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A proposed solar-hydro system in Bahrain

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Abstract

Hydro pumping stations are the largest storage of energy over the world. Other techniques for storing energy are still much behind the hydroelectric power stations. Pumping stations are cost effective to save power from availability at certain time of the day to the peak loads at other times. At the same time, solar energy systems are spreading all over the world very fast, due to the decrease of cost of solar panels. Solar energy are only available at day time. Hence the combination of hydro pumping stations and the solar systems seems to be a good combination. Such systems started to be part of sustainable energy sources for smart cities future power supply.

A proposal for a solar-hydro integrated power generation in Bahrain is proposed here.

With the large variation in electric daily load curves between day and night and the availability of sunshine during the day in Bahrain, it becomes clear that new ways of generation of electric power is possible. The solar system can provide electric energy during the day and the hydroelectric pumping stations can offer a benefit of storing such energy to other time of the day, so that water is pumped up from the downstream lake or sea, to the upper lake at low values of load and availability of sunshine; and water is let to flow downward generating electricity at peak load period or at night in general.

In Bahrain, with good availability of sunshine and nearby sea water, an integrated solar-hydro system seems to be cost effective.

The paper investigates the possibility of such system by showing the benefits of such system and investigates the possibility of implementing it.

1. Introduction

The first use of pumped storage was in the 1890s in Italy and Switzerland. The 1890s were sometimes referred to as the " Mauve Decade" because William Henry Perkin 's aniline dye allowed the widespread use of that in Switzerland. The ten largest pumped storage in the world at the moment are listed in Table 1

The technique is currently the best means of storing large amounts of electrical energy on an operating basis, but capital costs and the presence of appropriate geography are critical decision factors.[1]

Pumped storage power stations convert stored energy quickly to electricity. Hence plays major factor in stability of power system. It is useful in reducing harmonic distortions and elimination of voltage sag and surges.
They provide an alternative to peaking power by storing cheap base-load electricity and releasing it during peak hours. Overall efficiency are usually in the order of 70-80%[2].
Suitable elevation is required between the upper reservoir and the lower (which may be at sea level). The construction may take years but it may operate for decades with almost no running cost.
Table (1) shows the largest 10 hydro pumbed storage power srations in the world [3].

Portugal is home to the world’s first combined hydroelectric and solar power plant, which will produce enough energy to power the equivalent of 100 homes for an entire year. 840 floating solar panels have been fitted to the existing Alto Rabagao dam in Portugal, which will not only increase the installation’s energy capacity by 220 kWp, but also help to minimize the erosion of the banks and reduce algae build-up. Figure (1) shows the lake. [4]

Country	**Station**	**Capacity (MW)**
United States	Bath County Pumped Storage Station	3,003
China	Huizhou Pumped Storage Power Station	2,448
China	Gungdong Pumped Storage Power Station	2,400
Japan	Okutataragi Pumped Storage Power Station	1,932
United States	Ludington Pumped Storage Power Plant	1,872
China	Tianhuangping Pumped Storage Power Station	1,836
Australia	Tumut-3	1,800
France	Grand'Maison Dam	1,800
Spain	La Muela II Pumped Storage Power Station	1,772
United Kingdom	Dinorwig Power Station	1,728

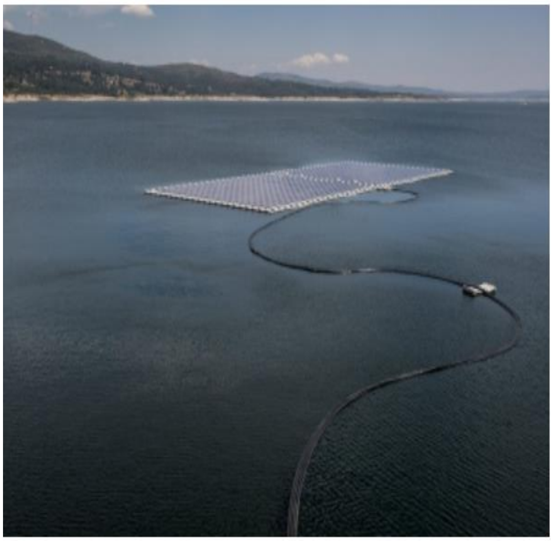


Figure (1) The first solar-hydro integrated system in Portugal.

2. Hydro-electric pumping system

2.1 Main Components of the System:

- Reservoir that needs to save water that acts much like a battery, storing water to be released as needed to generate power.
- Intake to prevent fish and wildlife from passing through any proposed energy generation equipment.
- Penstock is a pipe carries the water from the reservoir to the turbine.
- Turbine that converts the kinetic energy of fluids to mechanical energy that drives generator.
- Power House area will need to be established to contain turbines, pumps, machines and some other devices.

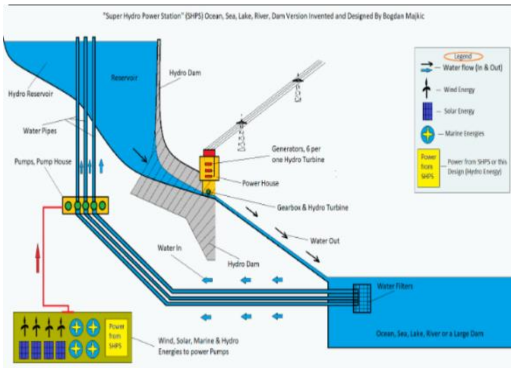
2.2 Operating Modes:

Under a proposed hydropower installation, either pumping or generation modes could occur at any particular time but not simultaneously.

