

SEA LEVEL RISE IMPACTS; EVALUATION AND ADAPTATION ON DEVELOPMENT PROJECTS IN DELTA'S COASTAL REGION IN EGYPT

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ABSTRACT

This paper predicts impact of sea level rise (SLR) on the micro-hydropower generation from Idfina barrage and submits a proposal to adapt the negative effect. Idfina barrage was constructed on Rosetta Branch. It is located 18 km far from the Mediterranean Sea, which reserves the sea water to overcome to the Nile River. Three scenarios referred to the discharge, net head and turbine's level are suggested, taking into consideration cases studies of SLR; (1) Pessimistic case, that consider the sea water level change according to (IPCC) plus the subsidence value, according to CoRII (Study1 in Coastal Research institute, CORI), which means SLR is expecting maximum rises. (2) Normal case; which is the base situation, which mean the actual measurements of SLR according to CoRI2 (study2 in CoRI) are used. (3) The optimistic case, which is the sea water level rise referred to (IPCC) only, which means SLR is minimum. Mathematical model is used to determine the different impacts of the sea level rise on the electric generation. Analyzing different levels of turbine is taken place to adapt the negative impact of SLR. Results concluded that; all cases of SLR have adversely impact on the hydropower generation. Reduction in generated power without adaptation in maximum and minimum sea level for scenarios with cases; pessimistic and optimistic are recorded 54% and 29%, respectively. Reduction in generated power with adaptation in maximum and minimum sea level for scenarios with cases; pessimistic and optimistic are decreased to 43 % and 15%, respectively.

Keywords: Coastal Region, Sea Level Rise, Hydropower

1. INTRODUCTION

In recent years, impact of climate change has become very important topics of study, especially on developing countries. Rising temperatures as a result of increasing greenhouse gas emissions will have a major impact on the global climate. According to the 4th assessment report of the Intergovernmental Panel on Climate Change (IPCC), by 2080's the average temperature will be 30C warmer than 1990, [1]. One of the most pronounced effects of rising temperature has been melting masses of ice around the world and sea level change. Developing countries are certainly identified mainly at risk. The consequences of sea level rise (SLR) for population location and infrastructure planning in developing countries should definitely be reviewed by the developing world, [2]. Egypt is among the countries which will be greatly affected by climate change, especially its coastal regions.

The Nile Delta region in the Mediterranean coastal zone represents the major industrial, agricultural, and economic resource of the country. Delta is home to over 50 percent of Egypt's population of 80 million and to about 70 percent of the nation's industrial and commercial activities. It is characterized by relatively low land elevation, which leaves it severely exposed to rising sea levels. Moreover, it suffers from local land subsidence, compounding the effects of rising seas. Some estimates indicate that the northern delta region is subsiding at a rate that varies from about 0.6 millimeters annually at Alexandria to about 3.5 millimeters annually at Port Said,[3]. The amount of water released from Idfina barrage is very important to satisfy the environmental security Delta region. Now days, new project proposed a rehabilitation of Idfina barrage. Therefore, it is very important how to take advantage of the rehabilitation to generate hydropower from the barrage .

Hydropower represents fifth of all global electricity production in the world. It is one of the world’s most widely used renewable, low-carbon energy resources. It plays an important role in enabling communities around the world to meet their power and water needs,[4]. Technical, hydropower plants emit very few greenhouse gases in comparison with other; fossil fuel powers; large scale energy options and thus helps slowing down global warming, [5].

Several studies have investigated the impact of climate change and sea level rise on coastal region, among these researches; Elsharkawy H., et al,[2] studied the impacts of sea level rise on Egypt and concluded that adaptation to climate change in Egypt is a major issue from the perspectives of food production, rural population stabilization, and distribution of water resources. Raymond G. Najjar and et al, [6] assessed the potential impacts of climate change on the mid-Atlantic coastal (MAC) region of the Unified States. A case study for Delaware based on digital elevation models suggests that, by the end of the 21st century 1.6% of its land area and 21% of its wetlands will be lost to an encroaching sea. Sea-level rise will also result in higher storm surges, causing 100 yr floods to occur 3 or 4 times more frequently by the end of the 21st century. S. Williams, [7] expected the change of SLR will accelerate and rise 1 meter or more in the Mississippi River Delta Plain. Mohamed Elray, [8] studied the implications of climate Change for the Coastal Zones of Egypt. Other studied have investigated the role of hydropower in the sustainable development, among these researches; the aim of this research is assessment and mitigates the impact of the Mediterranean Sea level rise on micro- hydropower generation from Idfina barrage using the previous scenarios of IPCC and the two studies of Coastal Research Institute .

