GSJ: Volume 9, Issue 11, November 2021, Online: ISSN 2320-9186
www.globalscientificjournal.com

Study of water transmission line from River Nile at Atbara to Port Sudan and utilize of hydraulic energy

Alaeldeen Altag Yousif 1, A/Rahman Mergani Hassan Shagali*2

Department of Mechanical Engineering-Red Sea University-Port Sudan.

1 a.altagyousif@gmail.com, 2 abdrahmanshagali@gmail.com.

This paper prepared to improve the previous study by using close system transmission pipeline and extend the term of the study to year 2050 through which reducing the number of booster pumps and avail the elevation between Summit (912m) to Port Sudan (0 m) to generate electrical power by using hydraulic turbine, hence reducing the capital cost of the project. The methods have been used in present work are four different designs for water supply and hydro power generation. The results showed that: the design2 and design4 are the best compared to the other designs.

In design 2 using 1.4 m diameter will be the best design to implement capable to supply the average demand flow rate until year 2030 using only the main pump, after that adding one booster pump for year 2050. In design (4) twin pipeline each one has 1m diameter will be used, with one main pump and 2 booster pumps to transport the half of demand flow rate of water. However, design4 is considered the second selection after design2, in this case one of these lines will transmit the water to facing the demand and the other will be standby until Year 2035. The hydro power generation started from location of Summite as the highest elevation of transmission line. The difference in the head to hydro turbine location is about 866.4m. The overall efficiency of unit selected and pipe line friction loses estimated to be 75%. The maximum power produced 16.97 MW, obtained in Year 2050 due to the increasing of water flow rate.

Keywords: Transmission pipeline for water supply, hydro power generation.

1. Introduction

River and ground water are the major sources of water for drinking, agricultural, and industrial purposes. The availability of water determines the location and activities of humans in an area and our growing population is placing great demands up on natural fresh water resources. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialization. In many parts of the country available water is rendered non potable because of the presence of heavy metal in excess. Drinking water for consumer must be free from disease carrying bacteria, toxic substances, and excessive amount of mineral and organic matter [1].

Proposed Transmission Water Pipeline (Atbara – Port Sudan). The city of Port Sudan and the Red Sea region in general are experiencing an increasing need for increased water consumption, whether for drinking or transportation or to supply ships, domestic use, industries or power generation. [2].

Hydroelectricity in Sudan is the largest source of on-grid power, represent about 68% of generation since 2011, followed by diesel and heavy fuel oil (27%) and biomass and waste (5%). Hydroelectricity is generating from five dams at Rosaries, Sinnar, Jebel Aulia, Khashm El-Girba, and Merowe [3].

Conducting hydraulic study of water transmission pipeline from River Nile at Atbara Town to Red Sea area into two aspects:

- Criteria is provided for pumping units operating as components in transmission system and pump's location.
- Hydropower generation.

The main objectives of present work to clarify and improve the defects followed by the proposed project that approved to conducting the transmission water from River Nile at Atbara town to Red Sea region by using close system of transmission pipeline to reduce numbers of booster stations, to provide the red sea state with fresh water for domestic usage and different purposed to meet future demands, utilizing creation pressure of the difference elevation between Summit and Port Sudan to generate electricity power and utilizing of turbine to reduce pressure to meet require transmission pipeline and auxiliaries' design.

2. The previous studies

2.1 Case No. 1: study to use of petrodar company pipeline oil to transport the river Nile water:

The study to use of petrodar company pipeline oil to transport the river Nile water from Atbara to Port Sudan. In case that the flow through it is stopped due to stoppage of pumping oil from the main fields of oil in Southern Sudan and their positions will be changed. The use of the pipe line in its present state- the use of pre-existing pumping stations without need to purchase boosters – contributes 80% of the total water needs in Port Sudan. The life time by using petrodar pipe line to supplying Port Sudan, Haya, Summit, Sinkat, by the main line of 13000 m3/day will be limited until 2025 [2].

