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Improving the Management of the Hydropower System as Clean Energy in Mosul Dam according to Water Storage Fluctuation

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ABSTRACT

The production of clean energy from the nature sources is important feature to conserve the environment and to enhance the infrastructure development of a country. The study focused on the Mosul Dam area to build effective system of hydropower production energy based on the analysis of the parameters that impact the water storage in the reservoir behind the dam and the weather conditions. The study took the data of average monthly flow toward the dam then processed the upstream area using ArcGIS Pro program to analyze the geological formation of the area. We used the equation of power production to find the variation in the power production based on the water level of water behind the dam. Number of effective graphs were built and showed by the study to explain the matter of electrical generation to ease the management of these line. The study showed the power production of inlet turbines discharge. We found that about 0.5 MW per one-unit discharge can be reached with 70% efficiency of the turbines system.

Keywords: hydropower, Mosul Dam, inflow rate, rainfall, final water quantity, relative head.

INTRODUCTION

Iraq, country rich in water supplies due to the Tigris and Euphrates rivers, has long recognized hydropower's potential as a clean and renewable energy source. Iraq's hydropower system uses the flowing water of these rivers to produce electricity, leading to the country's energy production and supporting its long-term development goals (Adamo and Al-Ansari 2016). Hydropower is an important part of Iraq's energy mix because it provides a dependable and environmentally friendly source of electricity. With abundant water resources and an increasing need for energy, hydropower development has emerged as a strategic priority for Iraq. It has several advantages, including renewable energy, large-scale generation capacity, and the ability to serve as a backup power source during times when there is an energy shortage (Algburi and Mahmood 2019). Iraq has several hydropower plants that have helped the country meet its energy needs. The Mosul Dam on the Tigris River is one notable facility. It is the country's largest hydropower plant, with a capacity of over 2,000 MW. In addition, the Haditha Dam on the Euphrates River is an important hydropower installation in Iraq. Despite the presence of existing hydropower plants, Iraq has significant untapped potential for future development in this sector (Al-Ansari et al. 2017). The problem of water level fluctuation in Iraq exists as result of the climate of Iraq in which it mostly dry, distinguished by the influence of hot summers and cold but short winters. For that reason, declining in flow rates in the Tigris River have affected the generation of hydropower generation. (Abd El Mooty et al. 2016). The Tigris River sources in the north of Iraq are influenced by the period of snow melting and the water share controlling. These reasons limit the overall quantities of water that flow in the year and lead to that declining in the river that contribute to the variation in the flow rate and as result the water storage behind Mosul Dam (Giovanis and Ozdamar 2023). The government understands the importance of increasing hydropower capacity in order to diversify the source of energy and reduce reliance on fossil fuels. A number new projects are currently in the planning and development stages, with the goal of utilizing the country's water resources to generate sustainable electricity (Adamo et al. 2020). The Al-Rasheed Hydropower Station and the Badush Dam are two projects that are expected to significantly increase Iraq's hydropower capacity (Adamo and Al-Ansari 2020). Iraq gains numerous environmental and socioeconomic benefits from investing in hydropower (Siskian et al. 2021).. The country can reduce greenhouse gas emissions and mitigate the effects of climate change by generating electricity from renewable sources (Wasti et al. 2022). Furthermore, hydropower projects generate jobs, stimulate economic growth, and improve the overall infrastructure and growth of the regions in which they are located (Abdullah and Al-Ansari 2020). The problem of water fluctuation can be solved by better management of water resources in Iraq including the monitoring and modeling of the rivers' flow rates and dams. The dams' management system must covers the upstream and downstream zones based on the water demand for human consumption, irrigation, and hydropower production (Molter et al. 2021).

Hydropower by dams, stands as a force in the renewable energy production (Berga 2016). Dams can store various amounts of water and can control flowrate to make turbines generate electricity (Hogeboom 2018; Zarfl et al. 2015). This sustainable clean energy without emitting unwanted gases, leads to a greener future. The water management in dams can cover the power generation and the agriculture demand. The environmental influencing on ecosystems can be reached by the production of clean energy in which hydropower as innovative solution (Lado et al. 2020). The using of hydropower system as a source for renewable energy is in large development with effective projects in the world (Kougias et al. 2019; Chowdhury 2017). Rivers are great point of view when the hydropower system been studied. The variation of water quantities that moved in a river body can control the ability to product hydropower electricity (Grill et al. 2019; Fick et al. 2015). The topography of the reservoirs behind dams are play important role to figure out the capacity of water storage for better managing the dam (Mehari 2017). GIS data can be processed in specific programs to get the regions of water accumulation toward the reservoir based on the behavior of the contour lines (Tian et al. 2020).

