Proceedings of the 2nd GCC International Conference on Industrial Engineering and Operations Management Muscat, Oman, December 1-3, 2024

Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/GC02.20240115
Published: December 01, 2024

Mitigating Negative Impacts of Renewable Energy Farms in Oman: A Comprehensive Analysis and Solutions Through Advanced Storage Systems

Navid Nasiri
Electrical and Computer Engineering Department
Sultan Qaboos University
Muscat, Sultanate of Oman
nnerpr@gmail.com

Morteza Mohammadzaheri
Engineering Department
German University of Technology in Oman
Muscat, Sultanate of Oman
morteza.zaheri@gutech.edu.om

Intisar Al-Buasaidi
College of Engineering and Technology
University of Technology and Applied Sciences
Muscat, Oman
intisar.albusaidi@utas.edu.om

Hooman Nasiri
Head of the Department of Economics and Customs
Islamic Azad University, Bushehr
Bushehr, Iran
Hoomannasiri@gmail.com

Maryam Farrizi
Electrical and Computer Engineering Department
Sultan Qaboos University
Muscat, Sultanate of Oman
maryamfarrizi@gmail.com

Akbar Karimi
Assistant Prof., Civil & Environmental Engineering Department, College of Engineering
National University of Science and Technology
Muscat, Oman
akbarkarimi@nu.edu.om

Abstract

Oman is strategically enhancing its renewable energy landscape, particularly through solar and wind energy initiatives. While these efforts contribute significantly to reducing greenhouse gas emissions and diversifying the energy mix, they also induce challenges related to fluctuations in electricity generation. This paper focuses on two types of fluctuations affecting the electricity grid: the slow, manageable changes and the rapid, unpredictable shifts primarily caused by solar energy generation disruptions, such as transient shadows. We conduct an in-depth analysis of renewable energy farms in Oman, assessing their impacts and the challenges they present. Furthermore, we explore innovative solutions to mitigate these rapid fluctuations, specifically through the use of advanced energy storage systems, including hydrogen storage and generators, as well as gravitricity and loop water dams. By proposing an Integrated Model and a Framework for Integration, this study underscores the potential of these technologies to stabilize the grid while enhancing energy reliability and sustainability. Ultimately, our findings provide actionable insights for policymakers, energy developers, and researchers seeking effective strategies for a resilient, low-carbon energy future.

Keywords
Renewable Energy, Solar Power, Wind Energy, Hydrogen Production, Energy Storage Systems, Gravitricity, Intermittency, Grid Stability, Oman 2050, Sustainable Development

1. Introduction
Oman has been making significant strides in the development of renewable energy sources, particularly solar and wind energy. The country benefits from abundant sunlight, with an average of over 3,000 hours of sunshine per year, making it an ideal location for solar power projects (Amoatey, Al-Nadabi, Chen, & Izady, 2024). In recent years, the government has initiated several large-scale solar farms (Study on Renewable Energy Resources, Oman, 2008). This facility not only contributes significantly to the national grid but also serves as a model for sustainable energy practices in the region. Additionally, wind energy has gained traction, with several wind farms being developed along the coastal areas, where wind speeds are optimal for energy generation.

The aforementioned initiatives are a part of a broader strategy aimed at reducing reliance on fossil fuels and promoting renewable energy sources. The integration of solar and wind energy not only contributes to a decrease in greenhouse gas emissions but also enhances energy security by diversifying the energy mix. Furthermore, local communities are increasingly engaged in these projects, benefiting from job creation and economic development opportunities (Study on Renewable Energy Resources, Oman, 2008). Educational programs are being implemented to raise awareness about the importance of renewable energy, fostering a culture of sustainability and encouraging the next generation to pursue careers in this vital sector (Hassan, MCREEE, 2024).

Besides numerous benefits, renewable energy farms may also present challenges, such as noise pollution and uncertainties associated with grid stability (Olabi, et al., 2023). These challenges can lead to community resistance and require careful planning and management to mitigate their impact. Additionally, the intermittent nature of sources like solar and wind energy necessitates advancements in energy storage technologies and grid infrastructure to ensure a reliable power supply. Policymakers and energy developers must work collaboratively to address these issues, promoting public awareness and engagement to foster acceptance. Furthermore, integrating renewable energy into existing systems may require significant upgrades to grid infrastructure, including the development of smart grid technologies that can manage the variability of renewable sources (Khalid, 2024). The integration of smart grid technology, along with energy storage systems characterized by rapid response times, is essential for ensuring a reliable and stable electrical grid.

This study investigates energy storage systems and their impact on grid quality in Oman. It provides a comprehensive overview of renewable energy farms in the country, detailing existing projects, ongoing construction initiatives, and their respective energy generation capacities. The analysis then addresses the challenges associated with these renewable energy farms, particularly focusing on intermittency and reliability issues, environmental impacts, economic considerations, and strains on infrastructure. Potential solutions are proposed, emphasizing the use of advanced energy storage systems, such as hydrogen storage and generators, alongside technologies like gravitricity and loop water dams. Additionally, a comparative analysis of these approaches will be conducted. Following this, an Integrated Model will be introduced, accompanied by a Framework for Integration and anticipated outcomes. The Integrated Model aims to synthesize existing theories and methodologies, offering a holistic approach to the identified challenges within Oman’s renewable energy sector.

