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Modeling and Feasibility Study on Pumped Hydro Storage System for Sri Lanka

Nimshan Avishka De Moraes
Department of Applied Computing
University of Kelaniya
Kelaniya, Sri Lanka
nimshanavishka94@gmail.com

Kasun Fernando
Department of Applied Computing
University of Kelaniya
Kelaniya, Sri Lanka
kasunf@kln.ac.lk

***Abstract*—Due to Sri Lanka's reliance on imported fossil fuel for a large portion of its energy needs, the cost of energy has significantly increased. Sri Lanka has agreed to zero carbon emissions in energy generation by the year 2050, and the country's future energy generation must depend on renewable energy sources. In the future, sustainable energy generation in Sri Lanka will be more favorable if water, wind, and solar energy are combined to generate energy. But since there are some limitations in the generation of that energy, measures should also be taken to store that energy for use within the required period. Pumped hydroelectric storage power plants are regarded as a reliable and effectively used energy storage technology. The thesis has mentioned the economic and environmental benefits of this pumped hydro storage system over existing non-renewable energy power plants by implementing this system using two existing reservoirs in Sri Lanka**

***Keywords*— Pumped Hydro Storage System, Floating Solar Panels, Randenigala & Rantambe Reservoir, Carbon Net Zero 2050 in Sri Lanka.**

I. INTRODUCTION

A Pumped Hydro Storage System (PHSS) is a power energy storage system that uses water to store and produce electricity using that potential energy of water. The system contains two water reservoirs located at distinct elevations. Water is pumped from the lower to the upper reservoir when the need for energy declines. When there is a significant demand for electricity or when additional power is required, the filled water is discharged from the upper reservoir to the bottom reservoir. When that water flows through turbines, it generates electricity. Pump Hydro Storage System Power Plants have many advantages. Some of them are,

- Pumped Hydro Storage power plants provide significant energy storage facilities. The grid can mainly balance the supply and demand of power by storing extra energy generated during times of low demand and releasing it during times of peak demand.
- Pumped storage facilities can respond quickly to variations in energy demand, which aids in power system stabilization. Can provide energy fast and dependably when needed, they are a crucial tool for grid operators to control system frequency and stability.
- Pumped storage facilities can store energy during times of low demand during the day and release it during times of peak demand at night. The requirement for costly peaking power facilities that are only used during periods of high demand can be decreased by permitting load balancing.

The purpose of using this pumped hydro storage is to reduce energy production using nonrenewable energy during periods of high electricity demand. Considering the daily load curve in Sri Lanka few peaks can be seen in the curve. But the nighttime is a very significant time during the whole day. Normally the peak time during the night starts at about 6.30 pm and it ends at about 10.30 pm The pumped hydro storage system is very important during peak time of power generation. There is no pumped hydro storage system in Reservoirs Sri Lanka yet, and for its implementation, new reservoirs have to be constructed. It is a long and expensive project. But in this study, mentioned in detail that the Pumped Hydro Storage system can be implemented using two existing reservoirs in Sri Lanka.

This project uses the existing two reservoirs in Sri Lanka, Randenigala and Rantambe. This means pumping water from the lower Rantambe Reservoir to the upper Randenigala Reservoir. Renewable energy sources solar energy used to pump this water. The floating solar panels will be installed on the Randenigala Reservoir to collect the energy in the afternoon and pump the water up during the afternoon time. By using an existing reservoir, it is possible to save a large cost of constructing a new pair of reservoirs. Similarly, since a country like Sri Lanka has limited land, this can increase the efficiency of generating electricity in the existing reservoirs. During periods of electricity demand, the water collected in the Randenigala reservoir can be released downwards through the penstock to rotate the turbines and fill the energy requirement.

