J. Int. Environmental Application & Science, Vol. 14(3): 70-74 (2019)

Research Paper

Pumped-Hydro Energy Storage Alternative Site Evaluation: A Case Study in Turkey

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Received June 08, 2019; Accepted September 03, 2019

Abstract: Among various energy storage methods pumped-hydro storage systems have been developed rapidly over the last decades because of their capability of the large-scale energy storage, time shift and the ability of being integrated with renewable energy. The component of system is an upper and lower reservoir connected with a pump/turbine. The technique works as pumping water from down to up during low demands on electricity and releasing back through the turbine to produce electricity during the pick hours. however, the availability of suitable places for such projects has difficulties for various reasons. The aim of this study is to investigate the principles and factors affecting the alternatives for site selection. The locations and topography of dams and lakes of Turkey have been explored using Google Earth to search for suitable locations, and the locations listed and ranked by factors that affect the applicability, efficiency, sustainability, and environmental friendliness of the projects.

Keywords: *Pumped Hydro Storage, Dam, lake, Energy Storage, energy, electricity.*

Introduction

Due to the limitations in the sources of fossil fuels as well as their environmental adverse effects, the implementation of renewable energy sources and the more efficient use of existing systems became critical to fulfill the increasing demands of our global for energy consumption. For managing the existing energy sources and their effective usages, energy storage systems are the most promising options due to their capability of being integrated by wind power plants, solar and other renewable energy systems.

PHSS (Pump-hydro storage systems) is the most suitable energy storage system that can be applied on large scales. The system consists of two reservoirs with different elevations connected with pump / turbine system in which water pumped to upper reservoir when electricity is not needed. During periods of high electricity demand, water is drawn from the turbine in a similar way to conventional hydropower plants to rotate generator. The amount of energy stored is proportional to the height difference between the two reservoirs and the volume of water stored (Steffen, 2011).

In all other energy storage systems such as thermal, gravity, electrochemical and chemical energy, which are supposed to store existing electricity by converting it into mechanical energy, the pumped hydro energy system is the only widely used storage technology today (IEA, 2014).

Pumped-hydro storage systems have many advantages by serving the grid system in wide ranges such as peak shaving, load balancing, frequency regulation, back-up reserve, spinning reserve, voltage support, quick start and black start capability (Yang, 2015). Despite all the advantages, geographical constraints have been identified as the most disadvantageous factor for many projects. In order to provide relatively large water reserves and sufficient capacity, a high difference in elevation of the upper and lower reservoirs is required. Since the construction of PHSS has taken many years, net investment in construction is high and regain can only be possible in decades, so it is difficult to persuade the private sector to invest (IHA, 2018).

According to master plan of DSI (Turkish State Water Works) by year 2023, dams and hydropower systems were planned to be constructed will be completed and the energy sourced from hydropower systems will be stay stable forward (DSI, 2014). Adding PHSS to the existing hydropower systems will be a promising choice for storing energy which also can be found in contribution to a stable energy supply by integrating with rapidly developing renewable energy like solar and wind power plants.

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#This paper has been presented in ISESER-2019, Konya, Turkey

The purpose of this study is to investigate the factors which affect the feasibility of the project considering the site selection. Therefore, some dams and lakes were taken into consideration and two were selected as the study area for a comparative feasibility assessment by preliminary assessment of their topography.

Materials and Method

Consideration of Alternative Project Sites

The topographical conditions of a high elevation gap with shorter distance makes the Project site attractive and viable for a PHSS development. After finding the suitable topography the applicability of the project to the specific site will be identify comparatively according to the followings:

