INTERNATIONAL BURCH UNIVERSITY

FACULTY OF ENGINEERING, NATURAL AND MEDICAL SCIENCES

ELECTRICAL AND ELECTRONICS ENGINEERING

RENEWABLE ELECTRICAL ENERGY SYSTEMS

Topic: Grand Ethiopian Renaissance Dam

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1. INTRODUCTION

The Grand Ethiopian Renaissance Dam (GERD), a gravity dam on the Blue Nile River, is a pivotal project in Ethiopia's mission to be energy self-sufficient. A gravity dam is a dam constructed from concrete or stone, designed to hold back water by using only the weight of the material and its resistance against the foundation.

Under construction since 2011, the dam should address energy shortages and become the largest hydroelectric power plant in Africa. The planned capacity is 5.15 gigawatts (GW). Located 14 km east of the Sudanese border in the Benishangul-Gumuz Region, the GERD has strategic significance for Ethiopia's regional ambitions.

FIGURE 1. Grand Ethiopian Renaissance Dam's Location

(Reference: https://news.chapman.edu/2021/11/18/chapman-research-study-heightens-concerns-about-the-safety-of-a-massive-dam-project-in-africa/ , retrieved: December 29, 2023)

This paper goes through the historical context, technical aspects, and its impact on international relations, focusing on the ongoing challenges and controversies. The filling of the reservoir in phases, started in 2020, presents certain complications for downstream nations. Despite its potential benefits, the GERD has sparked disputes, particularly with Sudan and Egypt, raising concerns about water security and geopolitical tensions.

2. HISTORICAL CONTEXT

In this part of the paper, the key principles behind the planning of this project and the historical significance of the Nile River will be discussed.

2.1. ORIGINS AND PLANNING

The site of the dam was identified when the US Bureau of Reclamation made a survey between 1956 and 1964. After surveys in 2009 and 2010, the design was submitted in 2010. The Ethiopian Government kept this design as a secret until one month before laying of the foundation stone. The filling of the main water reservoir (artificial lake) is completed in phases. *(Grand Ethiopian Renaissance Dam Project, Benishangul-Gumuz)*

Phase one began in July 2020 when the water levels increased to 540 meters. That is 40 meters above the Nile river bottom at this location. *(Ethiopia: First stage of the filling of the reservoir of the Grand Renaissance Dam". Tractebel Engie. 10 September 2020.)* The second phase finished in July 2021, with rises to 575 meters. The third filling was completed in August 2022, with rises to around 600 meters. The fourth filling was completed in September 2023, with rises to 625 meters. It is estimated that in 4 and 7 years the filling of the main reservoir will be completed.

2.2. THE NILE RIVER BASIN

The Blue Nile, originating in Ethiopia, meets the White Nile in Khartoum, before flowing through the Nubian Desert into Egypt. By this point, the majority of the water is from the Blue Nile. Ethiopia, often called Africa's water tower, has over twenty dams fed by highland rainfall.

The reason for tensions is the Grand Ethiopian Renaissance Dam. While intended for electricity generation, its completion will have Ethiopia holding a significant portion of the Nile's water, drastically reducing the flow into Egypt.

3. TECHNICAL ASPECTS

Technical aspects include the design (Figure 2), construction and layout of the dam (Figure 3), reservoir capacity and operational principle, as well as environmental aspects of the GERD.

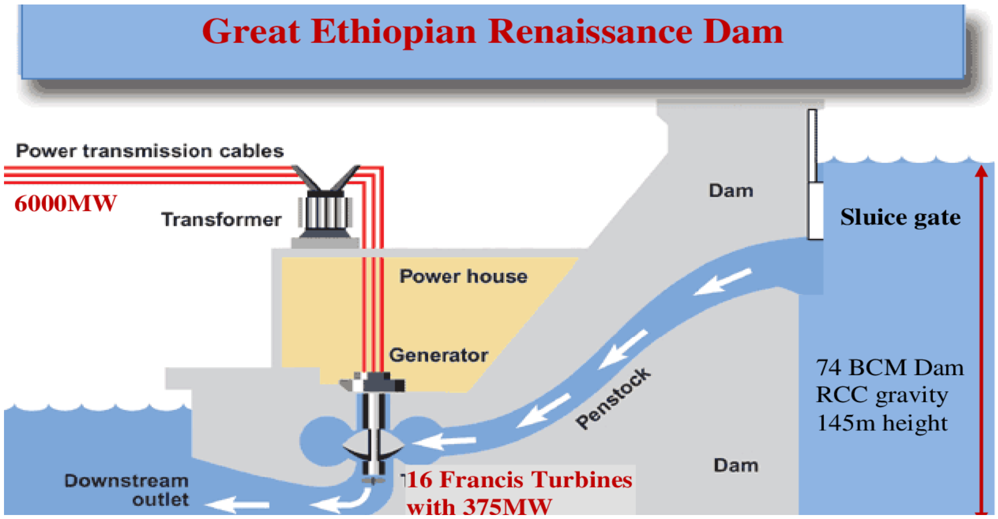

FIGURE 2. Schematic Representation of the GERD

(Reference: Grcheva, Irina 2015-2016)