II. LITERATURE DATA

This technology was firstly used in Switzerland, in the 1890s, when a provincial river was connected with a close lake via a little pumped storage plant. In 1907 the First plant was constructed. After that, the technology was tremendously improved and developed. The Connecticut Electric & Power Company of the United States used a storage reservoir near New Milford, Connecticut. The reservoir was used to pump water from the nearby river into a storage reservoir 70 meters above ground level. This was the first time Pumped Hydro Storage was used in the United States [1].

Although this is a new energy system for Sri Lanka. This system is currently being implemented in many countries of the world. Nowadays, using wind power and solar power to pump water can be taken as a new trend in pumped water storage. A study done for this purpose can be taken regarding the pumping of water to the upper reservoir with the energy obtained by solar photovoltaic for a pumped storage system in the country of Malawi in the African continent. The capacity of the solar photovoltaic system was 182 MW and the capacity of the turbine was 86 MW [2]. Also, there is currently a discussion about whether this Pumped Hydro Storage System can be implemented for the existing reservoirs as well. In this regard, previous research has described here how a Pumped Hydro System can be created using two existing reservoirs in Turkey. They identified Sariyar Reservoir Also Lower Reservoir and Gokceya Reservoir Also Upper Reservoir [3].

Multiple research and studies have been conducted during the last two decades to evaluate the potential of implementing Pumped Hydro Storage power plants in Sri Lanka. But still Pumped Hydro System Power Plants have not implemented in the country. The implementation of a PHSS system in Sri Lanka is a very essential factor in terms of time. It is because Sri Lanka spends a large amount of money on thermal power plants for energy production. Particularly during peak hours, Pumped Hydro Storage Power Plants can play an important role in the energy industry in the future of Sri Lanka as they aid in reducing generation costs during peak hours and whole generation costs. Research has been done regarding the construction of a pumped Hydro Storage Power Plant in Sri Lanka and the study done about Kiriketi Oya and Halgran Oya. An Initial study has been done regarding the following points related to them. These are Installed Capacity, Discharge Volume, Effective Head, Dam Height, Dam Length, Reservoir Volume, Headrace, Crest Length, Penstock length and Tail Race length [4]. An economic evaluation related to these Kiriketi Oya and Halgran Oya has also been done. Construction costs have been done for Upper Dam, Lower Dam, Intake, Penstock, Powerhouse etc. and Construction costs have been done for Hydro Mechanical Equipments [5]. Research on peak power generation possibilities, including pumped storage hydropower plants, was undertaken by CEB in 2014. With the help of JICA, research titled "Development Planning on Optimal Power Generation for Peak Power Demand in Sri Lanka". The JICA and CEB study initially identified 11 suitable locations for the construction of a 600MW pumped storage power plant. Each location was examined and graded based on its technical, environmental, topographical, and geological merits. Three potential sites for in-depth site investigations were discovered during the preliminary screening procedure. Halgran Oya, Maha Oya, and Loggal Oya were determined to be the most favorable locations for future development. The Maha Oya region was chosen as the best area for future pumped storage development, and this study concluded that to meet peak electricity demands beyond 2025, the projected pumped storage plant's capacity should be 600 MW. Similarly, in the study conducted with JICA in 2018, it is planned to construct a 1400MW Pumped Hydro Storage Power Plant by using two existing reservoirs, Victoria Reservoir as a lower pond and the Wewathenna Reservoir as an upper pond [6].

