Advanced Engineering Days

aed.mersin.edu.tr

PV connected Pumped-Hydro Storage System

Ayşenur Oymak*[1], Mehmet Rıda Tür [2] Nouha Bouchıba [3]

[1]Batman University, Electrical Electronic Engineering, Batman, Türkiye, ayse231994@gmail.com
[2]Batman University, Electrical and Energy Department, Batman, Türkiye, mrida.tur@batman.edu.tr
[3]Université de Moncton, Department Faculty of Engineering, Moncton, Canada, bouchibanouha@gmail.com

Cite this study: Oymak, A., Tur, M. R. & Bouchiba, N. (2022). PV connected Pumped-Hydro Storage System. 2nd Advanced Engineering Days, 10-12

Keywords
Energy Storage
Solar system
Mechanical storage
Pumped hydro storage

Abstract

Storage systems are needed to increase the number of renewable energy sources that can be integrated into distribution systems in smart grids and to ensure the continuity of energy. Energy storage can support system operators and provide many services such as energy time shifting, capacity backup, outage management, transmission congestion relief and power quality improvements. Batteries and storage are used due to interruptions and waves in renewable energy sources such as wind and solar. In order to expand the use of clean energy and to ensure energy continuity, mechanical storage methods are emphasized in large power systems. Storage studies have been carried out to increase efficiency, reduce costs and improve storage time. In this study, the stages of the PV integrated system model of pumped hydro storage systems, which is one of the mechanical storage methods, will be mentioned.

Introduction

The fact that renewable energy sources are far from consumption points, the weather forecasting cannot be done well enough, the inability to meet and regulate the continuous power supply has increased the importance of storage systems. Energy storage is a necessary technology that uses stored electrical energy when there is peak load demand. Energy storage has benefits such as increasing grid stability and security. The main technologies developed for energy storage are; electrical, mechanical, chemical and thermal storage technologies [1].

The contribution of energy storage systems to smart grids is expressed as meeting the frequency-controlled, instantaneous and highest power demands. The conversion and storage of energy is done with batteries, compressed air, flywheels, thermal power, ultra/super capacitors, superconductors, and fuel cells [2].

Mechanical energy storage technologies include pumped water-based energy storage systems, compressed air energy storage systems and flywheels. Mechanical energy storage is generally preferred in large power plants. The most preferred mechanical energy storage methods are compressed air storage and pumped hydro storage. In addition, hybrid renewable energy storage systems are important to ensure a high level of power quality and energy management. It is very important to be able to solve power quality problems. Because poor power quality affects efficiency and economy [3, 14]. The hybrid energy storage system can powerfully provide the dynamic load demand supported by the components of the photovoltaic power and grid connection [4].

If we look at some studies on this subject;

Mousavi et al. [5] the effects of the solar connected pumped storage system on the performance of the microgrid during sunny and cloudy times were investigated.

Javed et al. [6] In their study, they examined the studies on solar-wind pumped hydro storage. They concluded that it is a viable option technically and economically and can increase system reliability.

Bhoya et al. [7] In their study, they performed energy analysis and optimization of a hybrid system consisting of a solar system integrated with pumped hydro storage to power a residence.

In the study, the study of the PV connected hybrid storage system is explained and its mathematical expressions are mentioned. As a result of the study, the advantages of the system are given.

Material and Method

PHS is the most common energy storage technology with a round trip efficiency of 70-85%. It remains the most widely used and commercially viable electricity storage technology, especially for large energy storage systems of utility grids. The total installed power in the world is over 127 GW, making up 99% of the global storage capacity [8]. Pumped hydroelectric energy storage stores energy in the form of potential energy of water pumped from a lower reservoir to a higher reservoir. In this type of system, low-cost electrical power (electricity at off-peak times) is used to run pumps to raise water from the lower reservoir to the upper reservoir. During periods of high power demand, the stored water is released via hydro turbines to generate electrical energy. Reversible turbine/generator sets act as pumps or turbines when needed [9]. Pumped hydroelectric storage (PHES) uses mechanical storage to maximize solar energy use and prevent outages. This process is carried out to maximize the use of solar energy [6-8].

Energy Model of the System Components

The studied system consists of different stages that can convert solar radiation into hydro potential energy. First, the photovoltaic cell system works as an energy source. The output of the first stage is processed by a dc-dc converter to feed and electromechanical pump-hydro stage. It follows from this that the pumping system is able to raise a column of water through a water recovery pipe from the bottom to the upper reservoir [10].

