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A Comprehensive Overview of Sri Lanka's Pumped Hydro Storage Potentials

*Erabadupitiya H.R.S.M ,Pemarathana H.I.M , Wijerathne W.H.M.L.G, Hitige H.A.S

Faculty of Technology, University of Sri Jayewardenepura

*sasanga.erabadupitiya@gmail.com

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Abstract: Pumped hydro storage (PHS) is a well-established technology for storing energy in large quantities and over long periods. Sri Lanka, a country rich in hydropower resources, has significant potential for PHS development. The central highlands, where the country's major hydropower plants are located, offer many suitable sites for PHS development thanks to their favorable topography, high rainfall, and large reservoirs. PHS can provide a reliable energy source, reduce the country's dependence on fossil fuels, and mitigate the negative environmental impacts of conventional energy sources. Despite its potential, PHS development in Sri Lanka faces several challenges, including high capital costs, land acquisition issues, and environmental concerns. This paper reviews the current status of Sri Lanka's power sector, assesses PHS potential in Sri Lanka, and examines the benefits of PHS development for Sri Lanka.

Index Terms: Pumped hydro storage system, PHS potential in Sri Lanka, Benefits of PHS

1. INTRODUCTION

Pumped hydro storage (PHS), also called “The World's Water Battery," is an energy storage system that utilizes water to store and produce electricity. The PHS system moves water from a lower reservoir to an upper reservoir during periods of low energy demand, thereby storing potential energy. When electricity demands increase, the stored water is released from the upper reservoir to the lower reservoir and turns a hydroelectric turbine to generate electricity. This system can help balance the electricity supply and demand in power grids, making it a reliable and flexible energy storage source [1]. The system includes two reservoirs, one at a higher elevation than the other, and a pump turbine that can function as both a pump and a generator as follows in Fig. 1. During low energy demand, during off-peak hours, the pump-turbine moves water from the lower reservoir to the upper reservoir, storing potential energy [2]. When electricity demand is high, the stored water is released during peak hours and flows back down to the lower reservoir, turning the pump turbine and generate the electricity.

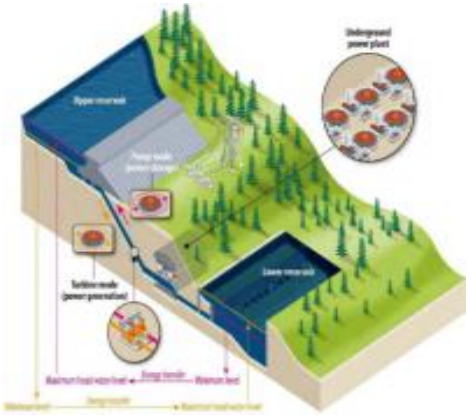

Fig. 1. Pump hydro storage system [3]

During peak hours in Sri Lanka, the electricity demand fluctuates significantly (Fig.2). The late evening peak demand (6:30 pm and 10:30 pm) is more than double the off-peak demand (10.30 – 05.30). This fluctuation was a considerable challenge for Sri Lanka's power system. According to the Ceylon Electricity Board (CEB) Long Term Generation Expansion Plan, a large amount of coal-fired generating capacity will not be connected to the power system. Since coal power plants will be run as base load facilities, there will be an excess of cheaper coal power above the base load requirements during off-peak hours (10.30 – 05.30) [4].To address this issue, Sri Lanka needs to develop mechanisms to manage and serve this peaking scenario, such as increasing the capacity of existing power plants or implementing demand response programs to reduce energy consumption during peak hours [5]. To manage peak demand electricity in Sri Lanka, pump hydro storage power plants can be utilized.