In water bodies including oceans, lakes, reservoirs, rivers, lagoons, irrigation ponds, wastewater treatment plants, abandoned pit lakes, fish farms, etc., floating PV systems can be deployed. A typical solar panel may produce power from 4–18% of incident sun energy. The remaining solar energy will be transformed into heat, raising PV cell temperature and decreasing module efficiency. PV panels will be cooled by proximity above water, enhancing efficiency [7]. The main obstacle when using water resources is thought to be evaporation. The economic and social consequences of evaporation have been the subject of numerous evaluations conducted globally. The available water resource in Turkey is around 107.3 x 109 m^3, and the yearly evaporation loss is about 68 x 109 m^3 in volume. It has been discovered that evaporation in Texas, USA, can be twice as high in a dry year as it is in a typical year [7]. Also found that evaporation can be reduced by using floating solar panels. A study of four lakes in Rajasthan, India demonstrates that 15% water surface coverage of each lake can conserve water evaporation by 191 to 372 million liters yearly [8]. A 24 kWp floating photovoltaic system has an average conversion efficiency of 7.6%, which is higher than a comparable ground mounted photovoltaic system. Additionally, floating solar systems achieve 13.5% and 10.3% efficiency over typical 100 kWp and 500 kWp photovoltaic power plants. A different study says that a floating photovoltaic system can increase electricity by 5.93% and reduce evaporation by 70%. A 24 kWp floating photovoltaic system in Spain was scaled up to 300 kWp as a result of its efficient operation and water savings. According to some developers, floating photovoltaic systems are 50% more efficient than ground-mounted solar PV [7]. Similarly, by using floating solar panels, space can be saved for ground mounted solar panels. It can save a lot of land space. Floating solar panels first established as a pilot project in Sri Lanka at the Killinochchi campus of the University of Jaffna. This floating solar system was installed with the technical assistance of a Norwegian company with a Capacity of 46kWp. Around 9,500,000 Sri Lankan Rupees (SLR) is the total cost of the floating solar project (component cost), which includes 157 Solar Panels (295 Wp & 315 Wp), a 50kW SMA Inverter, Beams and breakers, 13 PE Pipes, Data logger and sensors, and a ground mounted PV system. An average of 5000 kWh of power was produced each month [9].

Research has also found that a pumped hydroelectric system can be created using the Randenigala and Rantambe reservoirs in Sri Lanka. This is done by using the energy obtained from three wind turbines. But for this, the wind data of the Ambewela area, which is more than 1000 meters above the ground level of the Randenigala Reservoir, has been used for this purpose. Also, a height of 40 meters has been used as the pump head. It seems that the 40 meter pumps used here, i.e. the height required to pump water from the lower reservoir to the upper reservoir, are not suitable for this purpose [10]. Randenigala is a currently used reservoir and according to the data obtained during the design of the reservoir, the volume of water flowing through the penstock changes depending on the change in the water head of the reservoir. The table below shows it. [11]

TABLE I. DIFFERENT LEVELS OF RANDENIGALA RESERVOIR

Maximum Flood Level	236.2 m (Mean Sea Level)
Retention Level	232 m (Mean Sea Level)
Exceptional Drawdown Level	203 m (Mean Sea Level)
Normal Tailwater Level	152 m (Mean Sea Level)
Elevation at Intake to Penstock	179.3 m (Mean Sea Level)
Discharge at 232 meters (Mean Sea Level)	2 x 90 m3/s
Discharge at 203 meters (Mean Sea Level)	2 x 70.1 m/s

III. METHODOLOGY

Data obtained from recognized institutions and sources were often used for this, and a final conclusion was reached regarding the effectiveness of this method through calculations using that data. Problem identification, conduct, and validation are three main phases of the project Modeling and Feasibility Study on Pumped Hydro Storage System for existing reservoirs in Sri Lanka. Identification of the problem and understanding the expected needs of the proposer is the starting point for the project. An initial review of the literature was conducted using previous research papers relevant to the implementation of existing reservoirs and the construction of new pumped storage power plants in Sri Lanka and other parts of the world. Scope and boundaries were defined considering the resources available.