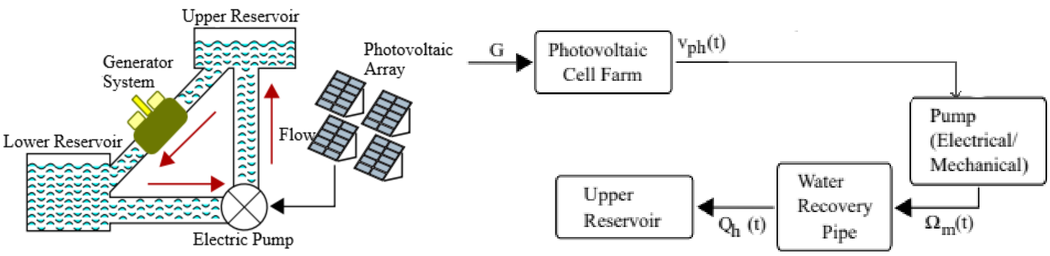

Figure 1. a) Model of the solar-powered pumped-hydro system for energy storage b) System blog diagram

The complete system is illustrated in Figure 1a with a more detailed block diagram given in Figure 1b, where the inputs and outputs of each of the subsystems (domains) are presented. In Figure 1b we see that the system has as input the current due to the sun's G radiation and as output the hydraulic flow Qc. A solar cell, also known as a photovoltaic cell, is an electronic system that converts solar energy into electricity using the photovoltaic effect.

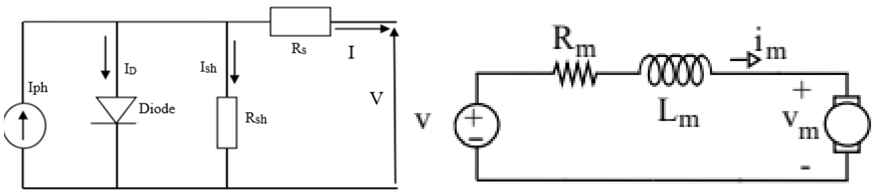

Figure 2 Photovoltaic cell circuit diagram and Pump circuit diagram

A single diode PV circuit diagram is used in the solar model. V output will be the pump voltage. The relationship between the outputs current (I) and voltage (V) of the PV panel for a single unit is expressed as follows [11, 12].

$$I = I_{Ph} - I_0\left(e^{\frac{V+IR_S}{aV_T}} - 1\right) - \frac{V+IR_S}{R_{sh}} \quad (1)$$

A pump is defined electrically and mechanically to store water from the bottom to the upper reservoir. First, the equivalent circuit for the electric field is shown in Figure 2. Inductance Lm stores kinetic energy and in Figure 2 the dynamics of the system is described.

$$L_m i_m = -R_m i_m + v - v_m \quad (2)$$

According to the Biot-Savart Law, the magnetic flux can be expressed as:

$$\emptyset_m = L_m i_m \quad (3)$$

The dynamics of the system, the q_m related to charge storage in the circuit are used. q_m is expressed as the ratio of magnetic flux to inductance.

In PV solar energy, a storage is needed due to the fact that the sun is not continuous, only for daytime production. A continuous supply of electricity can be provided by this solar-connected pumped hydro storage. In addition, the integration of pumped hydro storage with solar also supports supply and demand balance.

During low demand, the pumping process and hydroelectric generation are done during peak demand. Therefore, consumption during off-peak hours is covered by the sun. In the remaining period, power generation is completed from hydro if insufficient solar production is confirmed. Excess solar energy that is not used for consumption in the system is used for storage. In this way, the purchase prices of electricity from the grid are likely to decrease [13]. In order to make the energy management very well in system design, the output power estimations of the PV system are made by methods such as ANN and Fuzzy Logic. The planning and operating process of the power system are a good measure to increase the reliability of these systems. These performance values are examined for the processes of meeting the load demand for hybrid renewable systems. This is due to the power imbalance of the hybrid renewable energy source. Optimization methods are used to correct this. While optimizing the reliability of the system, the process is taken as a constraint or a target to be achieved. The value of the reliability index (IR) can be checked using optimization methods to find the optimal size of the hybrid renewable resource's configuration.