2. Literature Review, Overview of Renewable Energy Farms in Oman

Solar farms utilize photovoltaic panels to convert sunlight into electricity, while wind farms harness the kinetic energy of wind through turbines.

In recent years, advancements in technology have led to increased efficiency and lower costs for both solar and wind energy systems (Amoatey, Al-Nadabi, Chen, & Izady, 2024). Additionally, many governments and organizations are investing in renewable energy infrastructure, recognizing its potential to create jobs and stimulate economic growth (Sarker, Islam, Paul, & Ghosh, 2018). Oman, as a forward-looking nation, is among the countries that make substantial investments in this domain. There are several projects already running in Oman and injecting to the grid, like Dhofar Wind Power Project and Sohar Solar Power Plant. These initiatives are part of Oman's broader strategy to diversify its energy sources and reduce reliance on fossil fuels. The government aims to increase the share of renewable energy in its total energy mix to 30% by 2030 (Hassan, MCREEE, 2024). Figure 1 depicts the power generation capacity of wind and solar farms in Oman over the specified years (Hassan, MCREEE, 2024).

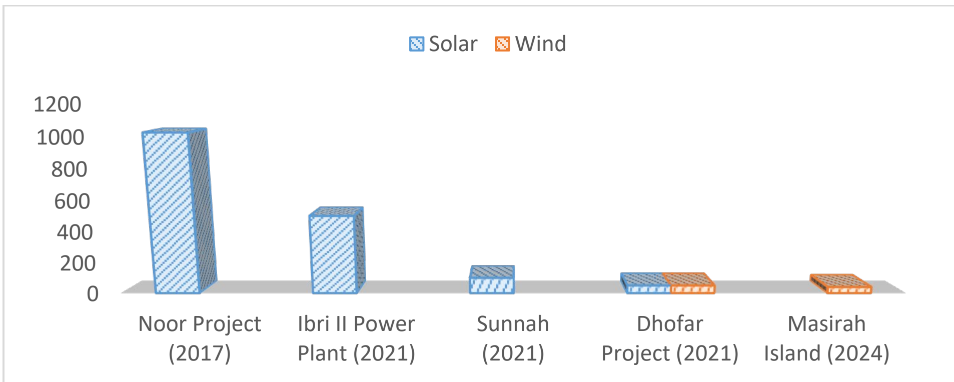

Figure 1. Renewables Power Plants in Oman (MW)

The government of Oman has initiated programs aimed at promoting energy efficiency and conservation across consumer and industrial sectors. These initiatives include providing incentives for adopting renewable energy technologies and retrofitting existing infrastructures to lower energy consumption. Notably, Table 1 outlines four significant renewable energy projects in Oman, highlighting their types, timelines, and capital investments. These actions underscore Oman's commitment to diversifying its energy portfolio in alignment with the global shift towards sustainable energy production, ultimately seeking to reduce dependence on fossil fuels, enhance energy security, and mitigate climate change effects (Study on Renewable Energy Resources, Oman, 2008).

Table 1. Key Future Renewable Energy Projects in Oman

	Project	**Type**	**Start Date**	**Estimated End Date**	**Estimated Capital**
1	Sohar Green Hydrogen Project	Green Hydrogen Production	2024	2026	$1.3 billion
	Description: This project aims to produce green hydrogen using renewable energy resources, particularly solar and wind.				
2	Dhofar Wind Farm Expansion	Wind Energy Expansion	2023	2025	$300 million
	Description: The expansion of the existing Dhofar Wind Farm, enhancing its capacity and contribution to the national grid.				
3	Oman National Energy Strategy 2040	Policy and Infrastructure Development	2021	2040	$20 billion
	Description: This comprehensive strategy aims to increase the share of renewables in Oman's energy mix to 30% by 2030 and 70% by 2040. It encompasses several projects in solar, wind, and other renewable sources.				
4	Salalah Solar Project	Solar Energy Plant	2025	2027	$500 million
	Description: A large-scale solar power plant aimed at boosting the capacity of renewable energies in the Dhofar region.				

The capital required for launching renewable energy projects varies greatly and is influenced by multiple factors. Securing financing, attracting both domestic and international investments, and fostering public-private partnerships are pivotal for drawing the necessary capital. Additionally, technological advancements and the recruitment of skilled personnel can significantly affect project costs and efficiency. A decline in the costs of solar panels, wind turbines, and energy storage solutions can further expedite the transition to renewable energy. The payback period for these projects typically ranges from 5 to 10 years, depending on investment scale, initial costs, electricity output, equipment quality, and maintenance (Amoatey, Al-Nadabi, Chen, & Izady, 2024).