3.1. DAM DESIGN AND CONSTRUCTION

The river diversion system, capable of discharging 14,700 m³/s, includes canals for dry season discharge and a temporary spillway for dam overtopping during the wet season. The roller compacted concrete (RCC) Main Dam, with a height of 175 m, stands as the central structure with a volume of 10.2 million m^3. The Main Dam has sections that fight against overflow. The concrete faced rockfill (CFRD) Saddle Dam, 60 m high and 5 km long, is crucial in preventing water from spilling out. *(Ethiopian Electric Power Corporation (January 2009))*

Three spillways include the service main gated spillway, free-flow spillway, and side channel un-gated spillway. Together, they protect against the probable maximum flood. The dam has two steel outlets for reservoir level control, sixteen penstocks (pipes) for electricity generation, and two outdoor power houses housing 16 Francis turbine units with a capacity of 6,000 MW. A 500 kV substation and transmission lines are present as well. Additionally, 85 monolithic blocks improve the dam's resilience.

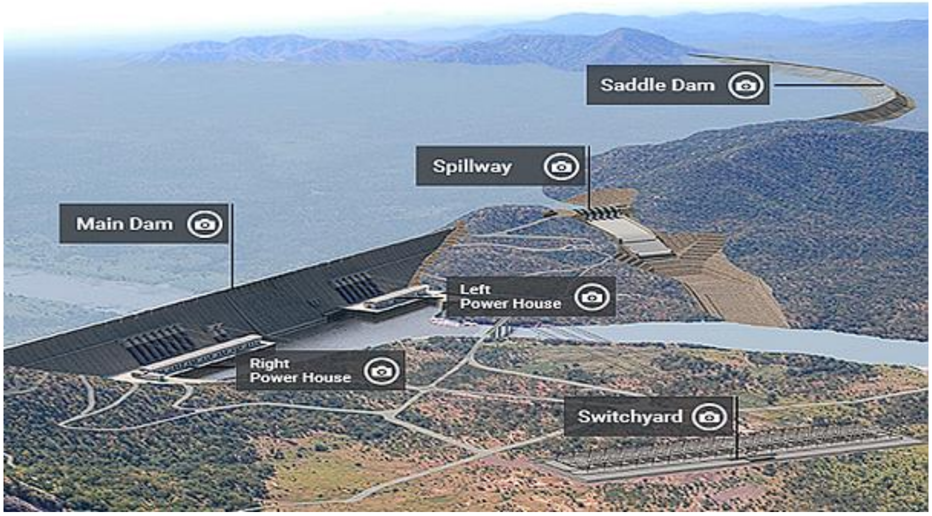

FIGURE 3. General Layout of the GERD

(Reference: Hagar ElBarbary (2021))

3.2. RESERVOIR CAPACITY AND OPERATION

As already mentioned, the filling of the main water reservoir (artificial lake) is completed in phases. The GERD had significant changes in its parameters over time. After assessment in 2013, adjustments were made. This included a main dam height increase to 155 m and a volume rise to 10.2 million cubic meters (m^3). The rock-filled saddle dam's height increased to 50 m, with a volume of 16.5 million m^3.

The reservoir, formed by both dams, has a storage capacity of 74 km^3 and a surface area of 1,874 km^2 at a full supply level. Power generation occurs between reservoir levels of 590 m and 640 m. An un-gated spillway is activated in extreme flood scenarios. GERD’s reservoir, with a strategic location and large volume, has the potential to enhance hydropower efficiency across borders.