Conclusion

The decrease in energy resources in the world and the search for alternative energy sources have increased the importance of energy storage systems. There is a need for new studies in the field of energy storage in order to ensure the efficiency of existing energy sources and to meet the energy need in a healthy way. This need can be met with new studies to be carried out in the field of energy storage by using developing technological opportunities. However, it is important to consider environmental factors, low cost and high efficiency in such studies. The pumped hydroelectric storage system, which is one of the energy storage systems, provides frequency and voltage stability, and it is predicted that it can meet the hourly energy needs with its integration with the PV solar system. A brief review of a solar coupled hybrid pumped hydro storage system is given. As a result of these investigations; It is said that optimization methods are used to solve the solar problems of the hybrid system and as a result, the ANN model is better. It is stated that this hybrid system provides good balancing in case of high supply-demand variability. The hybrid system can generate and store electricity at low cost in a self-contained solution that faces climate change and reduces its carbon footprint.

References

[1] Kutucu, N., Terzi, Ü. K., & Ayirga, H. Y. (2017, April). Technical and economic analysis of energy storage systems in smart grids. In 2017 5th International Istanbul Smart Grid and Cities Congress and Fair IEEE 166-170.

[2] Nehrir, M. H., Wang, C., Strunz, K., Aki, H., Ramakumar, R., Bing, J., ... & Salameh, Z. (2011). A review of hybrid renewable/alternative energy systems for electric power generation: Configurations, control, and applications. IEEE transactions on sustainable energy, 2(4), 392-403.

[3] Hossain, E., Tür, M. R., Padmanaban, S., Ay, S., & Khan, I. (2018). Analysis and mitigation of power quality issues in distributed generation systems using custom power devices. Ieee Access, 6, 16816-16833.

[4] Jing, W., Lai, C. H., Wong, W. S., & Wong, M. D. (2018). A comprehensive study of battery-supercapacitor hybrid energy storage system for standalone PV power system in rural electrification. Applied Energy, 224, 340-356.

[5] Mousavi, N., Kothapalli, G., Habibi, D., Lachowicz, S. W., & Moghaddam, V. (2020). A real-time energy management strategy for pumped hydro storage systems in farmhouses. Journal of Energy Storage, 32, 101928.

[6] Javed, M. S., Ma, T., Jurasz, J., & Amin, M. Y. (2020). Solar and Wind Power Generation Systems with Pumped Hydro Storage: Review and Future Perspectives. Renewable Energy, 148, 176-192.

[7] Bhayo, BA, Al-Kayiem, HH, Gilani, SI, & Ismail, FB (2020). Bağımsız elektrik üretimi için pompalı hidro-depolama sistemi ile entegre hibrit güneş fotovoltaik pilin güç yönetimi optimizasyonu. Enerji Dönüşümü ve Yönetimi , 215 , 112942.

[8] El-Jamal, G., Ghandour, M., Ibrahim, H., & Assi, A. (2014, November). Technical Feasibility Study of Solar-Pumped Hydro Storage in Lebanon. In International Conference on Renewable Energies for Developing Countries 2014 IEEE (pp. 23-28).

[9] Rehman, S., Al-Hadhrami, L. M., & Alam, M. M. (2015). Pumped hydro energy storage system: A technological review. Renewable and Sustainable Energy Reviews, 44, 586-598.

[10] Phillips-Brenes, H., Pereira-Arroyo, R., & Muñoz-Arias, M. (2019, November). Energy-based model of a solar-powered pumped-hydro storage system. In 2019 IEEE 39th Central America and Panama Convention (CONCAPAN XXXIX) (pp. 1-6).

[11] Al-Masri, H. M., Magableh, S. K., Abuelrub, A., Saadeh, O. (2020). Impact of different photovoltaic models on the design of a combined solar array and pumped hydro storage system. Applied Sciences, 10(10), 3650.

[12] Tur, M.R. S. Ay, A. Shobole, M. Wadi, Güç Sistemlerinde ünite tahsisi için döner rezerv gereksinimi optimal değerinin kayıp parametrelerin dikkate alınarak hesaplanması, Journal of the Faculty of Engineering & Architecture of Gazi University . Vol. (2018) Issue 18, Part 2, p1-20. 20p.

[13] Simão, M., & Ramos, H. M. (2020). Hybrid pumped hydro storage energy solutions towards wind and PV integration: Improvement on flexibility, reliability and energy costs. Water, 12(9), 2457.

[14] Tur. M.R., Yaprdakdal, F. Yenilenebilir Enerji Kaynaklarına Dayalı Bir Sistemde Güç Kalitesi Analizi, Kontrolü ve İzlemesi, Gazi Üniversitesi Fen Bilimleri Dergisi Part C: Tasarım ve Teknoloji, 8 (2020), Sayı 3, 572-587.