2.2 Case No. 2: Port Sudan water supply feasibility study and preliminary design:

Port Sudan water supply feasibility study and preliminary design proposed Transmission Water Pipeline from Atbara to Port Sudan River Nile at Atbara town surface water source

the project included surface water intake, raw water pump station on River Nile upstream Atbara River junction and water transmission work including 1 main transmission pipeline, booster stations include one in treatment plant, 7 boosters in main transmission pipeline located in the distance between Atbara to Summit, 7 pressure breakers in main transmission pipeline located between Summit to Port Sudan. also7 pressure breakers required in branch transmission pipeline to Sinkat, Suakin and Gabait and water treatment works of single train, including treatment facilities of pre-sedimentation [4].

3. METHODOLOGY ANDMATERIALS

The information about the distance of areas between the intake and sink of proposed pipe line and its elevation are provided as shown in Table 3.1 and illustrated in Figure 3.1. In addition, the water average demand of these areas until year 2050 is determined as shown in Table 3.2.

GSJ: Volume 9, Issue 11, November 2021
ISSN 2320-9186

Table 3.1: Show the data of proposed pipeline route [2].

Area	Elevation (m)	Distance from Atbara (km)
Atbara	365	0
	396	40
	429	80
	476	120
	514	160
	584	200
Haiya	652	230
	819	280
	912	300
Summit	929	307
Sinkat	876	315
Gabait	796	325
Suakin	22	410
Port Sudan	18	420

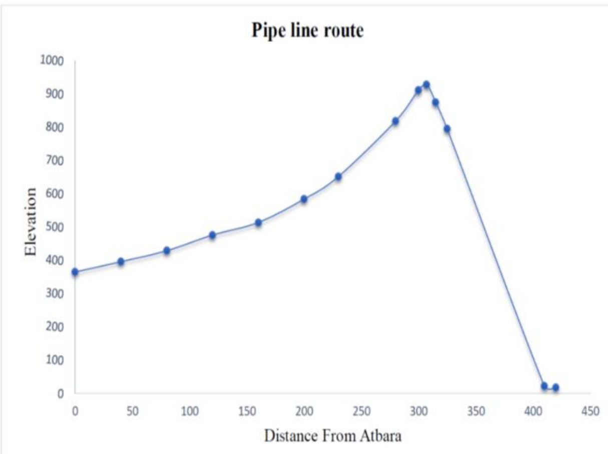

Figure 3.1: Illustrative topography of the route from Atbara to Port Sudan

Table 3.2: Average water demand of the project area in (m^3/day) [4].

Year	Port Sudan available	Port Sudan demand	Port Sudan required	Suakin	Sinkat	Gabait	Haiya	Derudeb	Total Demand
2015	80000	106428	26428	4137	6804	2340	6407	7424	53540
2020	80000	135555	55555	5301	8719	2998	8210	9512	90295
2025	80000	166805	86805	6735	11077	3809	10430	12085	130941
2030	80000	203369	123369	8510	13995	4813	13178	15269	179134
2035	80000	233271	153271	9724	15991	5499	15057	17446	216988
2040	80000	266312	186312	11060	18187	6254	17125	19842	258780
2045	80000	202230	222230	12521	20589	7080	19387	22463	304270
2050	80000	341214	261214	14112	23206	7980	21851	25318	353681

The equations used in hydraulic calculations [5]:

$hf = flV^2/2dg$ ………………….......................... (3.1)

$Hsys = \Delta Z + hf$ …………………………………. (3.2)

p (bar) = g * $Hsys$/ 100 …………………………. (3.3)

V = Q/A ………………………………….….…. (3.4)

Ph = H * Q * ρ * g ……………………..…...…. (3.5)

GSJ© 2021
www.globalscientificjournal.com

The calculations of hydraulic and hydro power shown in Tables 3.3 and Table 3.4 respectively below