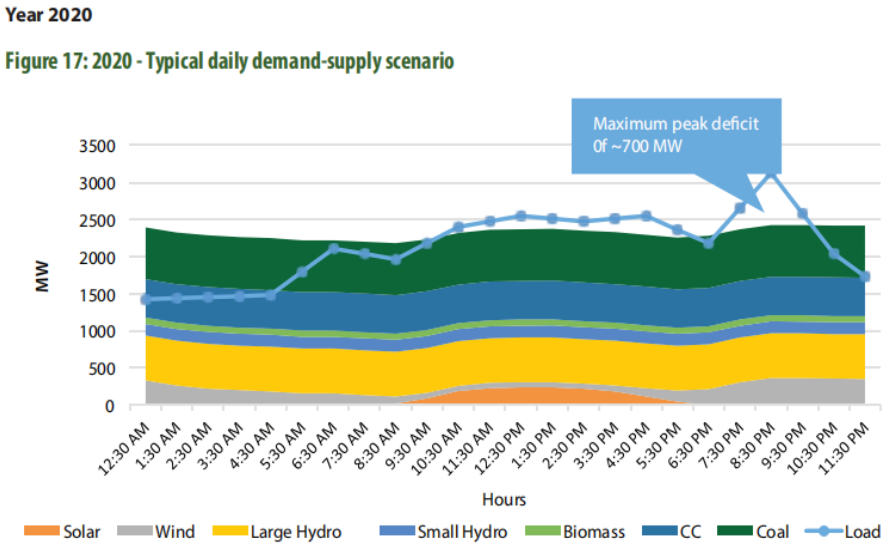

Fig. 2. Sri Lanka's daily electricity load curve [6]

The Sri Lankan government has recognized the potential of pumped hydro storage and included it as a priority area in its National Energy Policy and Strategies. The government aims to increase the share of renewable energy in the country's energy mix to 80% by 2030. The government hopes to use 100% renewable energy for electricity generation by 2050. Here pumped hydro storage is an essential tool to achieve this goal. In addition, several private companies have expressed interest in investing in pumped hydro storage projects in the country. Pumped Hydro Energy Storage (PHES) has significant potential in Sri Lanka [7] due to the country's abundant water resources and hilly terrain, providing ideal pumped hydro storage conditions. The development of PHES projects could be crucial in achieving this goal [8].

2. PUMP HYDRO STORAGE POTENTIAL IN SRI LANKA

Sri Lanka has a significant potential for pumped hydro storage, which can provide a reliable and flexible energy source for the country's power grid. Overall, pumped hydro storage has the potential to play a crucial role in Sri Lanka's transition to a more sustainable and resilient energy system, and the country has significant opportunities to leverage this technology to achieve its renewable energy goals. The Sri Lankan government has recognized the importance of pumped hydro storage and has included it as a priority area in its National Energy Policy and Strategies. The government is also taking steps to encourage investment in pumped hydro projects, including establishing a regulatory framework and providing incentives for private sector investment [9]. Establishing a pumped hydro storage facility requires several key requirements to be met. Here are some of the main requirements for establishing pumped hydro storage in Sri Lanka:

TOPOGRAPHY: The topography of a site is an essential consideration for establishing a Pumped Hydro Storage Plant as it can impact the ability to construct the necessary infrastructure, such as the reservoir and power generation facilities. A suitable site should have a significant elevation difference between the upper and lower reservoirs, which allows for efficient energy storage and generation (Sri Lanka Sustainable Energy Authority [9]. In Sri Lanka, potential sites for Pumped Hydro Storage Plants are typically located in hilly or mountainous areas with significant elevation differences that can be utilized for energy storage.
For example, when selecting Maha-oya (Fig.3) and Wewathenna-Victoria (Fig.4) for a PHS plant, consideration was given to its topologies.

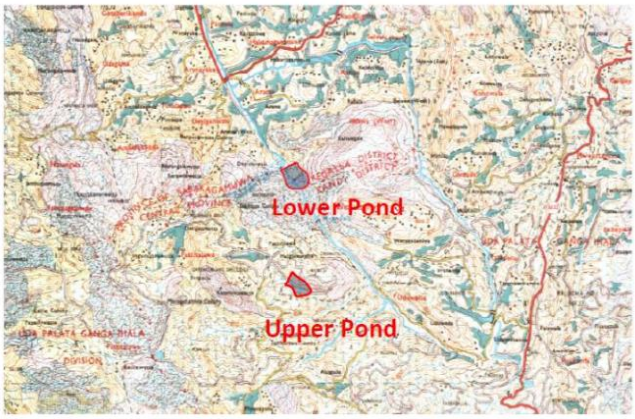

Fig. 3. Topography of Maha-Oya Site [10]