Supportive government policies, accompanied by systematic oversight, are crucial for the success of these initiatives. Such policies could encompass tax exemptions, grants, guaranteed purchases of generated electricity, and other incentives to attract investments. The estimated capital and timelines for these projects may change due to various influences, including funding availability, technological advancements, and government regulations. For the most current information, monitoring updates from Oman's Ministry of Energy and Minerals or relevant stakeholders in the renewable energy sector is advisable (Study on Renewable Energy Resources, Oman, 2008).

3. Negative Impacts of Renewable Energy Farms

One of the most significant challenges associated with renewable energy farms is the uncertainty in power production, particularly concerning **intermittency and reliability**. This necessitates a thorough examination of supply variability and its effects on the electrical grid. The inherent variability of inputs, such as solar radiation and wind speed, can lead to substantial fluctuations in output under specific conditions (Gopinath, 2018).

Below is an example of a hypothetical dataset that represents electricity generation in kW from a solar power plant over a specific period of 80 sec (Figure 2). This dataset reflects a relatively constant output disrupted by a significant drop due to a cloud cover (Hannah C. Bloomfield, 2022).

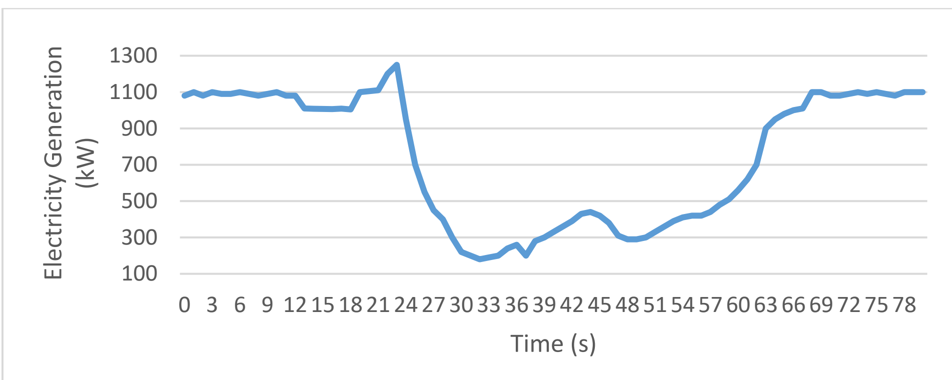

Figure 2. Hypothetical Data for a 1100 kW Solar Power Generation

The solar power generation data reflects key phases of production and fluctuation over time. Initially, a **Baseline Generation** is maintained around 1080-1100 kW. By the 13th second, a **Significant Drop** is observed, with power decreasing sharply to a low of 200 kW by the 32nd second, indicating potential shading or equipment issues. This is followed by a **Recovery Phase**, where output gradually rises again, reaching around 1100 kW by the 68th second, indicating system stabilization and return to full capacity. Fluctuations within this range suggest minor changes in solar irradiance, typical of a dynamic environmental setup (Hannah C. Bloomfield, 2022) (Mansouri, et al., 2016).
Here's an additional hypothetical dataset that showcases a solar power plant's electricity generation in kW over a specific time period (Ahshan, Nasiri, Al-Badi, & Hosseinzadeh, 2020). This dataset again illustrates a stable generation profile that is disrupted by a sudden decrease due to weather effects.

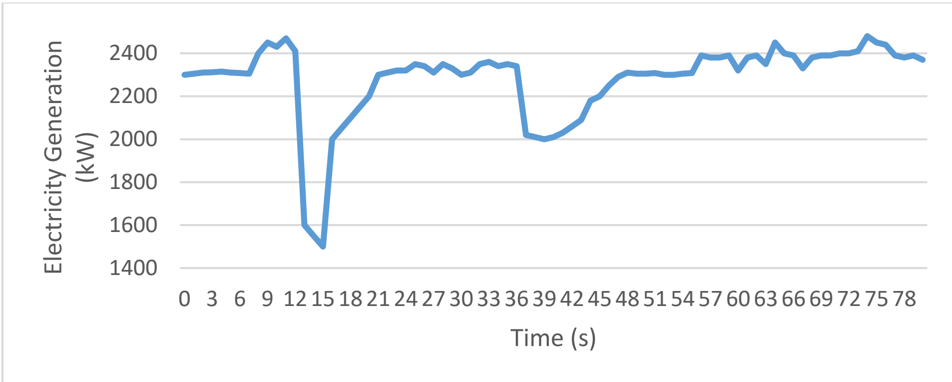

Figure 3. Hypothetical Data for a 2300 kW Solar Power Generation

Figure 3 illustrates hypothetical solar power generation over a span of 80 seconds, showing distinct phases. Initially, the **Baseline Generation** begins at 2300 kW, with steady increases up to 2450 kW by 9 seconds. Following this, a **Significant Drop** occurs between 13 and 15 seconds, with output dipping to 1500 kW, likely due to transient fluctuations in solar intensity or temporary shading. The **Recovery Phase** then starts around 16 seconds as output rebounds and reaches 2300 kW by 21 seconds. Over the remaining period, there are minor variations, with occasional spikes and dips, before stabilizing near 2400 kW at the 80-second mark, indicating a return to regular generation levels. This sequence highlights the variability in solar output due to environmental factors, which is crucial for understanding the dynamics of solar power systems (Hossein Salimi, 2020). This pattern indicates variability in output, possibly due to changes in wind conditions or operational factors, with recovery mechanisms that return generation levels to a stable state (Omid Alavi, 2016).