2. STUDY AREA DESCRIPTION AND ACCUMULATING DATA

Idfina Barrage is the main corridor linking the province of Kafr el-Sheikh and the provinces of the El Beheira and Alexandria, which lies at the end of the village Idfina city. The importance of Idfina barrage is preventing leakage of fresh water to the sea as much as possible and do not allow to enter the salt sea water to the course of the Rosetta Branch. The barrage gates faced with the problem of exposed to a direct effect of sea water located behind the barrage .

Available data for SLR belongs to Alexandria costal area, as Idfina is located on the borders of the coastal area of Alexandria governorate, and any increase in SLR would affect this region, Alexandria costal data measured for SLR will be used. Many types of data are collected; Water levels upstream and downstream of the barrage and the different discharges on turbines for different years; from 1998 to 2005. Table 4 and table 5 tabulated the maximum and minimum discharges and net head on turbines. Many studies indicate that, sea levels are expected to continue to rise, and the rate of increase will likely accelerate. In order to evaluate the effect of sea level rise on the Idefina barrage; three cases corresponding to SLR will be considered. First case, related to the Intergovernmental Panel on Climate Change (IPCC), where developed future emission scenarios that differ based on assumptions about economic development, population, regulation, and technology(1), (table1 includes the low (B1) and high (A1F1) risk probabilities). Second and third cases, (CoRI1 and CoRI2; studies carried out by Coastal Research institute), tables 2, 3, [3]. Table 2 represents the projected low and high average annual sea level rise related to year 2000. While table 3, summarized annual trends and expected sea level rise until 2100 according to field measurements for CoRI.

Table 1. Sea level rise according to IPCC

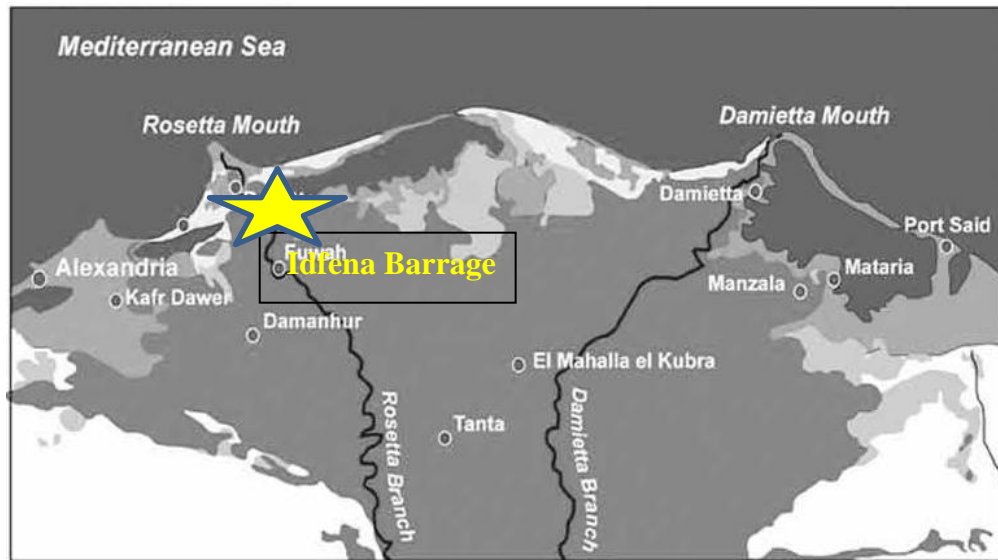
Scenarios	SLR, (m at 2090-2099 relative to 1980-1999)
B1	0.18 – 0.38
A1F1	0.26 – 0.59

Table 2. Annual SLR (m) relative to year 2000 consider CoRI 2007

Alexandria	Scenarios	2025	2050	2075	2100
	B1	0.07	0.16	0.27	0.28
	A1F1	0.13	0.34	0.55	0.72

Table 3. Trend and expected sea level rise according to CoR2 2007

Alexandria	Average SLR/ year (m)	SLR m 2025	SLR m 2050	SLR m 2075	SLR m 2100
	0.016	0.04	0.08	0.12	0.16

**Fig. 1: Study area region (Idfina Barrage)**

3. PROBLEM DEFINITION

Nile Delta region is the most vulnerable regions in Egypt to SLR, which is the closest region to the sea. Idfina Barrage of the oldest arches which was held to keep the waters of the Nile where it has been built since 1959. At present, Idfina barrage suffers from corrosion sector-iron gates due to increase the concentration of salt in the water, which speeds up the rate of occurrence of rust. This lead to leakage through vents which is estimated by 6 million cubic metres/year,[9] this means lost a part of Egypt's share of water without the benefit. In addition there is still no vision to use this lost amount of water and to use it in the development of the region such as re-distributed to farmland irrigation of crops or used in industry. Herein lies the problem, how it can manage the barrage to develop the region?. This approach introduces a vision for management the barrage in economically method after the rehabilitation; in addition to study the negative effects of SLR on hydropower generated from the barrage. Also the study introduces a proposal to mitigate the negative impact for SLR

4. THE MEHODOLOGY AND THE SCENARIOS OF GENERATION

The methodology is classified into three main modules;

- Module 4.1 gives details about the scenarios of hydropower generated.
- Module 4.2 represents the developed model which is used in hydropower generated and scenarios implemented.
- Module 4.3 shows the adaptation method to overcome the negative impact of SLR.

