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SCIENTIFIC PROGRAMME

POSTER SESSION 2 - THEME 05: BEYOND SOLAR: OTHER RENEWABLES AND ASSOCIATED APPLICATIONS, COMPONENTS, SIMULATION AND ANALYSIS - PART 1/2

91[H.II.1]	GEOSPATIAL CLUSTERING OF WIND/SOLAR POTENTIAL: IDENTIFYING HIGH-YIELD AREAS IN CEARÁ, NORTHEAST BRAZIL *Igor Hammom Rodrigues da Costa[1], Maria Ilana dos Santos Guedes[2], Paulo Honorio Filho[1], Ernande Eugenio Campelo Morais[1], Dalton Honorio[1]* *[1] Universidade Federal do Ceará; [2] Imperial College London*
114[H.II.8]	ANALYSIS OF SMALL-SCALE WIND TURBINE BLADES FOR OPTIMAL POWER GENERATION: A CFD-BEM STUDY *Jasson Fernandez Gurgel[1], Pedro Lucas Barros Martins[1], Carla Freitas de Andrade[1], Francisco Olimpio Moura Carneiro[2], Francisco Nivaldo Aguiar Freire[1], Felipe Cordeiro de Sousa[1]* *[1] Universidade Federal do Ceará; [2] Universidade da Integração Internacional da Lusofonia Afro-Brasileira*
167[B.I.11]	PHYSICOCHEMICAL CHARACTERIZATION OF MACAÚBA (ACROCOMIA ACULEATA) FOCUSING ON ENERGY APPLICATIONS *Kennedy Romualdo Guedes Coimbra[1], Eva Furtado de Sousa[1], Mauricio Dorneles Lima[1], Paloma Cavalcante Silva[1], Francisco Assis Bezerra da Cunha[2], Maria Alexsandra de Sousa Rios[1]* *[1] Universidade Federal do Ceará; [2] Universidade Regional do Cariri*
183[I.II.1]	NEURAL NETWORK-DRIVEN OPTIMIZATION: ENHANCING SPEED IN ENERGY SYSTEMS *Theresa Reinhardt[1], Viktor Wesselak[1], Rohith Krishnan Bala Krishnan[1], Christoph Schmidt[1], Sebastian Voswinckel[1]* *[1] Hochschule Nordhausen*
244[I.II.5]	UTILIZATION OF EXCESS ENERGY IN PHOTOVOLTAIC PLANTS CAUSED BY CLIPPING: EFFICIENCY COMPARISON BETWEEN BATTERY AND GREEN HYDROGEN STORAGE SOLUTIONS *Beatriz Souza Horn[1], Orlando Soares[2], Paulo Brito[3]* *[1] Polytechnic Institute of Bragança - IPB and Portalegre Polyth Polytechnic University - IPP; [2] Polytechnic Institute of Bragança - IPB; [3] Portalegre Polyth Polytechnic University - IPP*
271[E.I.12]	THERMAL AND CHEMICAL ANALYSIS OF TWO-STAGE THERMOCHEMICAL PROCESS BASED ON CeO2 IN SOLAR THERMOCHEMICAL REACTOR *Jasurjon Akhatov[1], Khushdil Akhmadov[1]* *[1] Physical-Technical Institute of the Academy of Sciences of Uzbekistan*
289[H.II.12]	THE ROLE OF WASTE HEAT RECOVERY IN ENHANCING POWER-TO-HYDROGEN AND POWER-TO-METHANE SYSTEMS *Malin Claudia Siegwart[1], Judit Tomás Verde[1], Curtis Meister[1], Jörg Worlitschek[1]* *[1] Lucerne University of Applied Sciences and Arts*
341[J.I.8]	EFFICIENT HEATING FOR HIGH ALTITUDE HOUSING IN PERU *Ajay Dalal[1], Walter Daniel Leon Salas[1], William Hutzel[1], Pedro Flores Larico[2], Miguel Angel Vizcardo Cornejo[2], Mauricio Postigo Malaga[2], Miguel Angel Ocharan Pichu[2]* *[1] Purdue University; [2] Universidad Nacional de San Agustin de Arequipa*
359[H.II.10]	SOLAR ENERGY FORECASTING USING NEURAL NETWORKS: INSIGHTS FROM REAL SYSTEMS IN THE AMAZON REGION *Maykon Silva Carvalho[1], Fábio de Lima Bezerra[1], Licinius Dimitri Sá de Alcantara[1]* *[1] Federal Rural University of Amazon*
490[I.II.8]	OPTIMIZATION OF GREEN HYDROGEN PRODUCTION IN AN ALKALINE ELECTROLYZER *Maria Gabriela Chagas de Oliveira[1], Caio Vinicius Pinheiro Vital[1], Luis Arturo Gómez Malagón[1]* *[1] Universidade de Pernambuco*
555[J.I.11]	SIZING AND PRELIMINARY EVALUATION OF THE DYNAMICS OF A PHOTOVOLTAIC SOLAR ENERGY GENERATION, CONDITIONING, AND STORAGE SUBSYSTEM DEDICATED TO GREEN HYDROGEN PRODUCTION *Pedro Henrique de Lima Gomes[1], Mario Genivan Aguiar Soares[2], Joao Pedro Melo Santos Martins[1], Vivian Carvalho de Araújo[1], Tobias Paixão Tavares[1], Vinícius de Carvalho Araújo[1], Gustavo Ellton de Oliveira Costa Teixeira[1], Daniel Silveira Serra[1], Carla Freitas de Andrade[2], Concepción Caravaca Moreno[3], Rita Ximena Valenzuela Balderrama[3], Mona Lisa Moura de Oliveira[1]* *[1] Universidade Estadual do Ceará; [2] Universidade Federal do Ceará; [3] Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas*