TABLE II. METHODS OF DATA COLLECTION

Type of data	Specific data	Method of data collection
Published data	Randenigala & Rantambe Reservoir Data	Literature Review reports and CEB reports .
Rainfall data	Monthly Rainfall data for one year	Meteorological department.
Solar Radiation data	Monthly Solar Radiation data for one year	SolarGIS Web source and RETScreen Expert Software
Wind Velocity Data	Monthly Wind Data for one year	RETScreen Expert Software and related wind velocity measure websites.
Other Data	Geographical catchment area	Using Google Earth and Google Map websites.
System Specific data	Floating Solar panels, Water pumps	Manufacturers spec sheets

IV. CALCULATION AND RESULTS

A. Pump Selection and Calculation

- The volumetric discharge rate at full capacity of one turbine (232 m MSL) = 90m3/s
- The volumetric discharge rate at full capacity of two turbines (232 m MSL) = 180m3/s
- Expected Turbine Running Time Use Pumping Water (Peak Time - Night Time) = 1 hour

$$\text{Total Discharge Water Volume} = \text{Discharge time x Flow Rate} = 1 \times 3600 \times 180 = \underline{648{,}000\ m^3} \qquad (1)$$

$$\text{Pumping Flow Rate} = \frac{\text{Total Discharge Water Volume}}{\text{Pumping time}} \qquad (2)$$

$$= \frac{648{,}000\ m3}{24 \times 3600\ s}$$

$$= \underline{\underline{7.5\ m3/s}}$$

7.5 m3/s of volume is required to pump the water from the lower reservoir to the upper reservoir. For this, it is suggested to use four water pumps with a flow rate of 2.5 m3/s.

The diameter of a pipe used for re-pumping water can be solved using the following equation [12]. Diameter of pipe,

$$D = \frac{(2Q)^{0.5}}{(3\pi)^{0.5}} \qquad (3)$$

D = Diameter of Pipe (m), Q = Pumping flow rate using one pipe (m3/s), $\pi = 3.14$

$$D = \frac{(2 \times 2.5)^{0.5}}{(3 \times 3.14)^{0.5}}$$

$$\underline{\underline{D = 0.73\ m}}$$

The pipe's calculated diameter is 0.73 meters. Due to their higher pressure capability, steel pipes with a diameter of roughly 0.73 m are used in the calculations. The equation can be used to determine the Velocity (V) of water inside the pipe [13]

$$V = \frac{4Q}{\pi D^2} \qquad (4)$$

$$\underline{\underline{V = 6\ ms^{-1}}}$$

The type of flow that will occur in the pipe is determined by the Reynolds number, which is crucial for water pumping. Low Reynolds numbers result in laminar flows, which are characterized by water that is flowing in smooth, parallel layers. This kind of flow is extremely effective and causes little friction. The flow, which is characterized by chaotic eddies and vortices, gets turbulent as the Reynolds number rises. Friction is increased and the flow is less effective. The Reynolds Number related to water pumping is shown in the following equation [14].

$$R_e = \frac{\rho VL}{M} \qquad (5)$$

$$R_e = \frac{1000 \times 6 \times 1000}{1.5 \times 10^{-3}}$$

$$\underline{\underline{R_e = 4{,}000{,}000{,}000}}$$

Re = Reynolds number, ρ= density of water (1000 kgm^{-3})
V = Velocity of Flow (6 ms^{-1}), L = Characteristic Length of the flow (1000 m) (using google earth software to measure

the approximate length), μ= Dynamic Viscosity (1.5×10^{-3} kg/m. s)

The resistance to flow caused by friction between the water and the pipe walls is measured by the friction factor when pumping water. The greater the flow resistance and the more energy needed to pump the water, the higher the friction factor. The following equation is used to find the friction factor (f) using the Reynolds Number obtained above [10]

$$f = 0.316(Re)^{-1/4} \qquad (6)$$

$$f = 0.316 \times (4{,}000{,}000{,}000)^{-1/4}$$

$$\underline{\underline{f = 0.00125768}}$$

f = friction factor, R_e = Reynolds number

The following equation is used to find the head loss during this pumping [12]. Head loss due to friction (h_f)

$$h_f = \frac{f \times L \times V^2}{D \times 2g} \qquad (7)$$

$$h_f = \frac{0.00125768 \times 1000 \times 6^2}{0.73 \times 2 \times 9.81}$$

$$\underline{\underline{h_f = 3.16 \text{ m}}}$$

f= Friction factor, D =Diameter of the pipe, L = Length of pipe, V= Velocity of water