4.1 Proposed Scenarios for Hydropower Generation

Many techniques are used in hydropower generation. Depending on the nature of the study location; there are two methods for the generation.

a) Generated power based on the discharge (Q) and head on turbine (H).

b) Generated power based on the velocity of the flow where the velocity must be at least 0.5 m²/sec, [10]. Depends on the rehabilitation method of barrage, generated hydropower technique will be discussed. The expected hydropower generation will be carried out in two techniques;

1) First one is closing some vents. So the flow and discharge is increased. In this case hydropower generation is preferred to using the discharge (Q) and head (H).

2) Second one All vents will be remained as they are, so generation hydropower is useless because the discharge will be distributed on all vents where its value is very small. Measurements in the study location gives velocity is less than 0.5 m²/sec. So the generated power is not achieved a good results. It is recommended; the first techniques is more suitable for hydropower generation from the barrage; figure 2 explains the following flow chart in the methodology for generated hydropower in both; SLR impact and adaptation technique. Three scenarios referred to the discharge on turbine with respect to the different cases from SLR are proposed as following;

1- First scenario, "S1", deals with the current or base situation for available discharges from 1998/1999 to 2004/2005 and upstream water level of the barrage with taking into consideration the SLR actual measurements cases according to CoRI2, data which is used in this case tabulated in table 3.

2- Second scenario, "S2", addressed with data of year 1998/1999 as a sample for the maximum discharge by considering the different cases of SLR according to IPCC, and CoRI1, data related to different cases of SLR tabulated in tables 1 and 2, respectively

3- Third scenario, "S3" addressed with data of year 2004/2005 as a sample for the minimum discharges considering the different cases of SLR, IPCC and CoRI1.