Table 3.3: Hydraulic calculations result of the design

L (Km)	L (m)	Z (m)	ΔZ (m)	hf (m)	Hsys (m)	P (bar)	V (m/s)	D (m)	f (F. Coff.)	Pump Location
0	0	365	0	0	0	0	2.66	1.4	0.01	Main Pump
10	10000	374	9	25.75943	34.75943	3.4099	2.66	1.4	0.01	
20	20000	380	15	51.51886	66.51886	6.5255	2.66	1.4	0.01	
30	30000	381	16	77.27829	93.27829	9.1506	2.66	1.4	0.01	
40	40000	396	31	103.0377	134.0377	13.1491	2.66	1.4	0.01	
50	50000	403	38	128.7971	166.7971	16.3628	2.66	1.4	0.01	
60	60000	405	40	154.5566	194.5566	19.086	2.66	1.4	0.01	
70	70000	418	53	180.316	233.316	22.8883	2.66	1.4	0.01	
80	80000	429	64	206.0754	270.0754	26.4944	2.66	1.4	0.01	
90	90000	437	72	231.8349	303.8349	29.8062	2.66	1.4	0.01	
100	100000	450	85	257.5943	342.5943	33.6085	2.66	1.4	0.01	
110	110000	457	92	283.3537	375.3537	36.8222	2.66	1.4	0.01	
120	120000	467	102	309.1131	411.1131	40.3302	2.66	1.4	0.01	
130	130000	482	117	334.8726	451.8726	44.3287	2.66	1.4	0.01	
140	140000	489	124	360.632	484.632	47.5424	2.66	1.4	0.01	
150	150000	503	138	386.3914	524.3914	51.4428	2.66	1.4	0.01	
160	160000	514	149	412.1509	561.1509	55.0489	2.66	1.4	0.01	
170	170000	537	172	437.9103	609.9103	59.8322	2.66	1.4	0.01	
180	180000	548	183	463.6697	646.6697	63.4383	2.66	1.4	0.01	
190	190000	567	202	489.4292	691.4292	67.8292	2.66	1.4	0.01	
200	200000	584	219	515.1886	734.1886	72.0239	2.66	1.4	0.01	
210	210000	600	235	540.948	775.948	76.1205	2.66	1.4	0.01	
210	0	600	0	0	0	0	2.66	1.4	0.01	PS#1
220	10000	622	257	25.75943	282.7594	27.7387	2.66	1.4	0.01	
230	20000	652	287	51.51886	338.5189	33.2087	2.66	1.4	0.01	
240	30000	688	323	77.27829	400.2783	39.2673	2.66	1.4	0.01	
250	40000	720	355	103.0377	458.0377	44.9335	2.66	1.4	0.01	
260	50000	735	370	128.7971	498.7971	48.932	2.66	1.4	0.01	
270	60000	765	400	154.5566	554.5566	54.402	2.66	1.4	0.01	
280	70000	819	454	180.316	634.316	62.2264	2.66	1.4	0.01	
290	80000	890	525	206.0754	731.0754	71.7185	2.66	1.4	0.01	
300	90000	912	547	231.8349	778.8349	76.4037	2.66	1.4	0.01	
307	97000	929	564	249.8665	813.8665	79.8403	2.66	1.4	0.01	