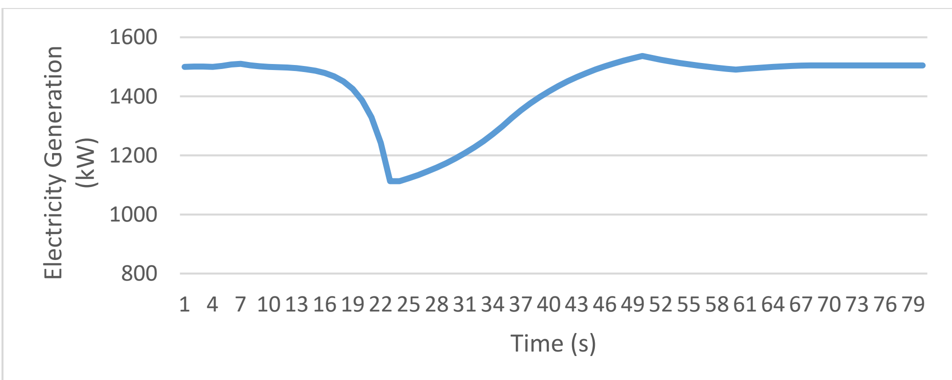

Figure 4. Hypothetical Data for Wind Farm Generation (kW)

This variability can lead to difficulties in integrating renewable energy sources into the existing power grid (Figure 4), which was primarily designed for stable, predictable energy sources like fossil fuels. Consequently, simplistic solutions such as forecasting techniques and slow-responding energy storage systems are inadequate for effectively managing these fluctuations. Furthermore, the integration of smart grid technologies, which facilitate improved communication between energy producers and consumers, does not adequately address this issue. Consequently, investments in advanced storage solutions, particularly in battery technologies, are essential and will be discussed in detail.

4. Potential Solutions

Advanced storage solutions are designed not only to improve the efficiency of energy storage but also to facilitate the effective integration of renewable energy sources into the grid. A comprehensive list of energy storage systems is presented to address this issue:

4.1 Hydrogen Production

Hydrogen production has garnered considerable attention in recent years, primarily due to the global imperative for cleaner energy sources and the pressing necessity to mitigate greenhouse gas emissions. Following its generation, hydrogen can be effectively stored and utilized in electric power generation systems. These systems can convert hydrogen back into electricity through fuel cells, which emit only water vapor as a byproduct, making them an environmentally friendly alternative to traditional fossil fuel-based power generation (Safari, Roy, & Assadi, 2021). The hydrogen generator can initiate power generation and achieve nominal voltage and power levels in a matter of minutes. This rapid startup capability is crucial for applications requiring immediate energy supply, such as backup power systems and remote installations. A hypothetical dataset is presented below, illustrating the output power of a hydrogen generator as it approaches its nominal output power over a defined time interval. This scenario highlights the generator's response time and performance dynamics during the startup phase, demonstrating the distinct operational phases involved (Pavlos & Poullikkas, 2017).

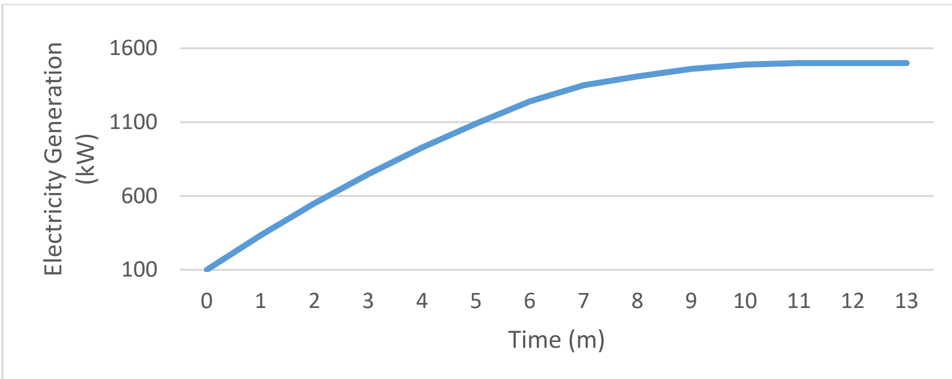

Figure 5. Hypothetical Data fora 1500 kW Hydrogen Generator Output

During the startup phase (Figure 5), the generator initially produces 0 kW, with output power gradually increasing over the first few minutes. A rapid ramp-up follows, where the output climbs from 0 kW to 600 kW within two minutes, reflecting a swift increase in power capability. By the tenth minute, the generator reaches its nominal output of 1500 kW, marking a successful transition to full operational status. From minute 10 to minute 13, the generator sustains this nominal output, indicating stable and reliable performance throughout the steady-state phase (Manas Mandal, 2018) (Perez, 2020).