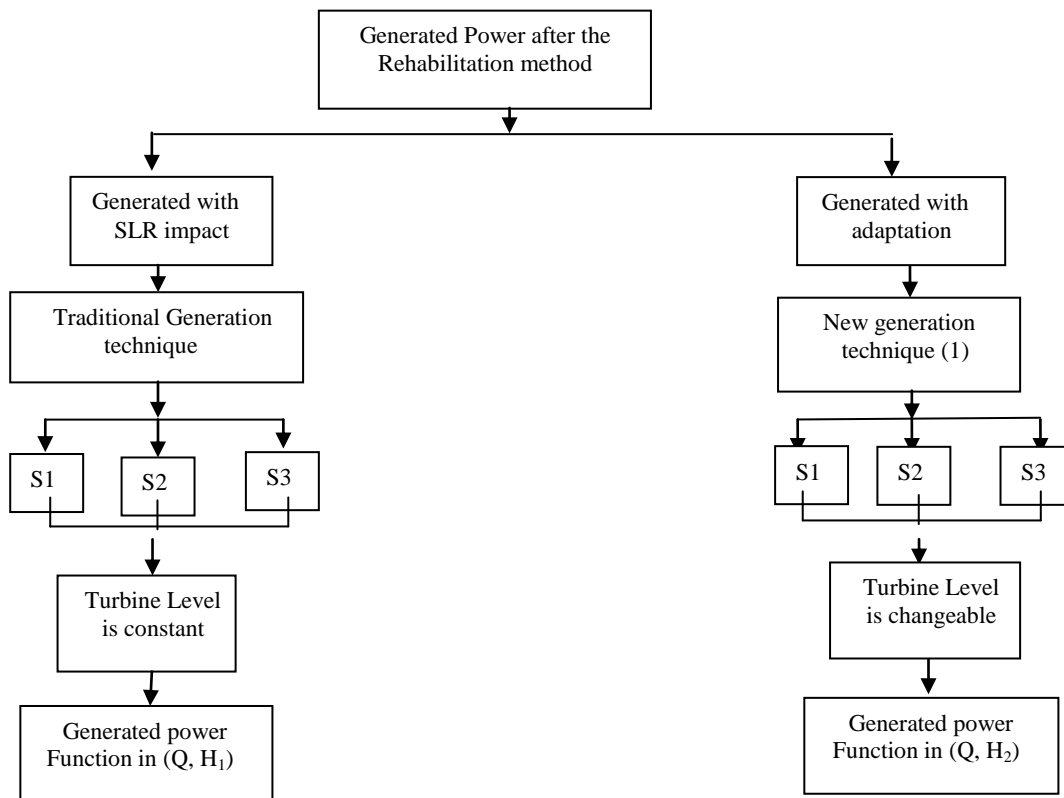


Fig. 2: Methodology flow chart

4.2 Developed Model and Scenarios Implemented

4.2.1 Developed Model

To generate the hydropower from the barrage, mathematical model is developed using Excel program considering all conditions; SLR cases which is tabulated in tables 1, 2, and 3, water levels upstream and downstream the barrage, and the different discharges on turbines for different years,

figure 3 shows the model flow chart. Processing in model depends on the equation referred to the generation by using methods (a) traditional technique or method (b) new technique as following, [9]:

$$\text{Power} = \frac{\Delta P \times E}{\text{time}} = \frac{mg \times \Delta h}{t} = \frac{m}{t} g \Delta h \tag{1}$$

$$\frac{\text{mass}}{\text{time}} = \frac{m}{t} = \frac{\text{density} \times \text{volume}}{t}$$

$$= \text{density} \times \frac{\text{volume}}{t}$$

$$\text{density} = 1000 \text{ kg/m}^3$$

$$g \approx 10 \text{ m/s}^2$$

$$\text{Power (watt)} = \frac{\text{volume}}{t} \times \text{density} \times g \Delta h$$

$$= 10^4 \times \text{Flow} \times \text{Head}$$

$$\text{Head} = \Delta h \text{ (measured in m)}$$

$$\text{Flow} = \frac{\text{volume}}{t} \text{ (measured in m}^3\text{/s)}$$

$$\text{Power (kw)} = 10 \times \text{Flow} \times \text{Head}$$

by considering the Overall efficiency of turbine

$$\text{Power (kw)} = 10 \times \text{Flow} \times \text{Head} \times \text{efficiency} \tag{2}$$

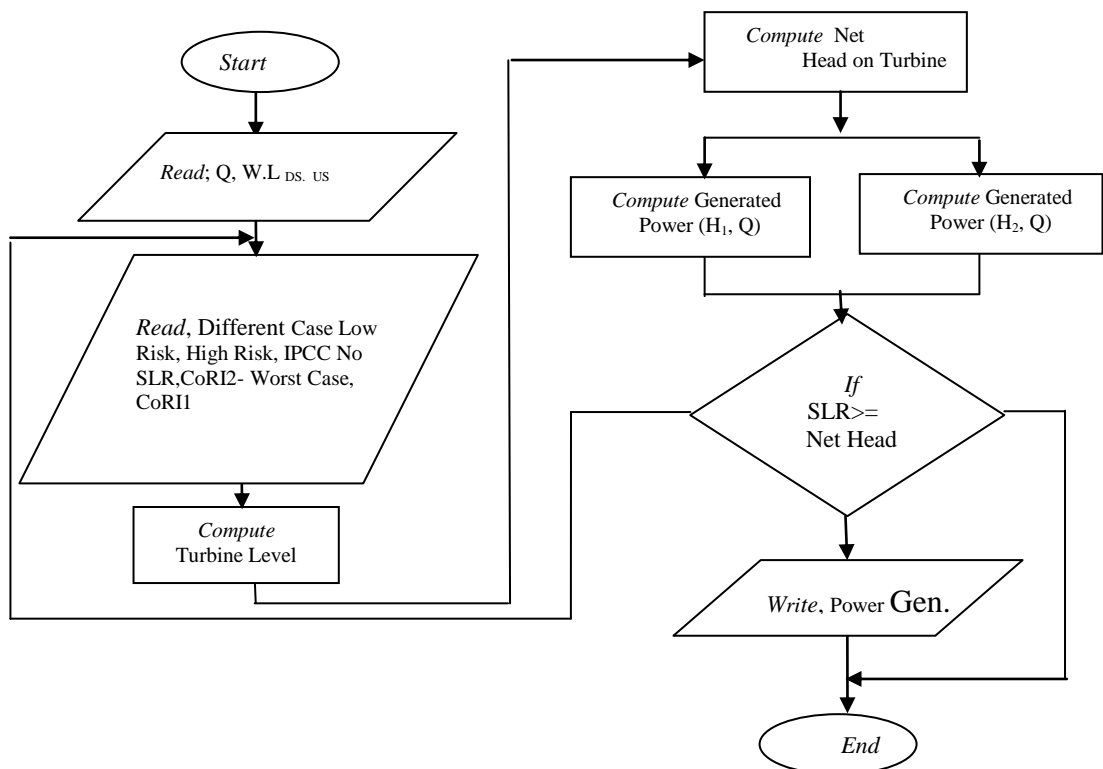


Fig. 3: Flow chart of hydropower generation model

4.2.2.1 First Scenario (Base Situation)

This scenario considers the actual measurements (CoRI2), data for SLR cases is tabulated in table 3, where the change in SLR is very small.