Table 3.4: Hydropower calculations result for single pipeline

Q (m^3/s)	ρ (kg/m^3)	m (kg/s)	Hgross (m)	Hnet (m)	η	P (w)	P (MW)	P (MWH)	Years
0.1286	1000	128.5995	912	866.4	0.75	819762.6	0.819763	2951.145	2020
0.257199	1000	257.1991	912	866.4	0.75	1639525	1.639525	5902.291	2021
0.385799	1000	385.7986	912	866.4	0.75	2459288	2.459288	8853.436	2022
0.514398	1000	514.3981	912	866.4	0.75	3279051	3.279051	11804.58	2023
0.642998	1000	642.9977	912	866.4	0.75	4098813	4.098813	14755.73	2024
0.715336	1000	715.3356	912	866.4	0.75	4559934	4.559934	16415.76	2025
0.787674	1000	787.6736	912	866.4	0.75	5021055	5.021055	18075.8	2026
0.860012	1000	860.0116	912	866.4	0.75	5482176	5.482176	19735.84	2027
0.93235	1000	932.3495	912	866.4	0.75	5943298	5.943298	21395.87	2028
1.004688	1000	1004.688	912	866.4	0.75	6404419	6.404419	23055.91	2029
1.089326	1000	1089.326	912	866.4	0.75	6943952	6.943952	24998.23	2030
1.173965	1000	1173.965	912	866.4	0.75	7483486	7.483486	26940.55	2031
1.258604	1000	1258.604	912	866.4	0.75	8023020	8.02302	28882.87	2032
1.343243	1000	1343.243	912	866.4	0.75	8562554	8.562554	30825.19	2033
1.427882	1000	1427.882	912	866.4	0.75	9102088	9.102088	32767.52	2034
1.4971	1000	1497.1	912	866.4	0.75	9543318	9.543318	34355.94	2035
1.566317	1000	1566.317	912	866.4	0.75	9984548	9.984548	35944.37	2036
1.635535	1000	1635.535	912	866.4	0.75	10425778	10.42578	37532.8	2037
1.704752	1000	1704.752	912	866.4	0.75	10867008	10.86701	39121.23	2038
1.77397	1000	1773.97	912	866.4	0.75	11308239	11.30824	40709.66	2039
1.850454	1000	1850.454	912	866.4	0.75	11795787	11.79579	42464.83	2040
1.926937	1000	1926.937	912	866.4	0.75	12283336	12.28334	44220.01	2041
2.003421	1000	2003.421	912	866.4	0.75	12770885	12.77089	45975.19	2042
2.079905	1000	2079.905	912	866.4	0.75	13258434	13.25843	47730.36	2043
2.156389	1000	2156.389	912	866.4	0.75	13745983	13.74598	49485.54	2044
2.239532	1000	2239.532	912	866.4	0.75	14275984	14.27598	51393.54	2045
2.322676	1000	2322.676	912	866.4	0.75	14805986	14.80599	53301.55	2046
2.405819	1000	2405.819	912	866.4	0.75	15335987	15.33599	55209.55	2047
2.488963	1000	2488.963	912	866.4	0.75	15865989	15.86599	57117.56	2048
2.572106	1000	2572.106	912	866.4	0.75	16395991	16.39599	59025.57	2049
2.662347	1000	2662.347	912	866.4	0.75	16971234	16.97123	61096.44	2050
2.752588	1000	2752.588	912	866.4	0.75	17546477	17.54648	63167.32	2051
2.842829	1000	2842.829	912	866.4	0.75	18121720	18.12172	65238.19	2052
2.933069	1000	2933.069	912	866.4	0.75	18696963	18.69696	67309.07	2053
3.02331	1000	3023.31	912	866.4	0.75	19272206	19.27221	69379.94	2054

4. RESULTS AND DISCUSSION

The results of hydraulic designs for water transmission pipeline from Atbara to Port Sudan

Table 4.1: Pipe Line specifications

Pipeline length	420 km
Pipe Material	Ductile Iron and Steel
Pressure	100 barg
Main Transmission Pipe Diameter	1000 to 1500 mm
Velocity	0.5 to 3 m/s
Gradient Slope	O.5 to 2.5 m/ km
No of pipes	2 in 2 stages
Booster station lift	55 to 240 m
H.W coefficient C	120

4.1 The results for the different designs up to year 2050:

The Table 4.2 below shown the different designs according to different selected sizes of pipes diameter and calculated velocity upon demand flow rate in year 2050, also Table 4.2 shown pipeline length and head between intake and the peak points in Summite.

Table 4.2: The results for the different designs in year 2050.