The water Retention Level of Rantambe Reservoir is 152 m (MSL) and that water should be brought to the Crest Elevation level of Randenigala Reservoir Dam. The Crest elevation of Randenigala Dam is 239m (MSL) [11]. Because the water is pumped up externally applied pipes and this process should happen without damaging the dam. Then the Vertical height between these two levels is 87 m. Since the pipes are moving above the crest level, Let's assume that the height is 3 meters from the crest elevation. Then the total height is 90m. Also the value of head loss due to friction during pumping should also add.

Pumping Head = 90m + 3.16m
= 93.16 m

Pumping Power (P), [10]

$$P = \rho g Q H \qquad (8)$$

$$P = 1000 \times 9.81 \times 7.5 \times 93.16$$

$$\underline{\underline{P = 6854.25 \text{ kW}}}$$

ρ=Density of the water (Kgm^{-3})
Q =Pumping flow rate (m3s^{-1}), H = Pumping head (m)
g= Gravitational Acceleration (Nkg^{-1})

The pump's efficiency is approximately 73%, according to the data in the research papers obtained earlier [10].
So the input power for four pumps

$$= \frac{6854.25 \times 100}{73}$$

$$= \underline{\underline{9389.36 \text{ kW}}}$$

B. Solar Power Calculation

- System Running time using solar power (day time) = 6 hours
- Daily solar energy received from solar power per square meter = 5.35 $\text{kWh/m}^2\cdot\text{day}$ [20]
- The area of the solar panels= 350,000 m^2
- Area of a one panel = 1.9306 m^2 [15]
- Watt Peak of a solar panel = 330 W

Number of solar panels that can be install in the reservoir

$$= \frac{\text{Solar Collector Area}}{\text{One Solar Panel Area}}$$

$$= \frac{350{,}000 \text{ m}^2}{1.9306 \text{ m}^2}$$

$$= \underline{\underline{181{,}290 \text{ Panels}}}$$

The Solar Energy that falls on the solar panel does not produce 100% of the output power. The efficiency of a solar panel can be obtained by the following equation. Floating Solar Panel Data Sheet, the Efficiency of the solar panel is 17.09% [15]. So the Calculation of the Solar Photovoltaic(PV) energy output of a photovoltaic system is an important part of the calculation of actual solar energy [16]

$$E = A*r*H*PR \qquad (9)$$

E. = Average Energy Output (kWh)
A = Total solar panel Area (m²)
r = Solar Panel yield/ Solar Panel efficiency (%)
H = Daily average irradiation on tilted panels (shadings not included) *
PR = Performance ratio, coefficient for losses

Losses details

Inverter losses	9%
Temperature losses	8%
DC cables losses	2%
AC cables losses	2%
Shadings	0%
Losses weak irradiation	3%
Losses due to dust, snow...	1%
Other Losses	0%

Calculation of Performance Ratio = 0.77

Average Energy Output for one day

$$E = A*r*H*PR$$

$$= 350{,}000 \text{ m}^2 \text{ X } 0.1709 \text{ X } 5.35 \text{ kWh/m}^2\text{.day X } 0.77$$

$$= \underline{\underline{246{,}407.90 \text{ kWh/day}}}$$

Average Energy output for 1 hour = <u>10,267 kWh</u>
Average Energy Output for 6 hours = <u>61,602 kWh</u>