4. ENVIRONMENTAL IMPACT

The GERD has raised concerns regarding environmental impact, prompting the NGO International Rivers to commission a field visit due to limited available information. The dam's impact on Ethiopia includes a reduction in downstream flooding, benefiting settlements and their agriculture. Resettlement of over 5000 people and significant changes in fish ecology are a concern. The impact on downstream countries, Egypt and Sudan, remains uncertain, with fears of water reduction and evaporation. *(Kamara, Ahmed, Mohamed Ahmed, and Arturo Benavides. 2022)*

Dam confinement in the high-water period prevents the downstream forest from being damaged by flood and increase the vegetation coverage in the upstream. However, around the GERD, an overall decrease in vegetation is seen (Figure 4), compared to the period before the dam construction.

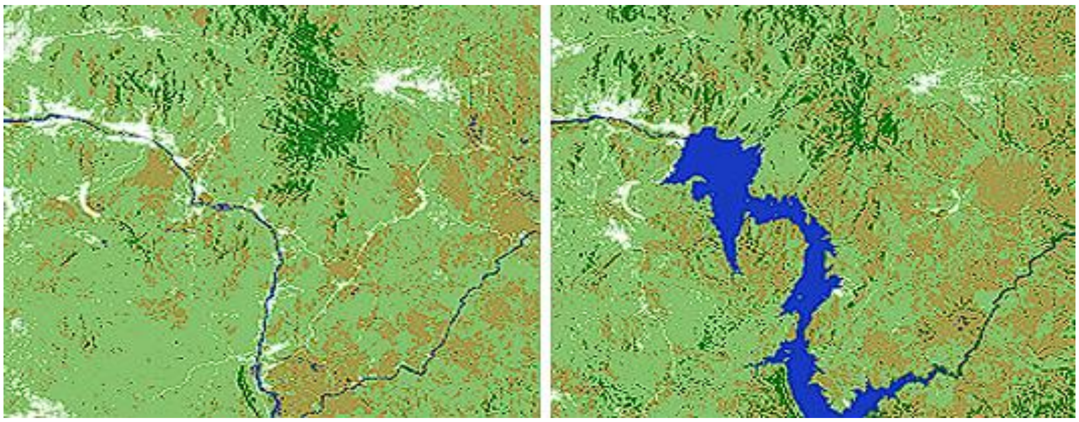

FIGURE 4. The Vegetation around the GERD in 2013 (Left); vs in 2021 (Right)

(Reference: Pengyu Chen et al 2022)

Since the dam slows down the water flow, suspended particles are reduced in it. Although this improves the water quality, it also makes the land along the downstream coast less fertile. This means that the land around Nile in Egypt, will be much less suitable for agriculture. Soil will be salinized because the seawater will naturally pour into freshwater with Nile levels decreasing.

5. CONTROVERSIES

The GERD has been a source of controversies, involving Ethiopia, Egypt, and Sudan. The Ethiopia's neighbors could have a lot problems in the future, caused by the dam's construction (Figure 5). The experts raised concerns about the dam's structural integrity, pointing out the potential risks related to the rock basement. Additionally, questions were raised about the economics of the dam, with critics suggesting that a smaller dam would have been more cost-effective. Its price was around $5 billion which is about 4% of Ethiopia's entire GDP for the year 2022.

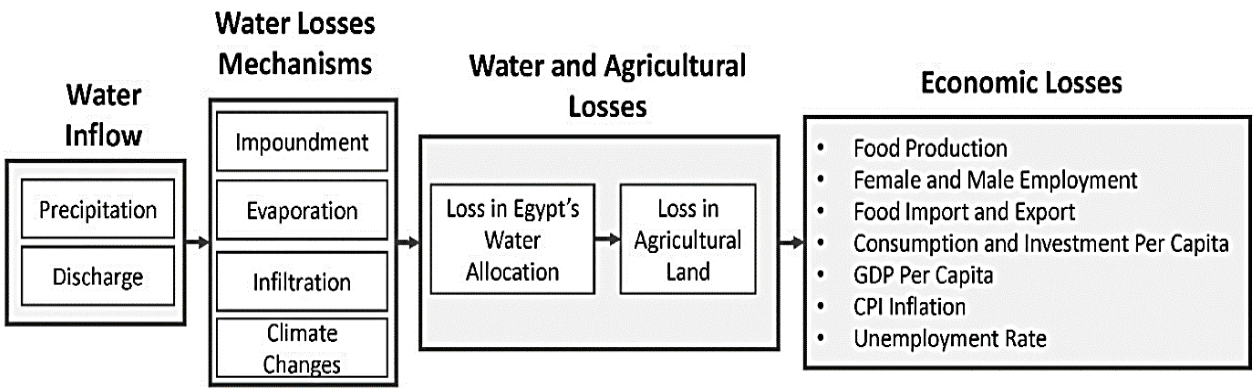

FIGURE 5. A Diagram showing the Water and Economic Losses for Egypt that can be caused by GERD

(Reference: Kamara, Ahmed, Mohamed Ahmed, and Arturo Benavides. 2022)

One of the main points of contention is the impact on the downstream countries, particularly Egypt and Sudan, who fear a reduction in Nile River flow (Figure 6). The filling of the dam's reservoir is a significant concern, with Egypt worrying about both temporary and permanent reductions in water availability. Ethiopia filling the dam's reservoir can potentially reduce Nile flows by as much as 25%.