UTILIZATION OF EXCESS ENERGY IN PHOTOVOLTAIC PLANTS CAUSED BY CLIPPING: EFFICIENCY COMPARISON BETWEEN BATTERY AND GREEN HYDROGEN STORAGE SOLUTIONS

Summary

When sizing a photovoltaic plant, oversizing can increase the utilization of the generation curve. However, during peak production with high irradiance, clipping may occur, resulting in unused energy. This surplus energy poses challenges for energy trading plants, which are limited in injecting it into the grid at the same time as production. This study proposes using energy storage systems to later inject excess energy into the grid. A comparison of battery storage and green hydrogen storage is conducted, considering identical initial conditions and respective process losses. The objective is to analyze energy utilization over a 25-year lifespan for both systems, considering scenarios with and without storage replacement. The results of this study, which only compares the energy efficiency ratio, highlight a greater stored energy for the battery system and a trend with more attenuated variations for the green hydrogen system.

Keywords: Photovoltaic Plant, Energy Storage, Battery Storage, Green Hydrogen, Energy Efficiency

1. Introduction

Photovoltaic plants can be oversized to maximize energy production, but high irradiance leads to energy loss (clipping) when inverters can't convert all DC (Continuous Current) to AC (Alternating Current). To mitigate this, energy storage solutions, like batteries and green hydrogen, are used to store excess energy for later use.

For the battery option, lithium-ion batteries were chosen for presenting higher energy density, greater efficiency and longer life cycle, compared to lead acid batteries and other technologies. Currently, a viable option for photovoltaic plants is the BESS (Battery Energy Storage System).

For hydrogen storage option, the production of green hydrogen through local electrolyzer in the photovoltaic plant was chosen. As for the return of the final energy, the coupling of a fuel cell was chosen after the compression and storage of the hydrogen produced by the electrolyzer.

This study compares the efficiency of these two energy storage solutions, as options to reduce clipping losses.

2. Sizing of the photovoltaic plant and energy for storage

For this study, a 300 MWp photovoltaic plant was used, with a 1.3 DC to AC power ratio, resulting in 230 MW of transformed power and an average of 30% clipping. After accounting for climatic and operational losses, only 5% of the installed power is available for storage. This means approximately 15 MW of unused power per hour, or 90 MWh per day, can be stored. The study assumes 90 days of clipping per year, mostly during the summer, when solar irradiance is higher. Based on the dimensioned photovoltaic plant and efficiency characteristics of each storage system, the assumptions used can be summarized in the following Tab. 1.