4.2.2.2 Second Scenario

It considers the discharge that will be passing through turbine similar to the discharge for 1998/1999 (maximum discharge). The discharge will be passing through turbine is estimated by 8.789 M.m³/day. Head on turbine calculated based on two factors; turbine level and the actual value of upstream level of the barrage. All cases of SLR; IPCC report, and CoRI1 for both Pessimistic scenario represented in A1F1 and Optimistic scenario represents in B1 been taken into account. Table 4,(a, and b) contains the maximum, minimum, upstream monthly levels of barrage and net head on turbines, which is used in traditional technique and new technique.

Table 4, (a) Head on turbine for method (a) corresponding to data of yea 98/99

Months	Up Stream Level m		Level of Turbine m	Range of Net Head (m)
	Max.	Min.		
Aug.	2.55	1.72	0.8	1.3
Sep.	3.25	2.52	0.8	1.95
Oct.	2.00	2.00	0.8	1.2
Nov.	2.00	2.00	0.8	1.2
Dec.	2.00	2.00	0.8	1.2
Jan.	2.00	2.00	0.8	1.2
Feb.	2.40	0.02	0.8	1.2
Mar.	2.32	2.00	0.8	1.4
Apr.	2.90	2.30	0.8	1.8
Jun.	2.93	2.3	0.8	1.8
Jul.	2.90	2.82	0.8	2.06

4.2.2.3 Third Scenario

Discharge is estimated by 0.404 M.m³/day (discharge in year 2004/2005). Table 5(a), and table 5b, represents the net head corresponding to the maximum and minimum upstream levels of barrage in the same period for both techniques

Table 5. (a) Head on turbine for method (a) corresponding to data of yea 04/05

Months	Up Stream Level m		Level of Turbine m	Range of Net Head (m)
	Max.	Min.		
Aug.	2.72	2.24	0.8	1.68
Sep.	2.9	2.57	0.8	1.94
Oct.	2.54	1.78	0.8	1.4
Nov.	2.9	1.77	0.8	1.5
Dec.	2.88	2.56	0.8	1.92
Jan.	2.9	2.04	0.8	1.67
Feb.	2.82	2.04	0.8	1.63
Mar.	2.04	1.78	0.8	1.11
Apr.	2.9	1.68	0.8	1.49
Jun.	2.9	2.41	0.8	1.86
Jul.	2.34	1.78	0.8	1.26

4.2.2.4 Adaptation with Negative Impact of SLR

Reducing the negative impacts of SLR begin to study the coastal area of all the surrounding circumstances and select the commensurate of new techniques to help in sustainable development. Impact of SLR is more highlighted using the traditional method of generation (method, a) because net head on turbine is decreased when SLR is increased as a result; generated power will be decreased. Another technology more appropriate in this condition is used in hydropower generation can cope with different levels at the barrage. This technology that depends on the turbine location is varies up and down using control system to deal with different water levels. Figure 4 illustrates three positions for the turbine; A) turbine is submerged and in operation mode. B) the turbine being shown in the operational position at another location. C) location illustrates the turbine when it has been above the surface of water.