While hydropower has many advantages, it also has some drawbacks that must be addressed. Water resource management, including efficient water allocation and mitigation of potential environmental impacts, is critical for the long-term operation of hydropower plants (Tzoraki 2020; Corà 2020). Furthermore, ongoing political stability and infrastructure investment are critical to realizing Iraq's full hydropower potential. Iraq's hydropower system has significant potential for meeting the country's rising energy demands while promoting sustainability (Ahmad-Rashid 2017). Iraq is poised to further harness the power of its rivers and strengthen its position as a regional leader in hydropower generation, thanks to abundant water resources and ongoing project development. Iraq can achieve a more diverse and sustainable energy sector by strategically expanding its hydropower capacity, thereby supporting economic growth as well as environmental stewardship (Uddin and Uddin 2018). In this research, the contribution of Mosul dam to the generation of electrical energy was investigated by analysis the monthly inflow rates and the water balance resultant based on the variation of the water elevation to figure out the productivity of hydropower energy.

METHODOLOGY

Collection and processing of data

The research built the analysis and modeling route by collecting the data of GIS system, the flow rates, the rainfall intensities, and the evaporation rates from the Iraqi Ministry of Water Resources. The data were obtained for the years 2012 to 2022. All the data were showed in the related figures and processed in the scientific analysis of this study. As the research used the data of GIS system that related to the area of Mosul Dam reservoir, it get the topographic behavior of the region and the storage variation according to the inlet quantity of water toward the reservoir and the relative participation and evaporation rates. The mapping work on the Mosul reservoir area was explained in Figure 1. The topography that analyzed by ArcGIS program were converted to the data in Table 1. For moving forward the aim of the research, the data in Table

2 were gained from the Iraqi ministry of water resources and the Iraq. The monthly flowrates and their variation are important to get the fluctuation in water elevation behind the dam as the water head is considered in the generation of hydropower system as explained in this research. The data of monthly rainfall intensity, monthly flow rate, and monthly evaporation rates were obtained from Iraqi Ministry of Water Resources. These data were explained in Figures 2, 3, and 4.

Analysis of data

The equation for identifying the hydropower electricity is written as (El-aziz and El-salam 2007; Tzoraki 2020):

$$p = \alpha \times \gamma \times Q \times H \quad (1)$$

where: P – generator output in (kW), Q – water flow through the turbine (discharge) in (m^3 /sec), H – net head of water (m), (the difference in water level between upstream and downstream of the turbine), γ – specific weight of water (N/m^3).

The head of water behind the dam was calculated according to the resultant of the inflow rates, the precipitation rate, and the evaporation rate as the following equation (Song et al. 2022; Fowe et al. 2015):

Table 2. The monthly resultant of accumulative storage and the change in water

Month	∆S	h (m)
January	2310	7
February	3812	5
March	3814	0
April	2939	-3
May	1826	-3
June	724	-3
July	-363	-3
August	-930	-2
September	-1180	-1
October	-1254	0
November	-997	1
December	116	3

Table 1. The processing of the geological data of Mosul Reservoir area

Contour minimum (m)	Contour maximum (m)	Area between contour lines (km^2)	Volume between contour lines (*10^6 m^3)	Total volume (*10^6 m^3)
280	300	12.38	247.6	247.6
300	320	324.57	6491.4	6739
320	340	246.85	4937	11676
340	360	390.76	7815.2	19491.2
360	380	346.78	6935.6	26426.8
380	400	263.91	5278.2	31705
400	420	191.28	3825.6	35530.6
420	440	209.12	4182.4	39713
440	460	141.04	2820.8	42533.8
460	480	46.74	934.8	43468.6