Tab. 1: Assumptions Considered

Attribute	Battery	Green Hydrogen	References

Initial Energy Stored per Day (MWh)	90	90	(Leonardo Micheli et al., 2024; Juan Manuel Guerrero-Calero et al, 2023).
Clipping Days per Year	90	90	(João Souza, 2019)
Initial Energy Stored per Year (MWh)	8100	8100	(João Souza, 2019)
Charge and Discharge Efficiency (%)	90%	43%	(Canadian Solar, 2021; Seddiq Sebbahi et al, 2022; Thyssenkrupp Nucera, 2022; Ender Ozden, Ilker Tari, 2017)
Annual Efficiency Year 1 (%)	95.00%	98.68%	Canadian Solar, 2021; Ender Ozden, Ilker Tari, 2017)
Annual Efficiency Year 2 to 20 (%)	97.00%	98.68%	Canadian Solar, 2021; Ender Ozden, Ilker Tari, 2017)
Annual Efficiency Year 21 to 25 (%)	94.00%	98.68%	(Canadian Solar, 2021; Ender Ozden, Ilker Tari, 2017)

3. Results

For the analysis of the results, two scenarios were considered. The first scenario does not consider replacement of the storage system. And the second scenario considering only one replacement to replace all equipment, in the thirteenth year of operation of the plant, depicting possible maintenance decisions. In this last scenario, the efficiencies are considered as the start of operation of the system.

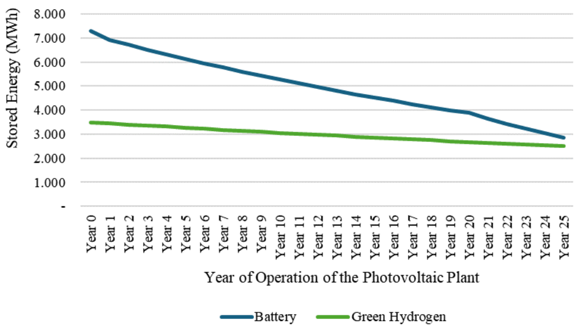

Fig. 1: Comparison of results without system replacement

In the first scenario (Fig. 1), the green hydrogen storage system initially stores about half the energy of the battery system due to its lower efficiency (43%) compared to the battery system (90%) after charging and discharging. This inefficiency is a result of the multiple transformations involved in the hydrogen process, leading to higher losses. The battery system's self-discharge rate also impacts its energy curve, causing a significant decrease in stored energy over time. By year 25, the battery system retains 39% of its initial energy, while the green hydrogen system retains 72%. Despite the initial difference, the battery system still has more stored energy at year 25, but the energy values of both systems converge over time, with their performance curves becoming more similar as the years progress.

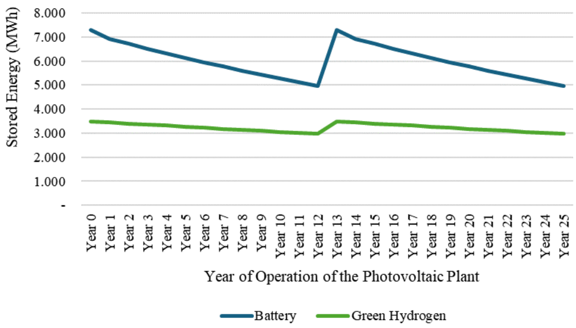

Fig. 2: Comparison of results with system replacement

In the second scenario (Fig. 2), where system replacements are considered, the battery storage system shows a more significant increase in efficiency and stored energy compared to the green hydrogen system, which experiences a more gradual improvement. By year 25, the battery system reaches an efficiency of 68%, up from 39%, while the green hydrogen system increases to 85%, up from 72%. Despite the battery system storing more energy annually throughout the 25 years, the green hydrogen system experiences a smaller efficiency drop by the end of the period. This analysis highlights the greater efficiency gain for the battery system with replacements, while the green hydrogen system shows more stable long-term performance.

The summary of the results can be seen in the Tab. 2 below.

Tab. 2: Results

Attribute	Battery	Green Hydrogen
Initial Energy Stored per Day (MWh)	90	90
Final Energy Stored per Day (MWh)	83.7	38.8
Daily Charge and Discharge Efficiency (%)	90%	43%
Initial Energy Stored in Year 0 (MWh)	7290	3492
Efficiency in 25 years without replacement (%)	39%	72%
Efficiency in 25 years with replacement (%)	68%	85%

4. Conclusion

The study concluded that battery storage is currently more efficient than green hydrogen, due to fewer transformations and lower losses. Batteries offer solid technology and wide applicability, while green hydrogen provides long-term storage, a longer lifespan, and the potential for by-products like oxygen and hydrogen for sale. If green hydrogen technology advances and losses decrease, it may surpass battery efficiency after a certain period.

The choice between battery and green hydrogen storage will depend on factors such as the photovoltaic plant's capacity, surplus energy, technologies, initial investments (CAPEX), operational expenses (OPEX), and expected operational time.

5. References

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