4.2 Loop Water Dams

Loop Water Dams is another Advanced Energy Storage System that utilizes the gravitational potential energy of water to store and release energy. This system operates by pumping water to a higher elevation during periods of low energy demand, effectively converting electrical energy into gravitational energy. When energy demand increases, the stored water is released, flowing back down through turbines to generate electricity. This method not only provides a reliable and efficient means of energy storage but also helps to stabilize the grid by balancing supply and demand. Loop water dam technology, which employs a closed-loop system to reduce water loss and mitigate environmental impact, has garnered significant attention for its efficacy in regulating water flow and generating hydroelectric power.

This innovative approach can be implemented in two distinct configurations: as an online supply generator or as a storage solution for supplementary supply systems. The storage solution is the use of extra electrical energy to pump and store water at a high-level reservoir. Water of this reservoir will then be released during peak demand times and its potential energy is converted to electrical energy to ensure a steady supply of electrical power. This system can mitigate the effects of climate variability by providing a buffer against droughts and floods. The natural flow of water can be harnessed too, within this system. This contributes to a more sustainable energy landscape.

In this system, the time required to achieve the nominal output power generation typically ranges from several seconds to a few minutes (Dai, Xiao, Shokooh, Schaeffer, & Benge, 2004). This duration is influenced by several factors, including water flow rates, reservoir capacity, and operational efficiency. Additionally, environmental conditions such as temperature and humidity can also play a significant role in the system's performance. For instance, higher temperatures may reduce the efficiency of the water damp system, leading to longer stabilization periods. The Figure 6 illustrates the initial phase of a water dam generator as it approaches its nominal operating point. The figure depicts the output power (in kW) versus time (in minutes) during the startup phase.

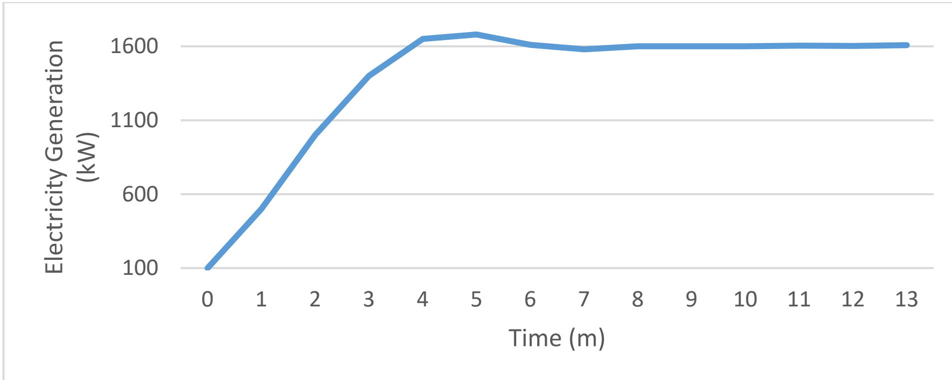

Figure 6. Output Power of a 1600 kW Hydro Generator

The generator starts at 0 kW as the dam reservoir releases water into the turbines, initiating the startup phase. In the rapid ramp-up that follows, the output power quickly rises to 500 kW within the first minute and continues to grow as water flow increases. In approximately 4 minutes, the system reaches an output of 1600 kW, its nominal capacity (Dai, Xiao, Shokooh, Schaeffer, & Benge, 2004).

4.3 Gravitricity

Examination of Gravitricity technology and its potential applications reveals a promising avenue for energy storage and management. Gravitricity utilities the gravitational potential energy of heavy weights, which are raised and lowered in a vertical shaft to generate electricity. This method offers a sustainable solution for balancing supply and demand in power grids, particularly with the increasing reliance on intermittent renewable energy sources such as wind and solar power (Hindocha & Shah, 2020). By storing energy during periods of low demand and releasing it during peak usage times, gravitational energy storage systems can help stabilize the grid and reduce the need for fossil fuel-based power plants. The initiation of the nominal point period in these systems is significantly shorter than that observed in other methods, often occurring in less than a minute. This rapid response capability allows for a more flexible integration of renewable energy sources, such as wind and solar, which can be intermittent in nature. By quickly adjusting to fluctuations in energy demand, gravitational energy storage systems enhance grid reliability and resilience.

Figure 7 shows the schematic representation of a gravitational energy storage system, illustrating how potential energy is stored and released. This system typically involves lifting heavy weights to store energy and lowering them to generate electricity when needed. The efficiency of this method is further improved by incorporating advanced control systems that optimize the lifting and lowering processes.

Here is a schematic representation of a gravitational energy storage system illustrating the process of energy storage and release. This diagram captures the fundamental components and operational dynamics of the system.

