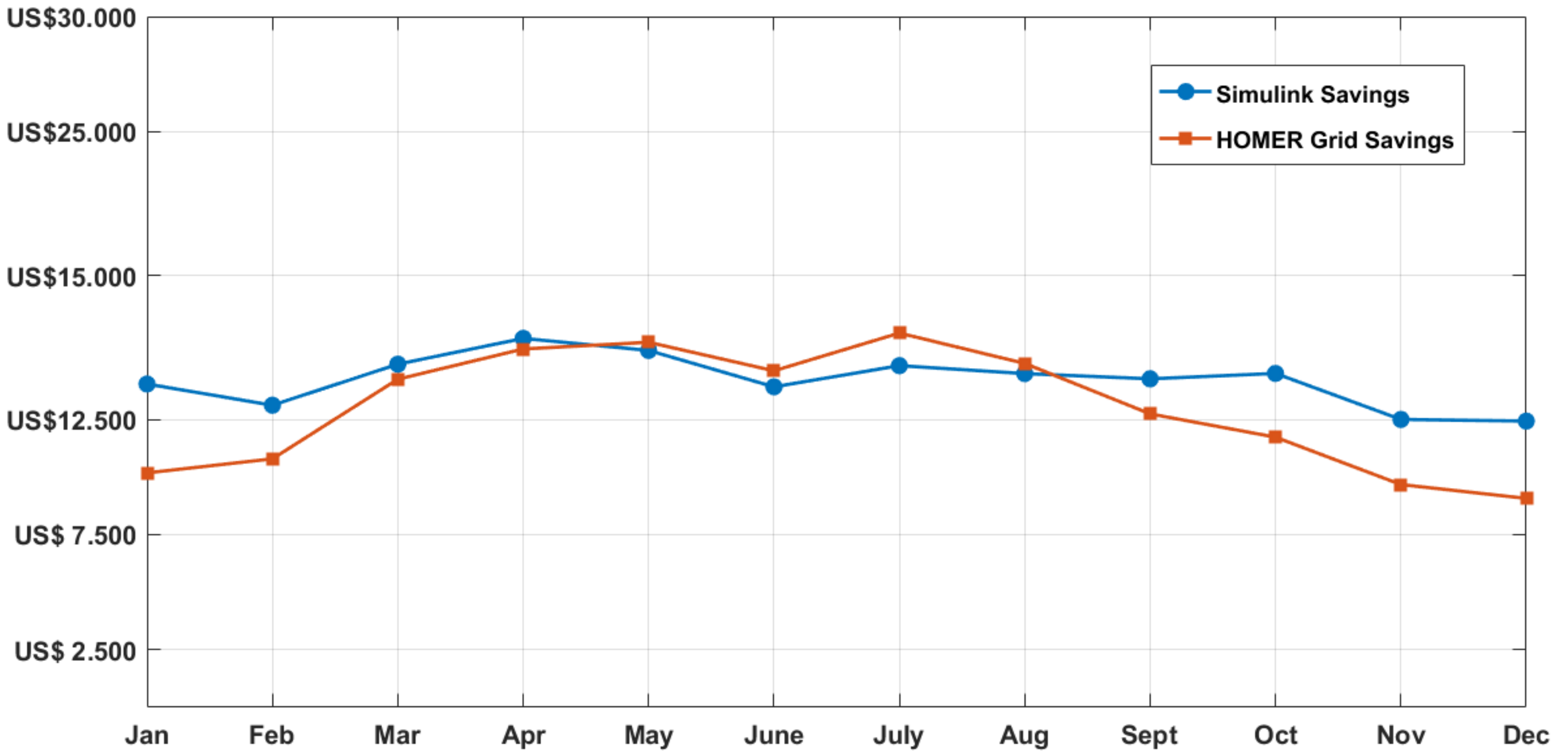


Power (kW)
Hours of Day
Charging
Charging
Discharging
Day Load Profile
PV
Microgrid
BESS



SOC (%)
Hours of Day
SOC

Results



Model	Annual Cost only main grid (US$)	Annual Cost PV+BESS (US$)	Annual Savings (US$)
Simulink	472,175.00	316,500.00	155,675.00
Homer	415,520.00	280,976.00	170,550.00

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Conclusions

- The results were very effective, both from the electrical point of view of the application and the financial benefits generated by the proposal.
- The work demonstrates the advantage of using energy storage in conjunction with renewable energy sources to save the end-consumer in electricity purchases, in addition to showing that the White Rate scenario also benefits the consumer who owns these technologies.
- The investigation of this application indicates the possibilities of operations in the future of DG in Brazil.