Design No	Flow rate (m^3/d)	Pipe diameter (m)	Pipeline length (km)	Head (m)	Velocity (m/s)
1	353681	1	307	564	5.20
2	3536811	1.4	307	564	2.66
3	353681	1.5	307	564	2.32
4	176840.5	1	307	564	2.61

4.1.1 The proposed of Design1:

In design 1 the distribution of booster pumps that has been used related to the distance from intake to the peak point shown in the Table 4.3 below:

In design (1) the specification of pipe line has been illustrated in Table 4.1 the number of boosters needed to withstand the cantors between and supply water from Atbara to Summite are determined to be 8 units and one unit as the main pump. The distance of boosters' distribution according to the elevation of pipe line route has been shown in the Table 3.1 and Figure 3.1.

Table 4.3: Pumps distribution for design 1

Elevation from sea level (m)	Distance from Atbara (km)	Pump Unit
365	0	Main pump
403	50	Booster pump (1)
450	100	Booster pump (2)
489	140	Booster pump (3)
548	180	Booster pump (4)
622	220	Booster pump (5)
720	250	Booster pump (6)
765	270	Booster pump (7)
890	290	Booster pump (8)

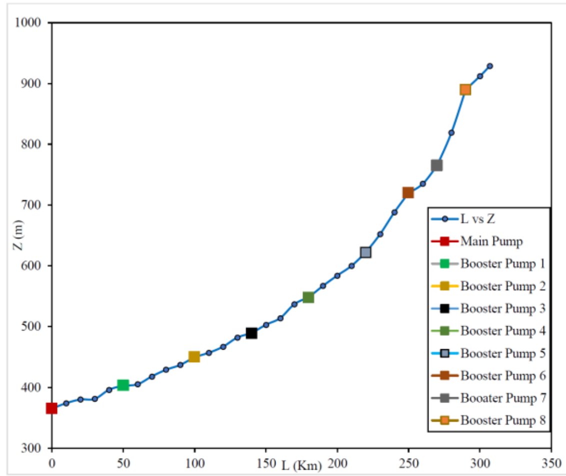

Figure 4.1: Distance of booster pumps from Atbara town in (km) for design 1

Figure 4.1 shows the position of each booster according to the elevation of point. As shown in Figure 4.1 the elevation from Atbara to the Summite increases linearly, starting from the value 365m as minimum level to the maximum level 929 m above sea level in Summite. The difference in elevation led to use 8 boosters in this design and the 8 units have same specifications.

4.1.2 The proposed of Design2:

In design (2) selected 1.4m as the diameter of transmission pipe line to be as suggested diameter for water supply to facing the average demand flow rate up to 2050. The specifications of design2 have been illustrated in Table 4.1 the number of units and the elevation in design2 have been explained in Table 4.4 This design needs one main pump and one booster to handle the water discharge to the peak point. In addition, the design capable to supply enough quantity of water up to Year 2030 with using the main pump only. Due to the increases of water demand from 2030 to 2050 one booster will be needed to be installed. However, this design compared to the desgin1 is better, because it has less number of boosters. Then 1 booster pump added in kilometer 210 from Atbara. The location of main pump and booster of design2 shown in Figure 4.2 below.

Table 4.4: Pumps distribution for design 2

Elevation from sea level (m)	Distance from Atbara (km)	Pump Unit
365	0	Main pump
600	210	Booster pump

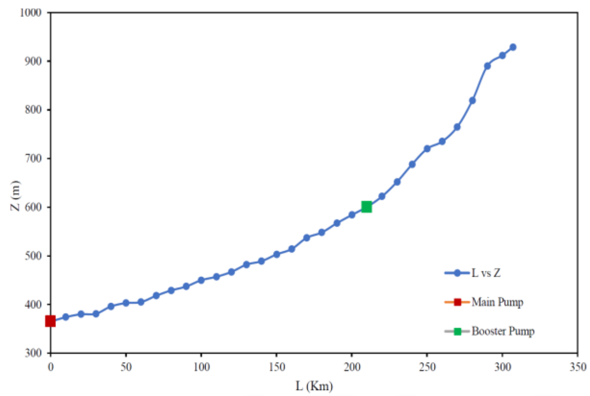

Figure 4.2: Distance of booster pump from Atbara town in (km) for design 2

From Figure 4.2 above the main pump capable to transmit the water from the suction side to the peak point, because it has a good pressure to resist the elevation and provide the correct demand of water until 2030.