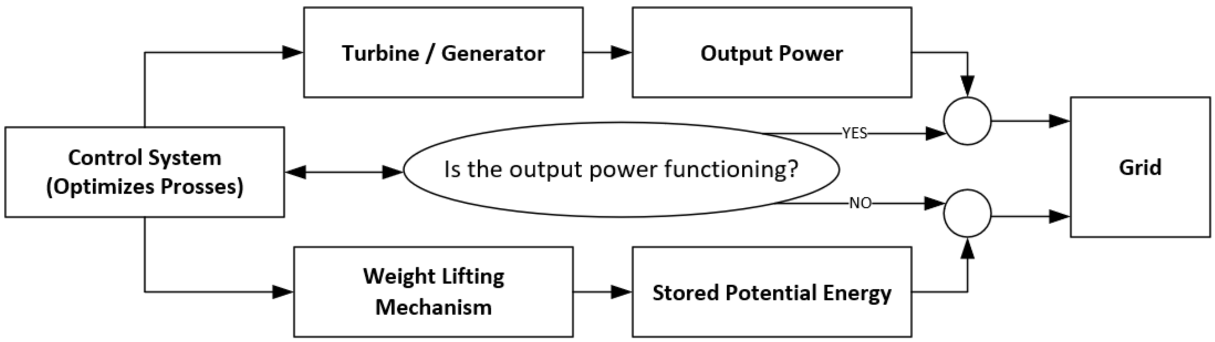

Figure 7. Energy cycle

The energy storage system consists of several key components, each playing a critical role in its operation. The **Control System** optimizes the lifting and lowering of weights, ensuring efficiency during both energy storage and release phases. The **Weight Lifting Mechanism** elevates heavy weights to store potential energy, with the height of the lift directly correlating with the amount of stored energy. Once elevated, this **Stored Potential Energy** can be converted back into electrical energy during release. The **Turbine/Generator** is responsible for this conversion, using gravitational energy to produce electricity as the weights descend. Finally, **Power Output** represents the electrical energy generated, which can be distributed to the grid or used locally.

The system operates through distinct phases: in the **Storage Phase**, weights are lifted, converting electrical energy into potential energy. During the **Release Phase**, weights are allowed to descend, driving the turbine to generate electricity. Efficiency is enhanced by advanced control systems, which minimize energy losses and improve the system's responsiveness to shifts in energy demand (Kucur, Tur, Bayindir, Shahinzadeh, & Gharehpetian, 2022).

This schematic provides a comprehensive overview of how gravitational energy storage systems function, detailing both the mechanical aspects and the role of control systems in enhancing efficiency. Figure 8, shows the initial phase of a graviricity system, approaching to its nominal output power during the discharge phase. The figure presents the output power (in kW) versus time (in minutes), highlighting the ramp-up in generation as the system stabilizes.

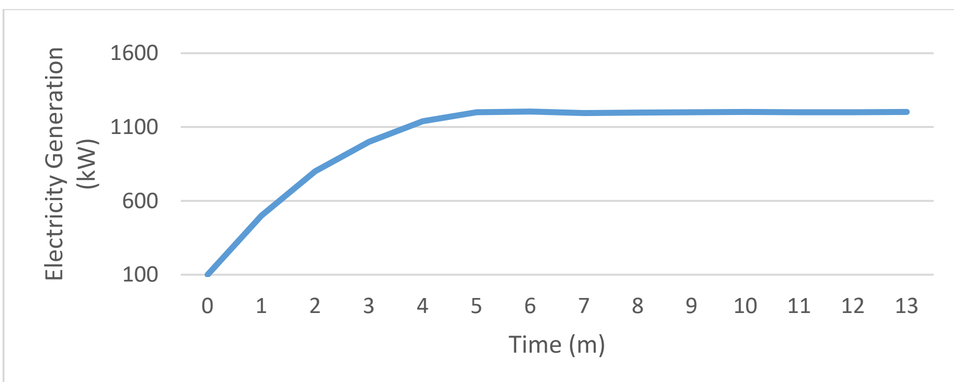

Figure 8. Output Power of Gravitiricity

The initial generated power is 0 kW, where initially stored kinetic energy is released. During the **Startup Phase**, power output quickly rises due to gravitational potential energy conversion, reaching 500 kW within the first minute. This **Rapid Ramp-Up** phase demonstrates efficient energy conversion techniques. By the **Nominal Output Achievement** phase at four minutes, the system reaches and stabilizes at 1200 kW, indicating operational stability and effective use of gravitational potential energy. (Anisa Emrani, 2022)

4.4 Comparative Analysis:

This section will compare the three systems based on the period from the initial generation point to the nominal generation point. The analysis will focus on key performance indicators such as efficiency, output stability, and response time. By examining these metrics, we can identify the strengths and weaknesses of each system in terms of their operational capabilities. The least efficient method is water dam generators, which require approximately one minute to achieve nominal output levels. This is followed by hydrogen generators, which can reach nominal output within a similar timeframe. The most efficient system is graviticity.

5. Results and Discussion

Moreover, the comparative analysis of the three energy storage systems (gravitricity, hydrogen production, and loop water dams) indicates that gravitic systems exhibit the highest efficiency and quickest response times, making them particularly well-suited for addressing instantaneous demand fluctuations. Hydrogen generators also demonstrate notable efficiencies but may require more time to stabilize compared to gravitricity. In contrast, loop water dam systems, while effective, are less responsive and may introduce delays in meeting peak demand.