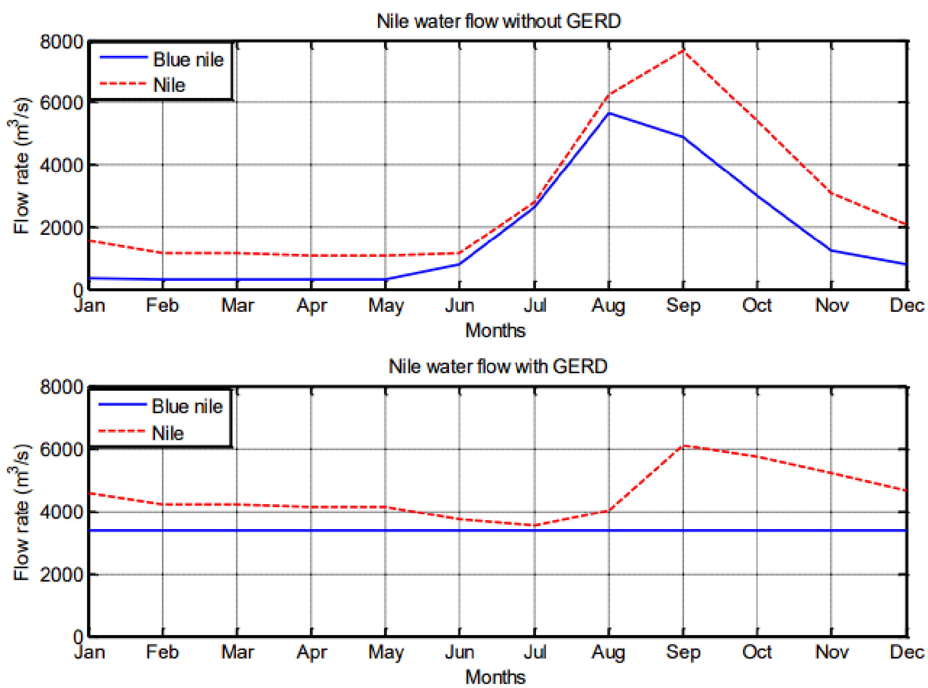

FIGURE 6. Nile Water flow affected by the Construction of the GERD

(Reference: Tesfa, Belachew (2013))

The fillings, estimated to take anywhere from 3 to 15 years, complicate negotiations, as each country wants to protect their interests. Sudan and Egypt both insist that there should be a three-side agreement on the filling of the reservoir, as well as other segments once the GERD starts fully generating power. Sudan is mostly worried about the safety and damages that GERD can create. Political tensions have escalated, with Egypt purchasing air defense systems and threatening to commit airstrikes on the dam. The lack of agreement on the dam's operation and filling procedures has led to negotiations being stopped multiple times.

7. CONCLUSION

The Grand Ethiopian Renaissance Dam (GERD) is a monumental infrastructure project. It is driven by Ethiopia's goal for energy self-sufficiency. It would become the largest hydroelectric power plant in Africa, with a 5.15 Gigawatt capacity. That would double Ethiopia's production of electricity, to which only half of the country's population of 120 million currently has access.

Despite its benefits, the dam a caused different historical, technical, environmental, and geopolitical controversies. The historical context emphasizes the Nile River's significance and the tensions because of Ethiopia's control over a significant water portion. Technical aspects, including design, construction, and operational principles, illustrate the nature of the project, while environmental concerns raise questions about downstream impacts.

Controversies involve structural integrity concerns, economic considerations, and disputes with downstream nations, particularly Egypt and Sudan. The main reservoir raises fears of reduced water flow, ecological shifts. This creates large political tensions, even having war threats.

Large diplomatic efforts are needed to resolve the issues between the three countries. International involvement will play a crucial role, as already done by the United States and the United Arab Emirates. Additionally, established frameworks from the past, like the Nile Basin Initiative and the Cooperative Framework Agreement can help reach a fair and sustainable solution.

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