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Prospects of the development of Electric Power Generation in Sudan and Proposals of its Advancement in the Future

ABD ALLAH MOKHTAR MOHAMMED ABD ALLAH
PhD Student
Power Engineering Department
School of Mechanical Engineering, College of Engineering
Sudan University of Science and Technology
Khartoum, Sudan
Dr. MOHAMMED ELTAYEB MANSOUR
Associate Professor
Mechanical Engineering Department
College of Engineering, Karary University
Khartoum, Sudan
· Dr. TAWFIG AHMED JAMALELDEEN
Assistant Professor
Department of Power Engineering
School of Mechanical Engineering, College of Engineering
Sudan University of Science and Technology
Khartoum, Sudan

Abstract:

Electric power generation is an important factor for the development of the countries and has an advantage of energy extraction technology of generation in the Sudan. Find reviews the history of electricity in Sudan, which containing the first stop through the laws of the Central Authority for Electricity and the stages through which the electricity industry in order to develop and ambitions in dam. The demand for electricity and then the stations currently operating in the national network electricity and an important stations planned and future plans of the National Authority for Electricity long-term and short ones as well as the most important

problems facing the power generation electrical solutions in Sudan and objectivity and their possible.

Key words: word, image, sound, advertisements/commercials, receiver, language, speech

1. Introduction:

Electrical power generation is an important factor for development of people. Electrical power from energy sources ease of use and represent the backbone for growth, development, economic, social progress and cultural also measured progress nation's average per person consumption of electrical energy. The electrical generation in Sudan beginning in 19centry, about 80 kilowatt hours a year per person compare to other nation that over 1,000 kilowatt hours. Electrical energy has an important role in moving the national economy, especially that we have adopted the large generation and transportation networks connected instead of generating units in sporadic. This is a call to separate multiple networks States have generation units where a large or medium rather than a national network one at this stage, in order to raise the proportion of electric energy independence in the economy compared to other sources of gradual current ratio. As the electric power direct impact on the economy, they are above it easier and cheaper types of energies in use is the catalyst and instigator to do a large-scale industries and small, and allows the (recruitment/employment) of human resources in the economic cycle, production and services, and particularly in the agricultural expansion irrigation and storage and industrialized. It also helps to maintain a clean environment and the availability of light left and cheaper than can be maximum benefit from the hours of the night with relatively mild weather. It is no secret also impact on the expansion of education, scientific research, and medical care and facilitates

home-based businesses, and improves the efficiency and economics of household cleaner and food and rearing of the child. It is enough to point out the impact of stop electricity supply in the national capital for three days in a period of disasters in 1988, which led to the suspension of water plants and mills grain, bakeries, service stations, petroleum and pumps sewage and affected by the industrial sector and the agricultural and commercial and residential have a direct impact.

2. Objectives:

The main objectives of study are follows:

1. Important of electrical generation for the nations developments
2. Studying the data of electricity generation and development in Sudan
3. Problems facing Generation power in Sudan.
4. Proposals and solutions of the problems facing power generation in Sudan.

3. Methodology:

1. Collect data of electric power generation in Sudan.
2. Economics electric power generation according to the standards and codes available.
3. Propose projects to provide generating economic electricity.

4. Electricity generation establishing in Sudan:

Seemed to generate electric power in Sudan in 1908 when it established company with a capital of foreign-Noor (private sector) station diesel generators in the area of Burie. The electric power sector continued to expand in cities distant

provinces, develops and expands in the framework of the national network of independent petroleum imported energy sources, as well as water under Government supervision. And assigned the state functions of the development of this sector of the Electricity Authority, which evolved in the denominations and frames her work over the years march, aimed at all to the independence of the sources of energy available economically to provide electrical power for purposes different, and take advantage of scientific development in the field of industry and electricity services to the extent permitted by the conditions of the environment Sudan, and expansion in their work on a commercial basis position to achieve annual revenue from investments at rates determined by their boards in order to save money required for the implementation of development plans. In 1982 a law was passed the National Electricity Authority to be instablishmente for electric power in Sudan.