The inherent variability of solar and wind electricity production—affected by cloud cover, atmospheric conditions, and transient shading—poses significant challenges for grid stability, necessitating effective energy storage solutions. The current study demonstrates that neither gravitricity nor hydrogen generation nor water dams alone can sufficiently mitigate abrupt cessations in energy output from both wind and solar farms. Although these advanced storage methods offer valuable means of energy management, their response times may be insufficient during periods of rapid fluctuations in generation.

Thus, the investigation of advanced battery systems and pumped hydro storage presents a promising opportunity. These technologies can effectively capture excess energy produced during peak sunlight hours and discharge it during periods of low generation. The findings suggest that while large battery systems may struggle to address sudden rapid drops in power supply, integrating online uninterruptible power supplies could provide a viable solution.

This study emphasizes the urgent need for continuous development and integration of advanced energy storage technologies to support the transition to a low-carbon energy future. The interdependencies of these systems call for interdisciplinary approaches that consider technological, economic, and environmental implications to achieve a balanced renewable energy mix in Oman.

6. Future Works

Future research should:

- Prioritize comprehensive mathematical modeling of energy generation and storage systems in Oman to facilitate simulation of various operational scenarios.
- Incorporate online storage-generator systems into modeling to examine operational efficiency, mechanical dynamics, electrical characteristics, and economic implications.
- Analyze the interplay between different systems to optimize integration strategies and enhance grid performance.

References

Ahshan, R., Nasiri, N., Al-Badi, A., & Hosseinzadeh, N., Control and dynamic analysis of an isolated microgrid system: A case study. *6th IEEE International Energy Conference (ENERGYCon)* (pp. 254-259). 2020. IEEE.

Amoatey, P., Al-Nadabi, A., Chen, M., & Izady, A., Transition to Sustainable Hydrogen Energy in Oman: Implication for Socio-Economic Transformation and Environmental Well-being. *Environment, Development and Sustainability*.2024.

Anisa Emrani, A. B., Assessment of the round-trip efficiency of gravity energy storage system: Analytical and numerical analysis of energy loss mechanisms. *Journal of Energy Storage*.2022.

Dai, J., Xiao, D., Shokooh, F., Schaeffer, C., & Benge, A., Emergency generator startup study of a hydro turbine unit for a nuclear generation facility. *IEEE Transactions on Industry Applications*, 1191-1199, 2014.

Gopinath, A. S., Feasibility Analysis of Solar Powered Power plant in Sultanate of Oman. *International Journal of Engineering Research & Technology (IJERT)*, 1-5, 2018.

Hannah C. Bloomfield, C. M., Characterizing the variability and meteorological drivers of wind power and solar power generation over Africa. *Meteorological Applications*.2022.

Hassan, H., *MCREEE*. Retrieved from Oman's Solar Power Landscape: A Closer Look at the Manah I Project, 2024. https://www.mcreee.org/19038/

Hassan, H, *MCREEE*. Retrieved from Oman's Knowledge Oasis Embraces Solar Power, 2024. https://www.mcreee.org/19022/

Hindocha, K., & Shah, S., Design of 50 MW Grid Connected Solar Power Plant. *International Journal of Engineering Research and Technology, 9*(4), 885-897, 2020.

Hossein Salimi, H. A. , Experimental analysis and modeling of weather condition effects on photovoltaic systems' performance: Tehran case study. *ENERGY SOURCES, PART A: RECOVERY, UTILIZATION, AND ENVIRONMENTAL EFFECTS*, 1-13, 2020.

Khalid, M., Smart grids and renewable energy systems: Perspectives and grid integration challenges. *Energy Strategy Reviews*.2024.

Kucur, G., Tur, M. R., Bayindir, R., Shahinzadeh, H., & Gharehpetian, G. B., A Review of Emerging Cutting-Edge Energy Storage Technologies for Smart Grids Purposes. *Iranian Conference on Renewable Energy and Distributed Generation (ICREDG)*. IEEE Xplore, 2022.

Manas Mandal, A. V., Analysis of Inkjet Printed Catalyst Coated Membranes for Polymer Electrolyte Electrolyzers. *Journal of The Electrochemical Society*, 543-552, 2018.

Mansouri, E., Pirsalami, M., Nasiri, N., Farrizi, M., Hashemizadeh, M., & Alihosseini, H., Optimum tilt angle for fixed-array solar panels at a constant latitude of 29 to receive the maximum sunlight. *Bulletin of Environment, Pharmacology and Life Sciences*, 30-39, 2016.

Olabi, A., Elsaid, K., Obaideen, K., Abdelkareem, M. A., Rezk, H., Wilberforce, T., . . . Sayed, E. T., Renewable energy systems: Comparisons, challenges and barriers, sustainability indicators, and the contribution to UN sustainable development goals. *International Journal of Thermofluids*, 2023.

Omid Alavi, A. S., Sensitivity analysis of different wind speed distribution models with actual and truncated wind data: A case study for Kerman, Iran. *Energy Conversion and Management*, 51-61, 2016.