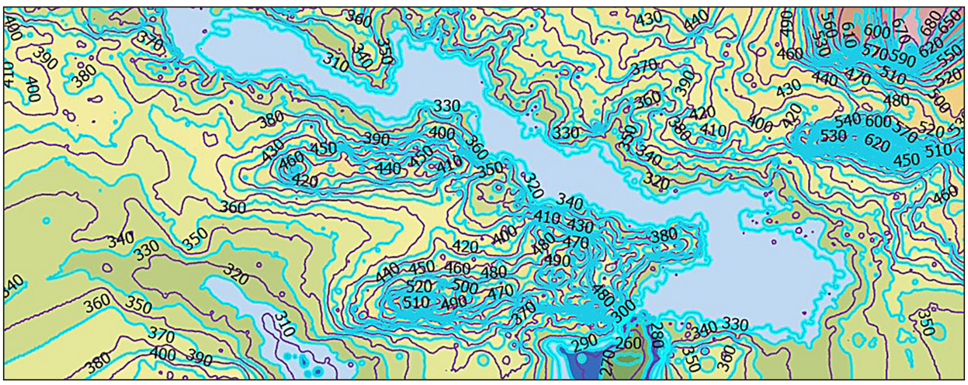

Fig. 1. The geological processing of Mosul Dam reservoir area by ArcGIS pro

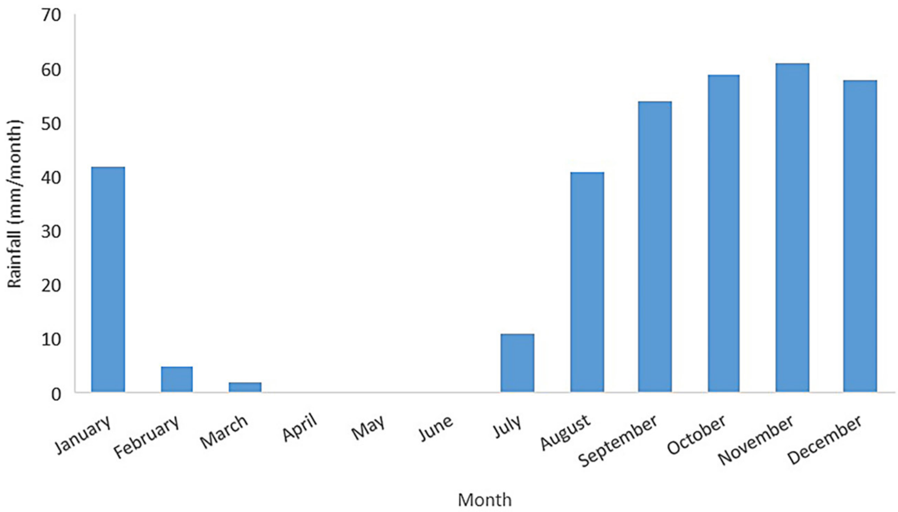

Fig. 2. The monthly rainfall intensity in Mosul Dam region

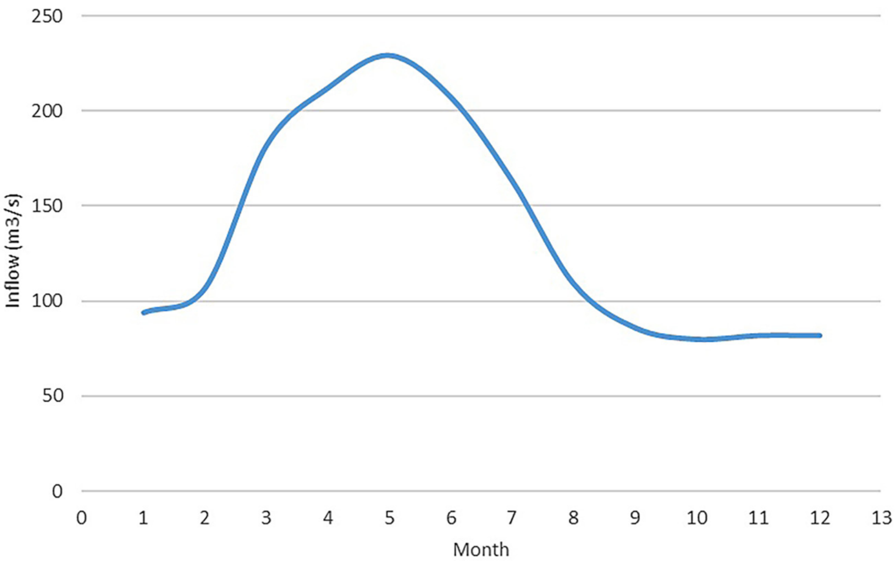

Fig. 3. The monthly inflow rate toward Mosul Dam reservoir

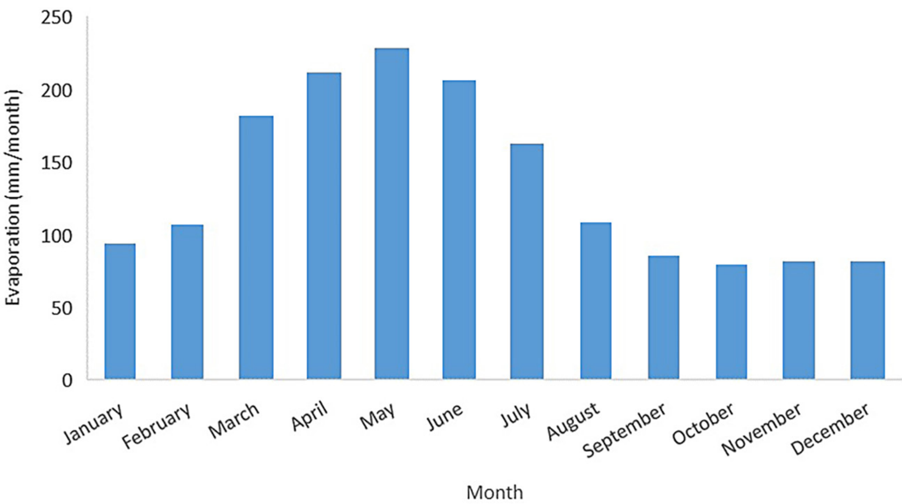

Fig. 4. The monthly evaporation rate in Mosul Dam region

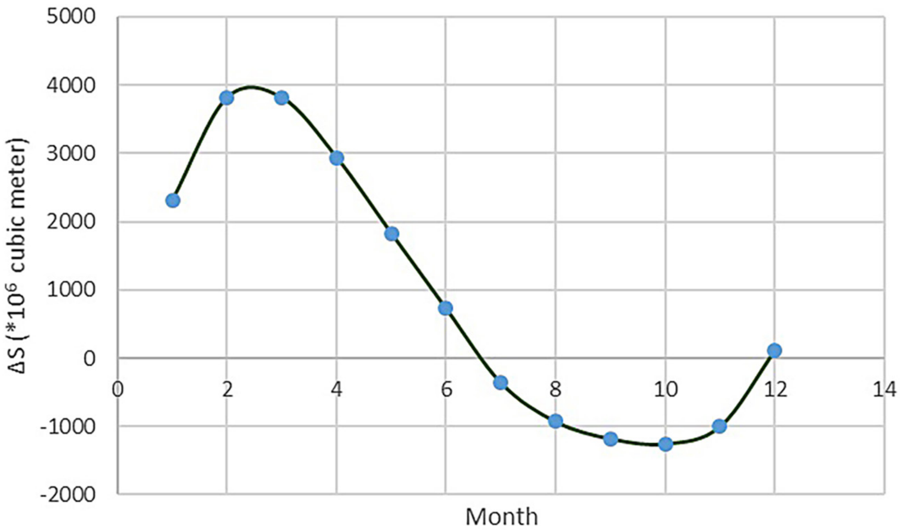

Fig. 5. The monthly resultant of accumulative storage in Mosul reservoir

Table 3. The monthly relative water head and the power production

Month	*H* (m)	*P* (*MW*)/*Q*
January	77	0.53
February	75	0.51
March	70	0.48
April	67	0.46
May	67	0.46
June	67	0.46
July	67	0.46
August	68	0.47
September	69	0.48
October	70	0.48
November	71	0.49
December	73	0.50

$$\Delta S = (R * \sum A + E * A_r + Q)\,T \quad (2)$$

RESULTS AND DISCUSSION

The resultant of accumulative storage changes from January and the variation of head change from the relative change of elevation between the upstream and the downstream zones is explained in Table 2, Figures 5 and 6. The H value in the hydropower equation can be obtained by adding the value of h to the typical difference in elevation between the reservoir and the downstream area which is 330 and 260 m respectively.