After Year 2030 and due to the increases of water demand the booster will be installed in distance 210 km from Atbara.

4.1.3 The proposed of Design3:

In design (3) selected 1.5m as the diameter of transmission pipe line to be as suggested diameter for water supply to facing the average demand flow rate up to Year 2050. The specifications of design3 have been illustrated in Table 4.1. The number of units and the elevation in design3 have been explained in Table 4.5. This design needs one main pump and one booster to handle the water discharge to the peak point. In addition, the design capable to supply enough quantity of water up to Year 2035 with using the main pump only. Due to the increases of water demand from 2035 to 2050 one booster will be needed to be installed in the pipe line. However, this design compared to the desgin1 is better, because it has less number of boosters. Then one booster pump will be added in kilometer 240 from Atbara to this design. There was no difference between design (2) and design (3) in hydraulic calculation accept the distance of the booster pump from intake point 240 km and the main pump capable to supply demand water until year 2035 before added one booster pump from 2035 to 2050. In addition, the difference appeared in cost of the pipeline which was vary in pipe diameter 1.4m to 1.5m.

Table 4.5: Pumps distribution for design 3

Elevation from sea level (m)	Distance from Atbara (km)	Pump Unit
365	0	Main pump
688	240	Booster pump

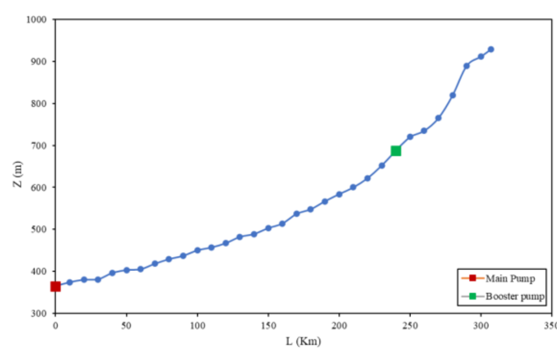

Figure 4.3: Distance of booster pump from Atbara town in (km) for design 3

From Figure 4.3 above, the main pump capable to transmit the water from the suction side to the peak point, because it has a good pressure (as shown in Table 4.1) to resist the elevation and provide the correct demand of water until 2035.

After Year 2035 and due to the increases of water demand the booster will be installed in distance 240 km from Atbara to appropriate the water demand.

4.1.4 The proposed of Design4:

In design (4) twin pipeline each one has 1m diameter will be used, with one main pump and 2 booster pumps to transport the half of demand flow rate of water. In this design 2 main pumps and 4 boosters will be needed. In addition, this design has a good advantage while doing maintenance or any defect has been occurred the water supply will continue because the other line as reserve one. however, implement in two phases to facilitate the capital cost payments of transmission pipeline. The hydraulic calculation result shown in Table 4.6 and represented in Figure 4.4 below:

Table 4.6: Pumps distribution for design 4

Elevation from sea level (m)	Distance from Atbara (km)	Pump Unit
365	0	Main pump
548	180	Booster pump (1)
819	280	Booster pump (2)