Pavlos, N., & Poullikkas, A., A comparative overview of hydrogen production processes. *Renewable and sustainable energy reviews*, 597-611, 2017.

Perez, R. , *Analysis of the Levelized Cost of Green Hydrogen Production for Very Heavy Vehicles in New Zealand.* Victoria University ofW ellington, Wellington, New Zealand: Master Theses.2020.

Safari, A., Roy, J., & Assadi, M., Petroleum Sector-Driven Roadmap for Future Hydrogen Economy. *Applied Sciences*, 11-21, 2021.

Sarker, P., Islam, M., Paul, A., & Ghosh, S., Solar Photovoltaic Power Plants: Necessity and Techno-Economical Development. *Renewable Energy and the Environment*, 41-69, 2018.

Biographies

Navid Nasiri is a PhD candidate in Electronics at Sultan Qaboos University, specializing in advanced electronics systems. With a Master's degree in Electronics from Sepidan Islamic Azad University, where he focused on the telemetry of methane using carbon dioxide lasers, Navid has cultivated a strong foundation in renewable energy solutions, solar energy systems, and robotics. His research encompasses innovative projects like oil spill detection using UAVs, microgrid inverter design, and water harvesting technologies. He has contributed extensively to academia through multiple publications in high-impact journals and is co-authoring a book chapter on AI and robotics applications in the oil and gas industry. In addition to his academic achievements, Navid has held leadership roles in green energy companies, focusing on solar and biomedical engineering projects. His work bridges the gap between academia and industry, driving innovations that address real-world energy challenges while advancing academic research in the field of electronics.

Morteza Mohammadzaheri received his PhD in Intelligent Control Systems from the school of Mechanical Engineering, University of Adelaide, Australia, in March 2011. Then, he served almost 3.5 years as a postdoctoral fellow and 10 years as a faculty member in Mechatronics and Mechanical Engineering. He is currently an Associate Professor in Mechanical Engineering at German University of Technology in Oman. He is also a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE). Dr Mohammadzaheri has 139 peer reviewed publications mostly in engineering application of artificial intelligence and control; he has also secured 17 grants to develop or present his research in 6 different countries and supervised/ co-supervised 74 PhD/ MPhil/ Masters/ Final Year projects towards completions.

Intisar Al Busaidi is an experienced research engineer and lecturer specializing in enhanced oil recovery (EOR). She holds a Ph.D. in Petroleum Engineering and a Master's in Petroleum and Natural Gas Engineering from Sultan Qaboos

University, along with a Bachelor's in Applied Chemistry. Her research focuses on polymer-enhanced oil recovery, and she has significant experience in conducting and analyzing advanced laboratory experiments.

Intisar has presented her research at international conferences and has been recognized for her contributions to the field. Notably, she won first place in the Ph.D. division of the student paper contest at the SPE Middle East, North Africa, and South Asia region. She has also been involved in several high-profile hydrogen energy projects and symposiums.

Dr. Hooman Nasiri is an Assistant Professor of Economics at the Islamic Azad University, Bushehr Branch. He was born on February 6, 1980, and is fluent in English. He obtained his Ph.D. in International Economics from the Islamic Azad University, Shiraz Branch, in 2020. Since then, he has been actively teaching and conducting research in his field. His areas of expertise include economic modeling and international trade, with a particular focus on the economic stability of Iran's industrial sector. He has been a faculty member at the Islamic Azad University, Bushehr Branch, since 2007, where he also serves as the Head of the Department of Economics and Customs. He has published several research papers in reputable journals, with his work exploring topics such as the impact of industrial export diversification on revenue stability and the use of composite leading indicators to forecast business cycles. Dr. Hooman has co-authored with various researchers and contributed to both national and international publications, showcasing his ongoing commitment to advancing knowledge in the field of economics.

Maryam Farrizi is an accomplished electronics engineer with expertise in project management and innovative design, particularly within renewable energy and electronic systems. She holds an M.Eng. in Electronic Engineering from Islamic Azad University of Sepidan, where her research focused on solar-based cooling systems. With over a decade of experience in R&D, Maryam has led significant projects in inverter design and solar power systems across multiple roles, including her current position as a Research Assistant at Sultan Qaboos University. She has published numerous articles and contributed to various international conferences, establishing herself as a knowledgeable figure in sustainable energy. Beyond her technical skills, Maryam has a creative side, actively participating in activities like swimming, dancing, and singing. She has recorded four music clips and maintains a presence on social media. Skilled in tools like MATLAB and Proteus, she brings a hands-on approach to her work, complemented by her background in training and teaching in robotics and solar energy system design.

Dr. Akbar Karimi is the graduate of Civil Engineering from Shiraz University in 2001. He has MSc in water resources engineering from Sharif University of Technology and Ph.D. in water resources from the same university. He has worked as faculty member of IAU-east Tehran branch and Visiting Professor in Sharif University – Kish Island Campus till 2013. In 2013 he continued his research work in SQU with the College of agriculture and marine sciences. In September 2014 he joined the Caledonian College of Engineering that later became a part of the NU. He has published more than 50 research papers in different journal papers and conferences.