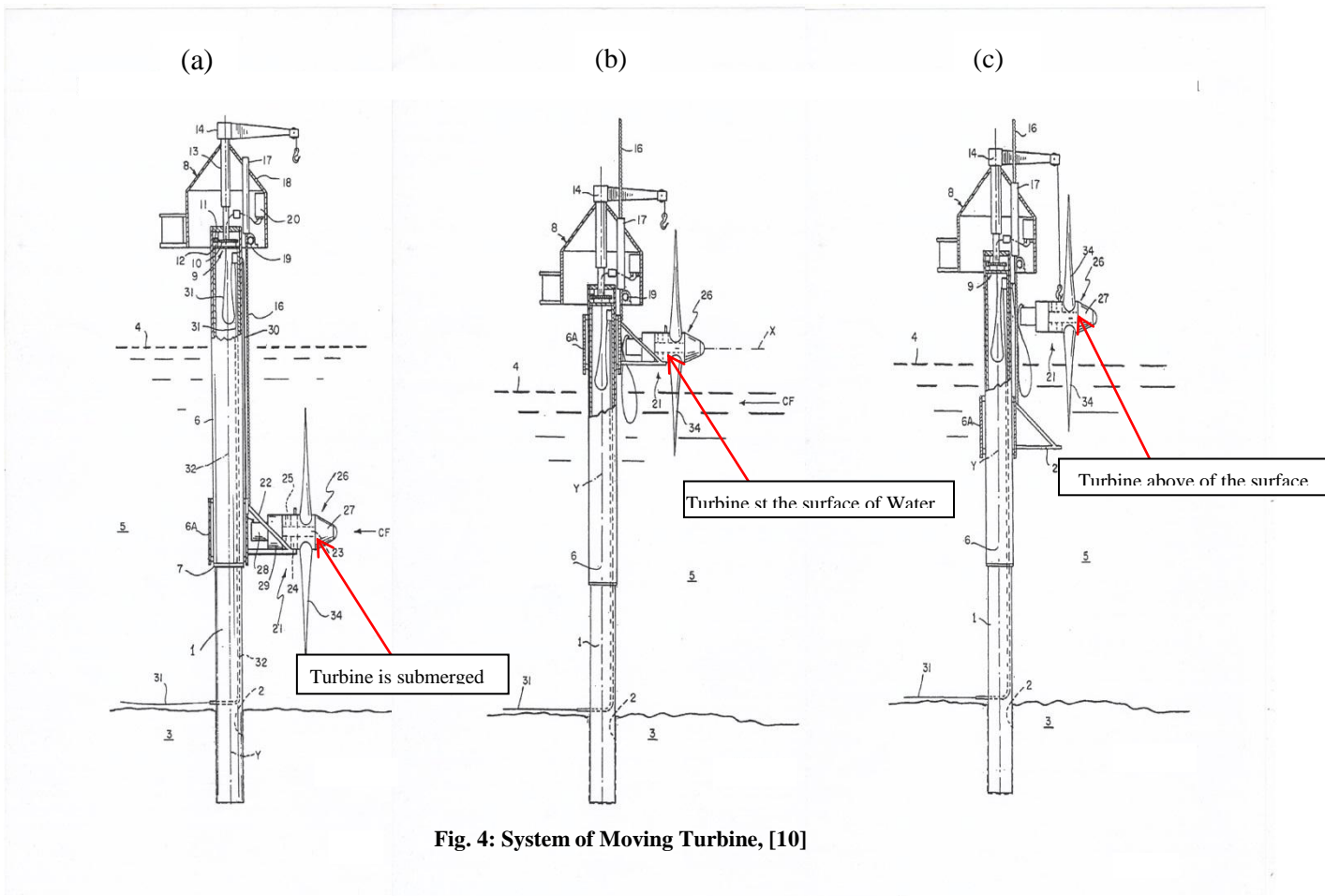


Fig. 4: System of Moving Turbine, [10]

Table 4. (b) Head on turbine for method (b) referred to data of yea 98/99

Months	Up Stream Level m		Level of Turbine m	Average Net Head (m)
	Max.	Min.		
Aug.	2.55	1.72	0.45	1.7
Sep.	3.25	2.52	0.62	2.3
Oct.	2.00	2.00	0.62	1.38
Nov.	2.00	2.00	0.55	1.45
Dec.	2.00	2.00	0.52	1.48
Jan.	2.00	2.00	0.38	1.62
Feb.	2.40	0.02	0.8	1.6
Mar.	2.32	2.00	0.19	1.97
Apr.	2.90	2.30	0.2	2.4
Jun.	2.93	2.3	0.4	2.2
Jul.	2.90	2.82	0.45	2.4

Table 5. (b) Head on turbine for method (b) referred to data of yea 04/05

Months	Up Stream Level (m)		Level of Turbine (m)	Average Net Head (m)
	Max.	Min.		
Aug.	2.72	2.24	0.38	2.1
Sep.	2.9	2.57	0.28	2.5
Oct.	2.54	1.78	0.17	1.99
Nov.	2.9	1.77	0.65	1.7
Dec.	2.88	2.56	0.2	2.5
Jan.	2.9	2.04	0.5	1.97
Feb.	2.82	2.04	0.45	1.98
Mar.	2.04	1.78	0.2	1.7
Apr.	2.9	1.68	0.36	1.9
May	2.9	2.41	0.25	2.4
Jun.	2.34	1.78	0.38	1.68
Jul.	2.43	2.23	0.36	1.97

5. APPLICATIONS AND RESULTS

Idfena Barrage plays an important role in saving the Nile water. Good rehabilitation of barrage allows the development in the region, where it can generate a clean energy using its vents. Three scenarios according to the discharge and variance water levels for different years from 98/99 to 04/05 are carried out to invest the hydropower generated from the barrage.