Volumetric flow rate that can be supplied using Floating Solar Panels

$$Q = \frac{P}{\rho g H}$$

$$Q = \frac{10{,}267 \times 1000 \text{ w}}{1000 \times 9.81 \times 93.16}$$

$$\underline{\underline{Q = 11.23 \text{ m3/s}}}$$

A volume of 11.23 m3/s can be provided using the energy obtained from floating solar panels and therefore four water pumps can be used for water pumping. The main function of Mahaweli reservoirs is firstly to release water for agriculture and secondly to generate hydropower. Therefore, the water in the reservoir cannot be stored for a long time. Mandatory, the water must be released into the Rantambe Reservoir through the turbines. And the energy produced by the floating solar panels power is to use for pumping water in the daytime, considering about 6 hours for one day and plan to pump the water in 3 days. Calculations for water pumping volumes are given below

Water pumping volume for one day (6 hours) using four water pumps = 2.5m3/s x 4 x 3600s x 6 = 216,000 m^3

Water pumping volume for 3 days (6 hours per day) using for water pumps = 216,000m^3 x 3days = 648,000 m^3

C. Economic Analysis for Pumped Hydro Storage System

All these calculations are done based on the value of Sri Lankan Rupees compared to the average United States Dollars for the year 2021 (201.5 LKR/USD)

For this purpose, it is planned to generate electricity by using pumped water every 3 days. The reason is that the water of the Mahaweli River has to be released for agricultural purposes as well as for other irrigation purposes. (Randenigala Power Plant capacity =122 MW)

Generation Electricity for 1 hour = 122,000 kWh

According to the previous research paper regarding the Randenigala Reservoir the Spinning Reserve Loading Plant Capacity was 82%. [10]
Spinning Reserve Loading Plant Capacity = 0.82

Electricity output = 122,000 x 0.82 = 100,040 kWh

The generation cost of Randenigala power plant for the year 2021 is Rs.2.08 per 1kWh. [21]

The total cost of generation electricity for 1 month (1 month=10 hours)
= 100,040 x 2.08 x 10 = **Rs. 2,080,832.00**

Depending on the location of the reservoir, there are some of the ways to obtain energy for this pumping function. Considering the efficiency of the pump as 73%, the input power required for the four pumps is 9389.36 kW. These four pumps operate 6 hours a day for 3 days and pump a total of 648,000 cubic meters of water. Therefore, the Total energy required to pump water for all 3 days
= 9389.36 x 6 x 3
= 169,008.48 kWh

According to the Long Term Generation Expansion Plan (LTGEP) (2023-2042) published by CEB [6], the unit cost of generation using the floating solar is Rs.18.70 (This Price according to the year 2021-unit price, Floating Solar (USD/kWh) = 0.0928 $)

The total cost of generation electricity for 1 month (1 month=10 hours) Using Floating Solar Panels
=169,008.48 kWh x 18.70 x 10
=**Rs.31,604,585.58**

- The profit for this entire electricity production process can be compared with three Non-Renewable Energy Sources Power Plants in Sri Lanka

Cost of KPS-Gas Turbines Operating for 10 hours per month
= Rs. 51,830,724.00
Cost of Randenigala Hydro Power Plant Power Energy 10 hours per Month = Rs. 2,080,832.00
Cost of Floating Solar Panels Energy Per Month
=Rs. 31,604,585.58
Energy Saving Per Month Using PHSS
=Rs. 51,830,724.00-(2,080,832.00+31,604,585.58)
=**Rs. 18,145,306.42**

Cost of Island Small Generators Operating for 10 hours per month = Rs. 68,957,572.00
Cost of Randenigala Hydro Power Plant Power Energy 10 hours per Month = Rs. 2,080,832.00
Cost of Floating Solar Panels Energy Per Month
= Rs.31,604,585.58
Energy Saving Per Month Using PHSS
= Rs. 68,957,572.00 -(2,080,832.00+31,604,585.58)
=**Rs. 35,272,154.42**

Cost of (Emergency Power-1MW x 50) Operating for 10 hours per month = Rs. 40,146,052.00
Cost of Randenigala Hydro Power Plant Power Energy 10 hours per Month = Rs. 2,080,832.00
Cost of Floating Solar Panels Energy Per Month
= Rs. 31,604,585.58
Energy Saving
Per Month Using PHSS
= Rs. 40,146,052.00 -(2,080,832.00+31,604,585.58)
=**Rs. 6,460,634.42**

D. Days to Cover the Cost of Panels and Inverters

The main consideration here is the basic cost of solar panels, solar inverters and (ignoring the installation and other costs). This is not the total cost of this project.