The system normally consists of two water reservoirs or lakes at different heights. These are connected by large diameter pipes or tunnels. Reversible pump / turbine machines are located in a power house connected to the pipes.

Table (1) The largest 10 hydro pumped storage in the world

These are first used to pump water from the lower to the upper reservoir, where it is stored as hydro energy. The pumps are powered by large electric motors, which can also act as generators in the reverse direction. When water is released from the upper reservoir, it flows back down through the reversible machines, which now act as turbines. The turbines are connected to reversible motor / generators, which were initially used as motors to drive the pumps, but now act as generators powered by the turbines and reconvert the hydro energy into electricity.



Figure(2) An integrated solar-hydro pumping station[5]

2.3 How to Measure Potential Power and Energy

- As an example, 1000 kilograms of water (1 cubic meter) at the top of a 50 meter tower has a potential energy of about 0.136 kW·h

- Head is height between upper reservoir and lower reservoir or sea level.
- Flow is how much water moves through the system—the more water that moves through a system, the higher the flow.

2.4 Hydro Power Calculations

Before a hydroelectric power site is developed, engineers compute the power that can be produced when the facility is complete. The actual output of energy at a dam is determined by the volume of water released (discharge), the vertical distance the water falls (head). So, a given amount of water falling a given distance will produce a certain amount of energy. The head and the discharge at the power site and the desired rotational speed of the generator determine the type of turbine to be used.

The theoretical power to be generated by a hydro-electric plant in horsepower or kilowatts can be computed as follows (1).

Power in turbine mode:

$$P = g\,\rho\,Q\,H\,\eta \qquad (1)$$

Power in pump mode:

$$P = g\,\rho\,Q\,H\,/\eta \qquad (2)$$

Where P = power in kilowatts (kW), g = gravitational acceleration (9.81 m/s^2), η = turbo-generator or pump-motor efficiency ($0 < \eta < 1$), Q = quantity of water flowing (m^3/sec), H = effective head (m), ρ = fluid density in kilograms per cubic meter [kg/m3] = 1000 [kg/m3] for water. We can calculate turbo-generator or pump-motor efficiency from equations below:

$$\eta=\eta_{pump}\times\eta_{motor} \qquad (3a)$$

or

$$\eta=\eta_{turbine}\times\eta_{generator} \qquad (3b)$$

The flow rate is dictated by the expected volumetric area of the limiting reservoir divided by the desired storage time to yield the available flow. The effective head equal difference between gross head and head loss. Formula of flow rate as below:

$$Q=A\times\upsilon \qquad (4)$$

Where, A= area of penstock, υ= velocity of water. And evaluate to variable from formula below:

$$A=\frac{\pi D^2}{4} \qquad (5)$$

$$\upsilon=\sqrt{2gH} \qquad (6)$$

where D is the diameter of penstock.

3. Bahrain Load Forecasting

Load forecasting for Bahrain, had been studies in some literature [6]. Different scientific models of forecasting had been suggested. Figure (3) shows one of these models using regression analysis. It indicates that a growth rate of load of about 6% yearly is going on since 2003 and expected to continue for the next few years.

The example shown in Figure (2) shows the possibility of an integrated hydro-solar system which may use solar energy to pump water to the upper reservoir from sea and use it when required to supply energy to the power system. Solar cells may be put on shore or floating on the water of the upper reservoir.

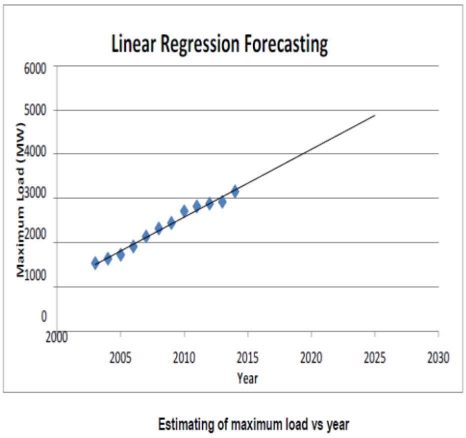


Figure (3) Linear Regression Forecasting for load in Bahrain

Figure (4) shows the daily load curves in Bahrain on 3rd June 2010. It shows the load curve for weekend (Friday) and week days. It indicated that at during the weekdays there are two peaks. One (the largest) in the afternoon, and one in the evening after sunset. The first peak occurs while sun is high in the sky. Hence solar cells may be very practical to supply such load. In the meantime the morning load is quite low. Hence the solar cell energy may be utilized to store energy in the hydroelectric pumping system.

Figure (4) Daily load curve in Bahrain on 3rd July 2010 [7]

3.1 Proposed System:

It seems that the best location for a solar hydro system in the south of Bahrain near the airport where there is hill of 40-60 m height above sea level. A channel from sea and a lower lake may be constructed at sea level nearby. Figure (5) shows the proposed location.

4. Conclusions

With the ever fall down of cost of solar energy panels, the good availability of sunshine in Bahrain, the availability of sea water around the Bahrain and the availability of hills not far from the shore, it seems that an integrated solar- hydro pumping station worth a feasibility study. It should be part of sustainable environmental development.

Figure (5) Proposed location south of Bahrain

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