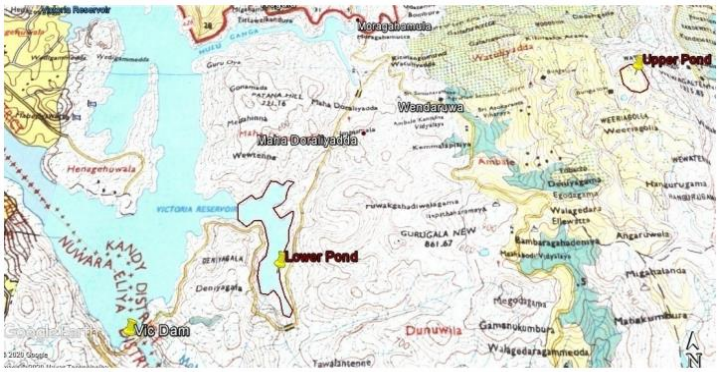

Fig. 4. Topography of Wewathenna-Victoria Site [10]

SUITABLE SITE: The first requirement for establishing pumped hydro storage is to identify a suitable site with the necessary topography and geological features to support the construction of a reservoir and power generation facility. According to a Sri Lanka Sustainable Energy Authority (SEA) report, the country has identified over 200 potential sites for mini-hydro and pumped storage projects (Fig.5), with a combined capacity of up to 4,000 MW of power generation. These sites are spread across the country, including in the central, southern, and northern regions, and have the potential to significantly increase the country's renewable energy capacity [11].southern, and northern regions, and have the potential to significantly increase the country's renewable energy capacity.

Table 1. Suitable sites for Pumped Storage Power plant. [4]

No.	Name	Project Features				1:50,000 Map No.
		Capacity (MW)	Length L (m)	Height H (m)	Ratio L/H	
1	Kiriketi I	500	1,180	770	1.5	76
2	Kiriketi II	500	2,300	720	3.2	76
3	Kiriketi III	500	2,700	1017	2.7	76
4	Halgran	500	3,500	575	6.1	62
5	Maha	500	3,750	520	7.2	61
6	Gurugal	400	4,600	620	7.4	61
7	Dambagasta	300	3,030	440	6.9	68
8	Agra	300	3,330	420	7.9	68

WATER SOURCE: Pumped hydro storage facilities require a reliable water source to operate, typically supplied from a nearby river or other water body. In Sri Lanka, water availability varies by region, so it is essential to identify sites with sufficient water resources to support the proposed project. Most high potential rivers originate from hilly areas show as Fig. 6, that revers make ideal locations for establishing new PHS plants.

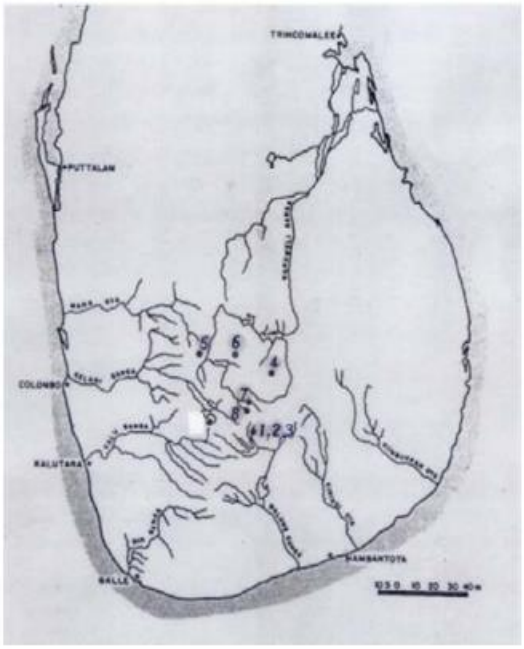

Fig. 5. Potential water resources for PHS Plant [4]

REGULATORY FRAMEWORK: Establishing a pumped hydro storage facility requires compliance with relevant regulatory frameworks and obtaining necessary permits and approvals. The Sri Lankan government has established a regulatory framework for renewable energy projects, including pumped hydro storage. It has set up the Sustainable Energy Authority (SEA) to oversee the development and implementation of these projects [12].