1) Economic efficiency (unit construction cost)
   The pumped-hydro storage systems have many components such as upper and lower reservoir, water tunnels, central building for mechanical facilities and electric transmission line and center; many activities like relocations, land acquisitions, building roads, excavation and dumping are included in project which effect the cost of the project (Dinglin *et al*., 2012). Therefore, economic efficiency conditions of the system considering the parameters effect the site location for the project.
2) Engineering feasibility
   Since pumped-hydro storage systems are function as hydro powers like dams and dikes the geology and geomorphology of the site which includes the earthquake condition and rock shearing strength and rock mass condition are crucial for appropriate site selection for this project (Kusakana, 2015)
3) Proximity of environmental sensitivities, such as nature reserves
   Pumped hydro storage system can have impacts on environment like regional climate changes due to evaporation and humidity; impacts on ecosystems and natural resources consequently the flexibility of the legislations and regulations will affect site selection alternatives (Serhat, 2014)
4) Necessity of resettlements
   Resettlements and relocation of human and properties is one of the challenges of all hydraulic projects like dams, dikes and pumped-hydro storages systems due to their need for large areas and long-term construction period. The number of people, properties and villages need to be relocated will affect the prioritization of the alternative's locations (Nazari *et al*, 2010)
5) Presence or absence of limestone caves in the limestone distribution area
   The geological stability of the location and their interaction with water and water reservoir is important for safety and efficiency of the project. Water can be losing due to evaporation and infiltration hereby the geological structure and characteristics of soil and rocks are considerable for site selection alternatives (Dimitris *et al*., 2013).
6) Distance from the nearest 400kW substation (power line length)
   Stabilization of electricity grid of large cities through pumped-hydroelectric storage systems is essential. The capability of being integrated by wind and solar and other renewable energy power plant of the storage systems, made their location critical to be optimized according to industrial cities, wind and solar performance of the geography and distance of the project from existing electric substation for suitability and economic of the project (Steffen, 2011).

Alternative for Upper Reservoir and Excavation Sites

- Upper reservoir

When determining a location for the upper reservoir of a PHSS, 1) enough elevation difference with lower reservoir for energy generation; 2) suitable topographical features depending on dam type, and; 3) Minimum environmental and social adverse impact shall be secured as pre-conditions (Telford, 1990).

- Excavated material storage areas

Excavation and dumping have huge effect on feasibility and economy of the project. Sometimes it requires additional land acquisition which needs understandings of neighboring residents and local administrative organizations, and countermeasures as appropriate, expansion of the affected area caused by dump trucks loading excavated materials (traffic congestions, accidents, noise, vibration and air pollution), or a sharp increase of project cost caused by reclamation of the outside disposal sites and longer-distance transportation (Telford, 1990).

Alternatives for Access Roads to Construction Sites, Disposal Sites, Quarry Sites and for existing Connecting Road for Neighborhoods

The construction of the project may require relocation of the existing roads, construction of new roadways for access to construction sites, disposal sites and quarry. Constructing and relocating roads will put impacts on citizen, farmlands and environments as well as affect the project to become out of economic. Therefore, the road alternatives have their role for selecting the right place. The impacts of the road can be categorized as, no impacts, a small impact but not serious, serious impact but not irreversible and irreversible; the locations with lower impact can be selected as alternative places (Frilz, 1984).

Alternative Route for Transmission Line

Grit connection is another important factor affecting the site selection for the project. The impact of the selected alternative existing dam, protected areas, migratory bird, waterfowls and landscapes must be lower and no serious for suitability, economic and environmental friendliness of the project (Melhem, 2013).

The project also has effects on air, water and soil quality and climate change of the area; can be referred as unsuitable location if effect ecosystem, protected areas and cultural heritages; effects of project on environment and society like waste production, changing hydrology of the area, disturbance to water usage, disturbance to the exiting social infrastructure and services land, land acquisition and deterioration of local economy also considerable (Henderson, 2018).

Criteria for priority of ranking

When evaluating the study area, the criteria and impacts stated in the table 1. Were taken into consideration. no impacts, a small impact but not serious, serious impact but not irreversible and irreversible

Table 1. criteria and impacts used for feasibility and prioritization of the project

Features	Impacts
Topography	Impact on houses built along the road
Natural Environment	Impact on agricultural land
Resettlement	Impact on grazing land for sheep, cows
Upper Reservoir and Excavation Sites	Impact on topography (erosion, landslides)
Proximity of main city	Impact on Landscape
Route for Transmission Line	Impact on Flora Impacts on natural and social conditions
Total Evaluation Scores	

The criteria which are given in table were evaluated and scored according the situations which are stated in table 2. The scored were sum up together and compared which each other. The alternative which took the highest score was identified as the most feasible location.