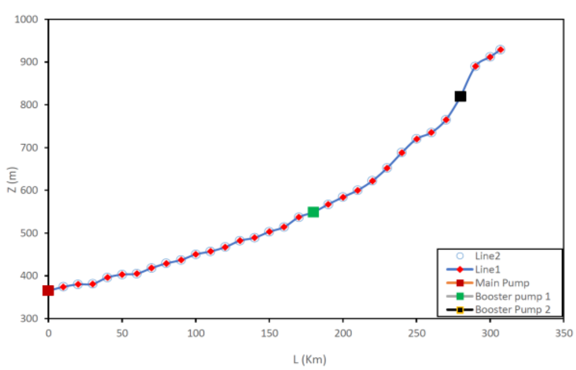

Figure 4.4: Distance of booster pumps from Atbara town in (km) for design 4

From Figure 4.4 above the two installed in same level and distance they will be in parallel. In this case one of these lines will transmit the water to facing the demand and the other will be standby until Year 2035. After this period the use of line2 will be important to supply water with the line to complete the water demand. This design will provide a good chance until 2035 to manage the cost of the second proposed line2 to established, in case installed line1 alone. However, design4 is considered the second selection after design2, because it has low cost and minimum number of boosters as well as maintenance.

4.2 Hydropower calculation:

4.2.1 Hydropower calculation for single pipe line:

The hydro power generation started from location of Summite as the highest elevation of transition line. The difference in the head to hydro turbine location is about 866.4m. The overall efficiency of unit selected and pipe line friction loses estimated to be 75%.

Selection of hydraulic turbine depended on the available head of water, for high head used impulse turbine and for low head used reaction turbine.

The calculated hydropower obtained by using Equation 3-5. The results of power generation for single pipeline shown in Table 4.7 below:

Table 4.7: Results of intervals hydropower in years 2020 – 2050 single pipeline

year	Mass flow rate (kg/s)	Head net (m)	Efficiency (η)	Power (MW)
2020	128.5995	866.4	0.75	0.819763
2025	715.3356	866.4	0.75	4.559934
2030	1089.326	866.4	0.75	6.943952
2035	1497.1	866.4	0.75	9.543318
2040	1850.454	866.4	0.75	11.79579
2045	2239.532	866.4	0.75	14.27598
2050	2662.347	866.4	0.75	16.97123

From the Table 4.7 above the generated power increased due to the increasing water flow rate demand from year 2020 to year 2050 as shown in Figure 4.5 below:

Pipeline phase 2. This design it will be used after year 2035.

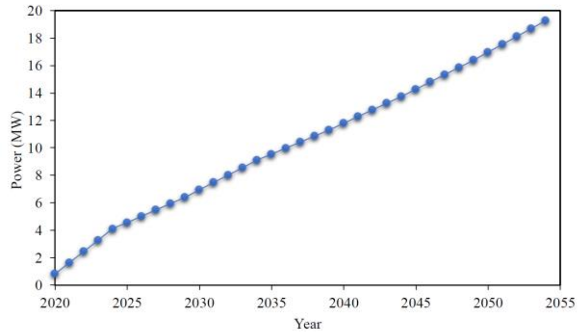

Figure 4.5: Relation between MW produced and the years

As shown in the Figure 4.5 above the power produced from the transmissions line increased linearly as the time increased based on Years. The maximum power produced 16.97 MW obtained in Year 2050 due to the increasing of water flow rate. This indicated that, the power used for water pumping from the intake point to the highest level of pumping is claimed. However, in this design no cost of water pumping except the maintenance cost of the unit. In case using diesel power station to operate the main pump and boosters, the electricity generated from the pipe line can be added to the national grid.

4.2.2 Hydropower calculations for twin pipeline

Calculations result for twin pipeline phase one shown in Table 4.8 below:

Table 4.8: Results of intervals hydropower in years 2020 –2050 twin pipeline (phase one):

year	Mass flow rate (kg/s)	Head net (m)	Efficiency (η)	Power (MW)
2020	64.29977	866.4	0.75	0.409881
2025	357.6678	866.4	0.75	2.279967
2030	544.6632	866.4	0.75	3.471976
2035	748.5498	866.4	0.75	4.771659
2040	925.2269	866.4	0.75	5.897894
2045	1119.766	866.4	0.75	7.137992
2050	1331.174	866.4	0.75	8.485617

Increasing of power generation from year 2020 to year 2050 according to increase of flow rate as shown in Figure 4.6 and it can be double after implemented of pipeline phase 2. This design it will be used after year 2035.