In summary, establishing a pumped hydro storage facility requires identifying a topography, a suitable site with a reliable water source, regulatory frameworks, and significant capital investment. Sri Lanka has substantial potential for pumped hydro storage and has established a regulatory framework and incentives to encourage investment in renewable energy projects, including pumped hydro storage.

3. THE WELL-BEING OF IMPLEMENTING A PUMP HYDRO STORAGE PLANT IN SRI LANKA

Pumped hydro storage is a technology that allows for storing excess energy during times of low demand and releasing that energy during times of high demand. This technology has several potential benefits if implemented in Sri Lanka.

One of the main benefits of pumped hydro storage is its ability to store large amounts of energy for use during peak demand periods. According to a report by the Asian Development Bank (ADB), Sri Lanka's peak demand for electricity is expected to increase from 3,500 MW in 2018 to 7,000 MW by 2030. Pumped hydro storage can help meet this future electricity demand by providing a flexible and reliable source of energy storage [13]. These plants can rapidly respond to energy demand and supply changes, ensuring a stable and reliable grid. PHES plants can also help to mitigate the effects of grid disturbances or power outages, providing an additional layer of support to the grid. The ability to store energy through PHES plants and release it during periods of high demand enables more efficient use of energy resources, leading to a more resilient and responsive power system that can better serve customers' needs.

Pumped Hydro Energy Storage (PHES) plants can play a critical role in integrating renewable energy sources, such as wind and solar, into the grid by storing excess energy when supply is high and releasing it during peak demand. In addition to meeting peak demand, pumped hydro storage can help integrate variable renewable energy sources, which can reduce greenhouse gas emissions by storing excess energy during low-demand periods. While operating costs for pumped hydro storage may be lower than other storage technologies, such as batteries, costs are still associated with the energy required to pump water to the upper reservoir.

Typically, renewable sources are non-dispatchable and often subject to fluctuations due to weather patterns, but pumped hydro storage can smooth out these fluctuations and provide a more consistent supply of energy to the grid. PHES plants can help reduce the country's dependence on fossil fuels, lowering greenhouse gas emissions and supporting Sri Lanka's climate goals [5]. The ability to store and discharge renewable energy through PHES plants also provides a more reliable energy system, enabling greater use of intermittent renewable sources and contributing to a cleaner and more sustainable energy future.

Another potential benefit of pumped hydro storage is its ability to reduce the need for expensive and polluting fossil fuel-fired power plants. By storing excess energy during low demand, pumped hydro storage can reduce the need for these power plants to be brought online during high demand, thereby reducing costs and emissions. Finally, pumped hydro storage can help improve Sri Lanka's energy security by reducing the country's reliance on imported fossil fuels. According to the ADB report, Sri Lanka relies heavily on imported fossil fuels, accounting for around 45% of the country's primary energy supply. Pumped hydro storage can help shift the country towards a more renewable and sustainable energy mix [14]

4 CONCLUSIONS

Sri Lanka's pumped hydro storage potential presents a promising opportunity for the country to transition towards a more sustainable and reliable energy system. The ability of pumped hydro storage to store and release excess energy during periods of high demand can help meet the country's increasing energy demand while integrating renewable energy sources into the grid. Additionally, pumped hydro storage can reduce the country's reliance on fossil fuels, lower greenhouse gas emissions, and improve energy security. While costs are still associated with implementing and operating pumped hydro storage systems, the potential benefits make it a worthwhile investment for Sri Lanka's energy future. Overall, a comprehensive overview of Sri Lanka's pumped hydro storage potentials highlights the potential and benefits of implementing a pumped hydro storage plant in Sri Lanka to meet the future energy demand.