Table 2. scoring system and criteria determining the values of the scores

2	It is economically superior and there are no significant natural/social environmental impacts expected/ no impact
1	It is economically superior, and there are natural/social environmental impacts or technical problems/small impact but not serious
-1	It is economically feasible and there are natural/social environmental or technical problems expected/ serious impact but not irreversible
-2	It is uneconomical or there are significant natural/social environmental impacts or technical problems expected/ irreversible

In this study the location of Gokcekaya dam in Eskisehir, Sariyar dam in Ankara, were investigated using Google earth for feasibility of pumped-hydro storage projects. According to the available data the probabilities of the projects were perused based on affecting parameters were in literatures. The possible downfall height of the Gokcekaya and Sariyar's PHSS could be 960m and 430 m, respectively in case of implementation. The ranking evaluation is done considering elevation between tow reservoirs, length of penstocks, hydro-morphological condition of the current reservoirs, land acquisition, resettlement and distances from electric grids, substations and major cities and their impacts.

Figure 1. Gokcekaya dam reservoir Eskisehir google map image

Figure 2. Sariyar dam reservoir Ankara google map image

Results and Recommendation

It was figured out that Gokcekaya dam in located in Eskisehir with the highest elevation and its proximity to the major cities and electric grids is more feasible. Sariyar dam located in Ankara province due topography, it is effects on agricultural lands, roads and houses and insufficiency of its upper reservoir was figured out as the second to be feasible.

Big industrial countries like USA, China, Japan and Germany recognized the important of energy storage and role of pumped hydro storage systems, therefore they have started investigation on them over decades before. İt is recommended that Turkey government should carry out a large investigation and provide a dataset on it. İdentify the feasible locations and classify them. İn parallel with them the integration possibility of the projects should be studied with respects of the natural conditions of the selected locations and in case of positivity the plans for wind and solar power also should be prepared.

Table 3. evaluation and scoring of the alternatives considering their features and different impacts

Factors/ Alternatives	Sarıyar	Gokcekaya
Topography	1	2
Natural Environment	2	2
Resettlement	1	2
Upper Reservoir and Excavation Sites	1	1
Proximity of main city	2	2
Route for Transmission Line	1	2
Impact on houses built along the road	-1	1
Impact on agricultural land	-2	-1
Impact on grazing land for sheep, cows	1	1
Impact on topography (erosion, landslides)	1	1
Impact on Landscape	-1	-2
Impact on Flora	1	1
Impacts on natural and social conditions	2	2
Total score	**9**	**14**

References

Dinglin L, Yingjie L, Kun Z, Ming Z, (2012) Economic evaluation of wind-powered pumped storage system. *Systems Engineering Procedia* **4,** 107 –115.

Steffen, B (2011). *Prospects For Pumped-Hydro Storage In Germany.* Germany: University of Duisburg-Essen.

Dimitris A, Katsaprakakis, Dimitris G, (2013). Technical details regarding the design, the construction and the operation of seawater pumped storage systems. *Energy*, 619-630.

DSI. (2014) *Devlet Su İşleri Genel Müdürlüğü*. Retrieved from stratejik-planlama-Faaliyet Raporu: http://www3.dsi.gov.tr/stratejik-planlama/faaliyet-raporu

Frilz JJ, (1984) *Small Andmini Hydropowesry Stems Ressurce Assessment and Project Feasibility.* Hamburg: Mcgraw-Hill Book Company.

Henderson PA, (2018). *Ecological Effects of Electricity Generation, Storage and Use.* Boston: CABI.

IEA. (2014) Technology Roadmap Energy storage. *OECD/IEA*.

IHA. (2018) *The world's water battery: Pumped hydropower storage and the clean energy transition.* London: International Hydropower Association.

Kusakana K, (2015). Feasibility analysis of river off-grid hydrokinetic systems with pumped hydro storage in rural applications. *Energy Conversion and Management*, 352–362.

Melhem, Z. (2013). *Electricity transmission, distribution and storage systems.* Cambridge: Woodhead Publishing Limited.

Nazari , M., Ardehali, M., & Jafari , S. (2010). Pumped-storage unit commitment with considerations for energy demand, economics, and environmental constraints. *Energy*, 4092-4101.

Serhat K, (2014). Finding the most suitable existing hydropower reservoirs for the development of pumped-storage schemes:An integrated approach. *Renewable and Sustainable Energy Reviews*, 502–508.

Telford, T. (1990). *Pumped storage.* London: The Institution of Civil Engineers.

Yang C-J, (2015). Pumped Hydroelectric Storage. *Center on Globle Change, Duke University, Durham, NS, USA*.