5.1 First scenario S1, (Base, or normal Situation)

The study examined the application of model for two type of data; first; consideration the measurements of SLR (CoRI2 data), second without consideration SLR. From the results it is found; electric generated in both type of data is very closed which mean negative impact for SLR on coastal region is very small. Results of this scenario tabulated in table 6, and indicated that, generated power is more in year 2001/2002, where the generated value reached 279.2 Mw/month and the minimum

value was 0.6 Mw/month occurred in year 2002/2003. From table 5, annual average value for period 1998 to 2005 for hydropower generation is estimated by 552 Mw/year.

5.2 Second Scenario S2, (High Discharge, data of year 98/99)

Results in table 6, show the output of second scenario for all cases of SLR. The first case low risk with different degrees (B1= 0.18, and 0.38, IPCC). The second case high risk with different degrees (A1F1, IPCC = 0.26 and 0.59, IPCC). Output of model illustrates that; generated in low risk ranged between 0.9982 and 825.3 Mw/year, generated in high risk ranged between 0.929 and 643.9 Mw/year. Last case that is the worst case (A1F1, CoRI1=0.72) which is the same high risk, IPCC beside the subsidence) recorded generation equal 531.6 Mw/year

5.3 Third Scenario S3, (Low Discharge)

Expected hydropower generated due to third scenario the decrease in generation from low risk to high risk ranged between 0.0891 and 67.3 Mw/year. Slide in generation is more illustrates in the worst case (A1F1, CoRI1) where its generation is recorded around 60 Mw/year. Table 6 represents the results for two scenarios.

According to the comparison between based and first scenario as well as the base and second scenario it is found that; decreasing in generation for base comparison varies from 14% to 29% for low risk and 19% to 44% for high risk. In worst case, the decreasing reaches to 54%. Decreasing for second comparison, varies from 10% to 21% for low risk and 14% to 32% for high risk and the decreasing in worst case recorded 39%.

5.4 Adaptation Technique

Adaptation strategies should be implemented according to region conditions, regular assessment, and sustainable development. New technology that has been used in adaptation in this search; increased the hydropower generated from barrage despite the impact of sea level. Table 7 and Figure 5, (a, b, c, d, and e) and (f, g, h, I, and j) represent the comparison between the generated power after and before the adaptation for all cases of SLR. Where figures a, b, c, d, and e show the generation with SLR and there is no adaptation. Figures f, g, h, i, and j show the generation after the adaptation.