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Thank you!!

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References

1. Mehta, VK.RM. Principles of Power System, 4th ed.; S. Chand: New Delhi, India; 2005.
2. Nourai, A.;Kogan, V.;Schafer, CM. Load leveling reduces T&D line losses. *IEEE Trans Power Deliv* **2008**; 23, 68–73.
3. Uddin, M. et al. A review on peak load shaving strategies. *Renew Sustain Energy Rev* **2018**; 82(3), 23-32.
4. Akhil, A.A. et al. DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA. Sandia National Laboratories., Albuquerque, New Mexico 87185 and Livermore, California 94550, Jan. 2015.
5. Omer, M.; Ibrahim, M.; Pillay, P.; Athienitis, A. Design and Control of a Peak Load Shaving System for the Louis-Hippolyte-La Fontaine Tunnel, 2018 IEEE Canadian Conference on Electrical & Computer Engineering (CCECE), Quebec City, QC, 2018, pp. 1-4.
6. Lobato, E.; Sigrist, L.; Rouco, L. Use of energy storage systems for peak shaving in the Spanish Canary Islands, IEEE Power & Energy Society General Meeting, Vancouver, BC, 2013, pp. 1-5.

References

7. Jeong, H.C.; Jung, J.; Kang, B.O. Development of Operational Strategies of Energy Storage System Using Classification of Customer Load Profiles under Time-of-Use Tariffs in South Korea. Energies **2020**, 13, 1723.
8. Papadopoulos, V.; Knockaert, J.; Develder, C.; Desmet, J. Peak Shaving through Battery Storage for Low-Voltage Enterprises with Peak Demand Pricing. Energies **2020**, 13, 1183.
9. Finotti, A.S.; Almeida, M.P.; Zille, R. Simulation of Battery Usage Adopting the White Rate for a Residential Class Photovoltaic Microgeneration, VII Brazilian Congr. Solar Energy, Brazil, 2018.
10. Santos L.L.C. Methodology for the Analysis of the White Rate and Distributed Generation of Small Size in Low Voltage Residential Consumers. M.S. thesis, UFSM, Santa Maria, Brazil, 2014.
11. Bernardes, J.P.S.; Mello, A.P.C. Minimizing the Impact of the White Rate Using Distributed Generation to Low Voltage Consumers, Ann. VII International Salon Teaching, Research and Extension., Brazil, 2015.
12. Salamanca, H.L.L.;Arruda, L.V.R.; Magatao, L., Using a MILP Model for Baterry Bank Operation in the White Rate Brazilian Context, Fifth International Renewable Energy Congr., Tunisia, March 25 – 27, 2014.

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References

13. Costa, V.; Zambroni de Souza A.C.; Ribeiro, P.F. Economic Analysis of Energy Storage Systems in the Context of Time-of-Use Rate in Brazil. 2019 IEEE Power & Energy Society General Meeting, Atlanta, 2019.
14. Normative Resolution Nº482, April 17th, 2012. Avaiable online: http://www2.aneel.gov.br/cedoc/bren2012482.pdf (accessed on 15 March 2020).
15. 10-Year Energy Expansion Plan 2029.Available online: http://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/plano-decenal-de-expansao-de-energia-2029 (accessed on 23 April 2020).
16. Andrade, J.V.B.; Rodrigues B.; Santos, I.F.; Haddad J.; Filho, G.L.T. Constitutional aspects of distributed generation policies for promoting Brazilian economic development. *Energy Policy* **2020**, 143.
17. ESMAP, I. a. (2017). Energy Storage Trends and Opportunities. Conference Report.
18. Ribeiro P. F.; Johnson B. K.; Crow M. L.; Arsoy A.; Liu Y. Energy storage systems for advanced power applications. *Proceedings of the IEEE* ***2001***, 89, no. 12, 1744-1756.

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References

19. Battery Storage Systems - Applications and Relevant Planning Issues. Avaible online: http://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/plano-decenal-de-expansao-de-energia-2029 (accessed on 23 April 2020).
20. ANEEL - National Agency of Eletric Energy, 2019. Available on: http://www.aneel.gov.br/tarifa-branca (acessed on 15 January 2020).

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