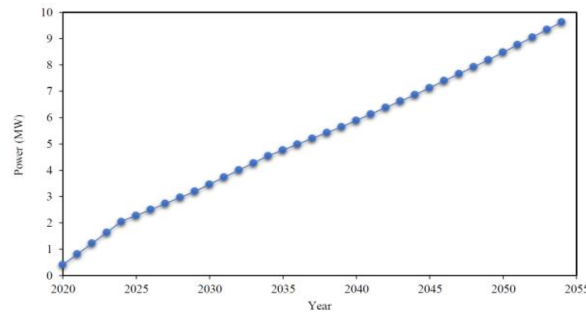

Figure 4.6: Relation of MW produced to the years

When using a single pipe line, the power generated will decreased compared to case1 due to the reduction of mass flow rate. The advantage of this design the cost of pumping and maintenance are decreased. In addition, the second line will be considered as reserve line to ensure the continuity of water supply when any damage or problem occurred in line1.

5. Conclusion:

The main objective of present work is to supply drinking water from River Nile at Atbara town to Port Sudan city and surrounding areas. In addition, the availability of power generation from this line is included. The methods have been used based in different designs. The results obtained in present work can be concluded in these points:

1- In desing1main pump plus eight (8) booster pumps should be installed to transfer water from Atbara to peak point Summit which representative very high cost installing and maintenance and also too high velocity (5.2 m/s) not accepted for Düsen Saug Infiltration (DSI) [6] a technology also known as Fast High-Volume Infiltration (FHVI) [7] to transfer drinking water.

2- In design 2 using 1.4 m diameter will be the best design to implement capable to supply the average demand flow rate until year 2030 using only the main pump, after that adding one booster pump for year 2050, comparing this design with design (3) there is slightly different in hydraulic calculations, only the distance of booster from Atbara changed, but different in cost due to different in pipes diameter.

3- Design 4 using twin pipe line each one had 1m diameter, this design will be the second option in case divided the execution stage into two phase, phase one supply the average demand until year 2035, then implement phase two to supply the completed water average demand until year 2050.

4- Among the above design 2 and design 4 are the best technically and cost wise. Design 2 is considered the best one, although the design4 has a good facility such as: pre cost installation, low cause implement in two phases sequently upon flow rate demand, capital cost low, availability of pipe size in local market from GAID piping factory (maximum diameter manufacturing in GAID industry 1.2 m), operation and maintenance.

5. The hydro power generation started from location of Summite as the highest elevation of transition line. The difference in the head to hydro turbine location is about 866.4m. The overall efficiency of unit selected and pipe line friction loses estimated to be 75%. The maximum power produced 16.97 MW, obtained in Year 2050 due to the increasing of water flow rate.

6. Recommendations

- Sinkat town branch also can put hydro- power turbine to generate electricity.
- Further study is required regarding the pressure breakers for the branches serves Derudeb and Suakin towns.
- The economic analysis for these designs for water supply and power generation showed be estimated.
- Conducting study to connect electricity power by national grid.
- Increasing capacity of water treatment plant to meet the incredible of flow rate demand due to extended the life time of proposed pipe line.

7. REFERENCES

[1]https://shodhgangotri.inflibnet.ac.in/bitstream/123456789/1213/2/2 introduction.pdf ,2019.

[2] Study to use of petrodar co pipeline oil to transport the river Nile water to Port Sudan- University of Khartoum 2014.

[3]https://www.ashleyedisonuk.com/world-voltages/africa/voltage-sudan-913, 2019.

[4] Port Sudan Water Supply Feasibility Study and Preliminary Design.

[5] Mohammed Hashim Siddig – Fluid Mechanic 2014.

[6] International Journal of Engineering Technologies Necati Gulbahar, Vol.2, No.1, 2016.

[7] https://www.yuniko.nl/projects/dsi-rainwater-infiltration-and-ground-drainage-at-apeldoorn-netherlands, 2020.