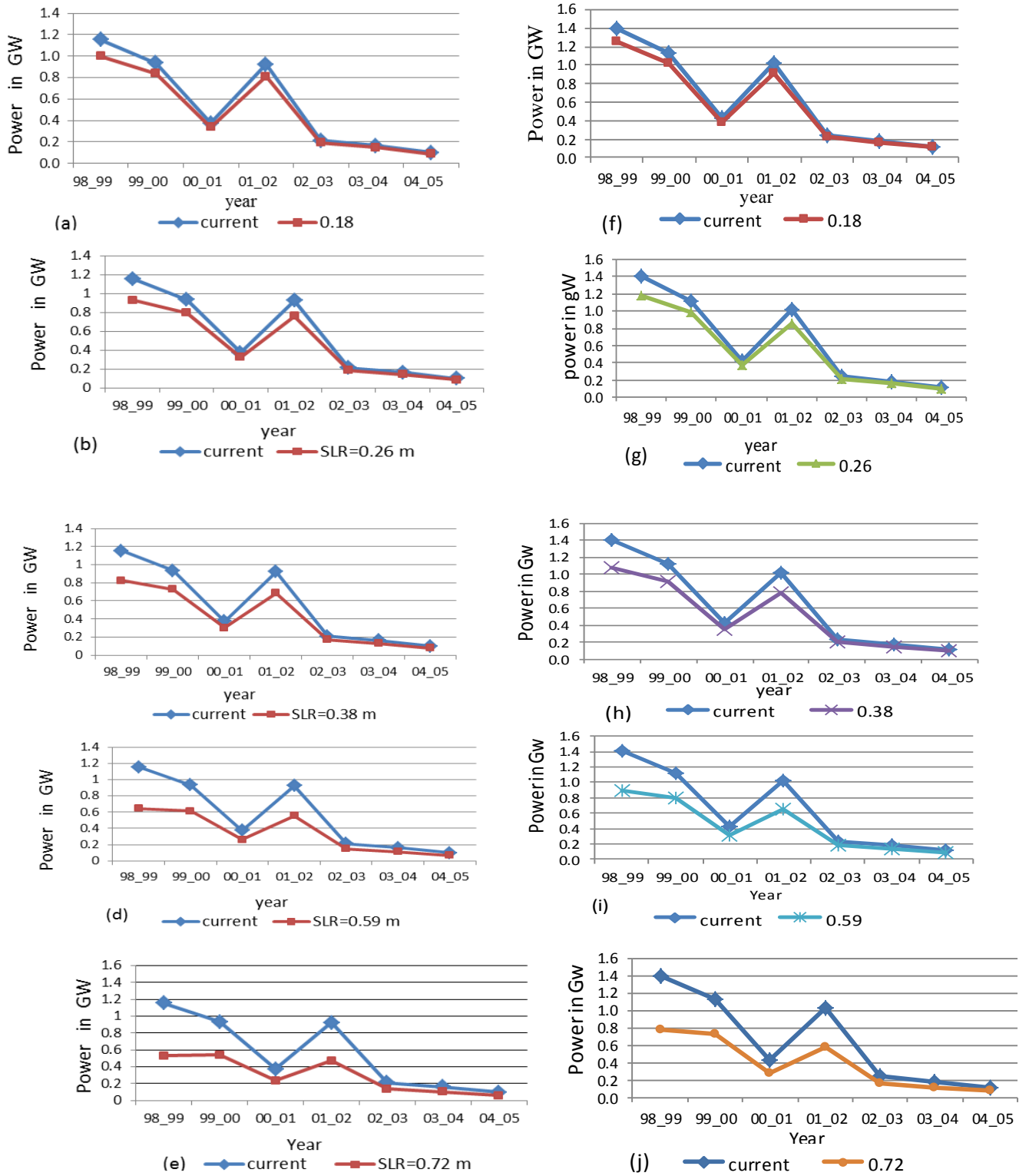


Fig. 5: (left side in figure, a, b, c, d, and e) show the generation without adaptation (wright side in figure, f, g, h, I, and j) show the generation with adaptation

Finally; according to plane of the Water Resources and Irrigation Ministry, Rehabilitation of Idfena barrage must be occurred, so it is very important re-use the barrage in developed and economic vision, this approach will be achieved this goal. Results of model indicate that; around 6 milliard $m^3/year$ will be released from the barrage enough to generate a suitable value of electricity possible to be a source to

extend the region by the requirements from the clean energy. This article introduced adaptation method to overcome negatively impact of SLR.

Table 6. Total hydropower generation in “miga-watt” corresponding to all scenarios

Year	Scenarios	Hydropower Generation (megaWatt)					
		Base Case S1	Cases for SLR (m)				
			0.18	0.38	0.26	0.59	0.72
			Low Risk		High Risk		Worst case
98-99	S2	1154	998	825	929	644	532
99-00		935	837	727	793	612	541
00-01		374	339	301	324	261	236
01-02		924	811	685	760	553	471
02-03		212	193	172	184	150	136
03-04		164	148	130	141	112	100
04-05	S3	99	89	78	85	67	60

Table 7. Total hydropower generation in “miga-watt” corresponding to adaptation

Year	Scenarios	Hydropower Generation					
		Base Case S1	Cases for SLR (m)				
			0.18	0.38	0.26	0.59	0.72
			Low Risk		High Risk		Worst case
98-99	S2	1400	124	107	117	893	781
99-00		1120	102	915	981	800	729
00-01		420	387	348	371	308	283
01-02		1020	911	786	861	654	572
02-03		240	221	213	221	178	164
03-04		181	165	158	165	129	117
04-05	S3	117	107	103	107	86	79

Table 8. Comparison for generated power after and before the adaptation

	Average Generation in Base Case (mW)	Hydropower Generation (mW)					
		Cases for SLR (m)					
		0.18	0.38	0.26	0.59	0.72	
		Low Risk		High Risk		Worst case	
		Before	644	569	486	536	400
After	750	677	599	648	508	454	

6. CONCLUSION AND RECOMMENDATION

Mathematical model and three scenarios are developed to accomplish this work. Annual average of hydropower generated from Idfina Barrage expected to be 552 Mw. While the generation in base situation ranged between 1154 Mw/year in maximum discharge and 99 MW/year in minimum discharge. Generated power decreased in optimistic case in SLR for second scenario from 14% to 29%, but in the pessimistic case the decreasing ranged between 19% 44%. In third scenario, Optimistic case the decreasing ranged from 10% to 21% and pessimistic case the decreasing ranged from 14% to 32%. Decreasing in generation in worst case for second second and third scenario ranged between 54% and 29% respectively. Due to applied the new technology generated power in the same condition from SLR impact is increased around 21%.

1. Although SLR has a negative impact on the development projects in the coastal regions, it can be overcome using a suitable technology as it used in this approach.
2. Adaptation scenario helped to increase the generated hydropower from 450 mw/year to 800 mw/year in worst case.
3. Based on important to release around 6 billion cubic meter per year from the barrage to be defense line at Idfena region to overcome the saltwater incursion into the region, Region electrical requirements can be available without overloading the united network electric power.

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