TABLE III. COST OF SOLAR PANELS & INVERTERS

Description	Quantity	Rate(Rs.)	Total(Rs.)
The cost of 181,290 floating solar panels with floating structure [17]	181,290.00	7052.50	1,278,547,725
500kW output solar inverter [18]	120	13,903,500.00	1,668,420,000
			2,946,967,725

All these calculations are done based on the value of Sri Lankan Rupees compared to average United States Dollars for the year 2021 (201.5 LKR/USD)

The cost of electricity generated per hour by floating solar panels = 10,267 kWh x Rs.18.70
= Rs. 191,992.90

The cost of electricity generated for 6 hours by floating solar panels = Rs. 191,992.90 x 6
= Rs. 1,151,957.40

Days to cover the cost of floating solar panels and inverters (assuming only 6 hours of solar electricity generation per day)

$$= \frac{\text{Rs.2,946,967,725}}{\text{Rs. 1,151,957.40}}$$

= 2558 Days

E. Environment Analysis for Pumped Hydro Storage System

This PHSS system does not emit direct GHG, and this power generation is a 100% economical as well as environmentally sound process. Compared to existing thermal power plants in Sri Lanka, this PHSS system greatly reduces greenhouse gas emissions. The table below shows the total greenhouse gas emissions from Kelanitissa Thermal Plant from 2011 to 2017. [19]

TABLE IV. GHG Saving Comparing Kelanitissa Power Plant

Year	2011	2012	2013	2014	2015	2016	2017
GHG Saving if Using PHSS (Year) (million kg CO2e)	16.29	16.84	15.51	15.24	15.39	15.26	15.44

(1 year = Total 120 Hours)

The above table shows the amount of GHG that could have been saved if the PHSS system had been operational in previous years.

V. Discussion/Conclusion

The Pumped Hydro Storage System is a very important milestone in the journey towards saving the energy and using renewable energy in the future world. By doing this process by using the two reservoirs of Randenigala and Rantambe, which are currently in Sri Lanka, it was shown that this method is profitable instead of the energy generation cost of the existing non renewable energy sources power plants in Sri Lanka. By implementing this PHSS system, the monthly cost of **KPS Gas turbine (18 million), Island small generators (35 million) and Emergency power (1MW x 50) (6million)** power generation can be saved greatly. It has been shown above that by implementing this PHSS, GHG emissions from non-renewable power plants can be reduced. In the same way, when the water level of the reservoir is very low, the power can be supplied to the national electricity system during the day with the power of **60 MW** each by the floating solar panels system without operating the PHSS. Immense of environmental benefits can be achieved by implementing PHSS with alternative low cost renewable energy power supply. The study does not examine the economic benefits at the national level, but PHSS can be a better option for energy storage to promote the integration of more domestic energy systems to the national grid and lessen the amount of foreign exchange needed to import fossil fuel. Below show how the sustainable development goals related to this study.

1) SDG No 7-Affordable and clean energy: The Electricity produced throughout this system is Renewable Energy and the This electricity also Storing it or supply to the National Grid. The Efficiency of existing hydropower plants can also be increased.

2) SDG No 13-Climate Action: Greenhouse gases are not added to the atmosphere while using this system and thus this system does not contribute to global weather and climate change.

3) SDG No 15- Life on Land: Floating solar panels installed on the Randenigala Reservoir are used to obtain energy, and thus there is no damage to the sanctuary around the reservoir.

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