5 REFERENCES

[1]. Rehman, S., Al-Hadhrami, L. M., & Alam, Md. M. (2015). Pumped hydro energy storage system: A technological review. Renewable and Sustainable Energy Reviews, 44, 586–598. https://doi.org/10.1016/j.rser.2014.12.040

[2]. Harby, A., Sauterleute, J., Korpås, M., Killingtveit, Å., Solvang, E., & Nielsen, T. (2013). Pumped Storage Hydropower. Transition to Renewable Energy Systems, 597–618. https://doi.org/10.1002/9783527673872.ch29.

[3].The Prospect of Pumped Storage Hydro in Asia. (n.d.). Retrieved April 12, 2023, from https://assets-global.websitefiles.com/5f68760121a35e589e08f8d6/60cca8a6521f5dcb98df3a0e_IFPSH_ACEF_Slide%20Deck.pdf

[4]. Wickramarathna, T. (2011). Review of PLANNING OF PUMPED STORAGE POWER PLANTS IN SRI LANKA. 16–25. https://www.researchgate.net/publication/318849793

[5]. Wickramarathna, M. T. A. P. (2015). Economic Evaluation of Pumped Storage Power Plant Complexes and Comparison with other Candidate Pumped Storage Power Plants Proposed for Sri Lanka. SLEMA Journal, 18(2).

[6]. 100% ELECTRICITY GENERATION THROUGH RENEWABLE ENERGY BY 2050 Assessment of Sri Lanka's Power Sector. (n.d.). https://www.adb.org/sites/default/files/publication/354591/sri-lanka-power-2050v2.pdf

[7]. Kucukali, S. (2014). Finding the most suitable existing hydropower reservoirs for the development of pumped-storage schemes: An integrated approach. Renewable and Sustainable Energy Reviews, 37, 502–508. https://doi.org/10.1016/j.rser.2014.05.052

[8]. Fernando, M. a. R. M., Athputharajah, A. A., Vivekanathan, C., Anparasan, M., Anunprasanth, S., & Ratnayake, U. R. (2011). Incorporating Pumped Storage Power Plant in the Sri Lankan Electricity Sector. Iesl.nsf.ac.lk. http://iesl.nsf.ac.lk/handle/1/905

[9]. Sri Lanka Sustainable Energy Authority. (n.d.). Www.energy.gov.lk. Retrieved April 12, 2023, from https://www.energy.gov.lk/web/wp-content/uploads/2019/03/NEP-English.pdf

[10]. Ceylon Electricity Board. (n.d.). The Pre-Feasibility Study and the Detail Feasibility Study for a Pumped Storage Hydropower Project. Green Power Development and Energy Efficiency Improvement Investment Program.

[11]. Sri Lanka Sustainable Energy Authority. (n.d.). Www.energy.gov.lk. Retrieved April 12, 2023, from https://www.energy.gov.lk/web/wpcontent/uploads/2019/09/SEA-Annual-Report-2018.pdf

[12]. The Gazette of the Democratic Socialist Republic of Sri Lanka PART I : SECTION (I) –GENERAL Government Notifications Ministry Of Power, Energy And Business Development National Energy Policy And Strategies Of Sri Lanka National Energy Policy And Strategies Of Sri Lanka Ministry Of Power, Energy And Business Development Government Of Sri Lanka. (2019). https://www.energy.gov.lk/images/resources/downloads/national-energy-policy-2019-en.pdf

[13]. Danthurebandara, M., & Rajapaksha, L. (2019). Environmental consequences of different electricity generation mixes in Sri Lanka by 2050. Journal of Cleaner Production, 210, 432–444. https://doi.org/10.1016/j.jclepro.2018.10.343

[14]. Lahimer, A. A., Alghoul, M. A., Sopian, K., Amin, N., Asim, N., & Fadhel, M. I. (2012). Research and development aspects of pico-hydro power. Renewable and Sustainable Energy Reviews, 16(8), 5861–5878. https://doi.org/10.1016/j.rser.2012.05.001