$$H = h + 70 \quad (3)$$

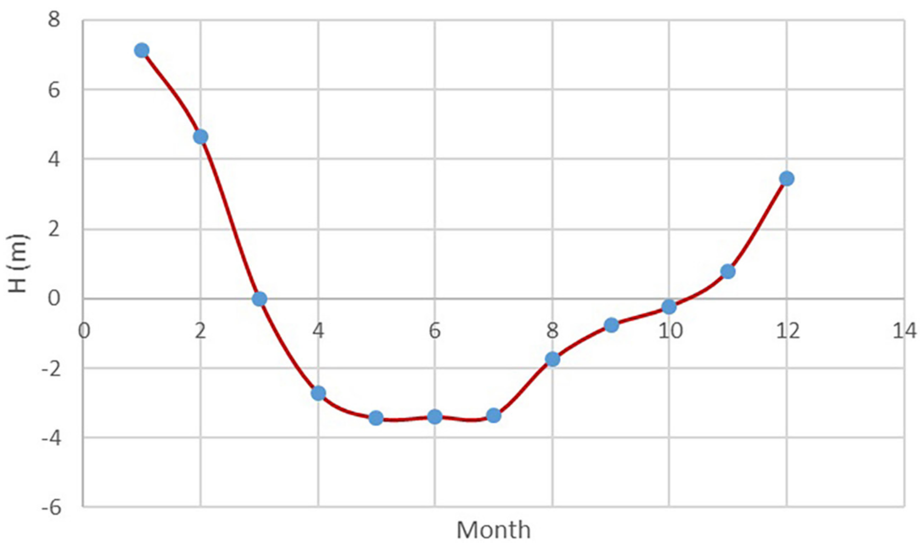

Fig. 6. The monthly variation of height quantity in Mosul reservoir

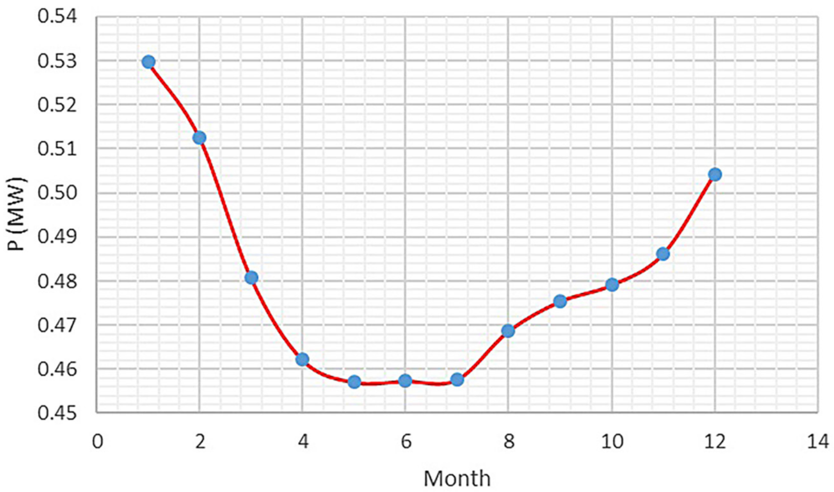

Fig. 7. The monthly power production per one unit of turbine inlet discharge

The values of final relative head in each month and the power productivity were showed in Table 3 and Figure 7. The study showed noticeable lacking of water storage behind the dam from April to August, these reduction in water storage can be managed by the controlling of water demand and use better ways of irrigations system to conserve the downstream water flow rates in these periods. The study showed great contribution for these management by the determination of the relative head in each month. The relative head can be obtained as index for the availability of the dam to produce sufficient hydropower energy. The variation in the hydropower generation in Mega-Watt per flow rate unit was expectable according to the fluctuation of water storage behind the Mosul Dam.

CONCLUSIONS

The productivity of electrical power as clean energy was examined by the study in Mosul Dam by using hydropower system. The study found that there are considerable fluctuation in the resultant relative head of water behind the turbines at which it impact the power generation. The inlet discharge to the turbines was taken as average value 500m^3/s. The study processed the upstream area using ArcGIS pro program. The study showed high increment of the relative total head in the months of (December, January, and February) these fact related to the decreasing of the evaporation that can cause considerable losses in the water body. The increasing of rainfall intensity in these period lead to raise the water level in the reservoir. The study showed in graphs the variation of the resultant accumulative storage data and the relative head. The production of electrical power was found by the study as magnitude of MW of electricity per one unit of discharge toward the turbine system. The generation power can reach about 50 MW/s if the inlet discharge toward the turbines equal to 100 m^2/h. The study results can be used to enhance the development of the clean energy to set more turbines system and to manage the reservoir storage to get sufficient water quantity without spreading more than the calculated demand. The study concepts lead to improve the management system of the Mosul Dam by identifying the relative head behind the dam. The relative head can be used as index for both the available water storage and the capability to produce sufficient hydropower energy. The productivity of hydropower energy per unit flow rate that reached by the study can be considered as effective item to improve the public electrical network in Iraq and to put more consciousness to product the clean energy as scope of the sustainable development.

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