4.1. Stations operating in the national electricity corporation:

1 - Rossaries water turbine.
2 - Sennar Dam hydro turbine.
3 – Khasm elgirba water turbine.
4 - Borre steam station (burned) and gas station. .
6 - Station, Dr. Mahmoud Sharif steam and gas.
7 - Station Garri (1) the gas with a capacity of 120 Mega watts.
8 - Station Garri (2) co-generation capacity of 210 Mega watts.
9 - hydro-generating unit (turbine pending) with a capacity of 3.6 Mega watts * 8 unit Jable Awlia.
10 - Darfour generators Chinese cities of different states which are a generator 2 Mega watt
11 - in addition to the Project Authority to light in 1000 solar village in darfour.
12. There are some small local generations in some cities and regions under the supervision of electricity. Administration and

the provincial and local councils, and enjoys the support of some of the Central Authority There is also a private generation and reserves in some areas of industrial, commercial, and residential service.

We have adopted the electric power sector to finance foreign currency component in the past three decades on loans from international financial institutions or regional or loans or grants from the sisterly and friendly countries or grants from governments Chinese, Indian, British, French, Italian and Dutch, where he was funding in the last three decades by the government until 1989 more than 660 million dollars.

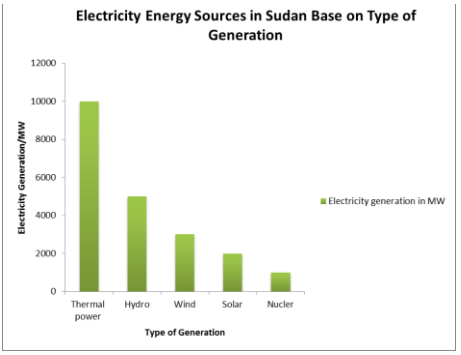


Figure1. Electricity generation sources in Sudan base on type of generation

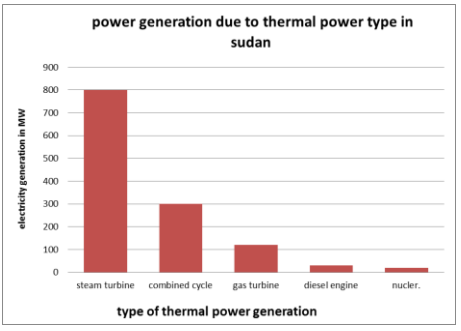


Figure2. Power generation used thermal power in Sudan

Table1.Compare between power generations types (Cost, feasibility and live time) according to standard and codes as shown below:

Type of generation / Generation function	Thermal power plant					Hydro-power	Wind -power	Solar
	Nuclear	Steam	gas	Combined (Gas& steam)	diesel			
Construction(Initial) cost	Very high	high	Relatively high	Relatively high	low	Very very high	high	Very high
Transmission lines cost	High	Relatively low	Relatively low	Relatively low	low	high	low	low
Operation cost	High	High	High	High	Very high	Nil	Nil	Nil
Maintenance cost	Relatively high	High	High	High	Very high	low	low	Very low
Economic feasibility for large plants	Yes	Yes	Yes	Yes	No	Yes	No	No
Economic feasibility for small plants	No	No	Yes	Yes	Yes	No	Yes	Yes
Live time	Long	Long	medium	medium	Very Short	Very Long	Long	Long
possibility of use in Sudan	Yes	Yes	Yes	Yes (recommend for small)	Yes	Yes (Recommend for large)	No	Yes

The Electricity Generation types:

Table: illustrates the power stations in Sudan according to their destinations:

Thermal power generation	Hydropower generation	Diesel generation
KOSTI	MERRAWI DAM	PORT SUDAN
GERRI	GABEL AWLEYA DAM	ELOBAYID
BAHRI	CENAR DAM	ELNOHOOD
	ALROSAIRIS DAM	KADOGLI
	KHSHAM ELGERBA DAM	ELDEAIN
		NEYALA
		ELFASHIR
		ELGENAINA
		ELFOULA
		ABUHAMMAD

Thermal Power Generation in Sudan:

Table: Shows the thermal power stations in Sudan

Project	Place	Completed units	Units under commissioning	Stand by generators	Capacity in MW	Percentages
Bahri thermal power plant	Khartoum north	6 units	_	3 units	380	28.35%
Garri combined cycle power plant	Khartoum north	2 units	_		460	34.32%
Kosti	Rabak_	2 units	2 units	3 Units	500	37.31%

thermal power plant	white Nile state					

Bahri Thermal Power Plant:

Bahri power station is located at the north side of Khartoum. It consists of six units, these units are: units 1 and 2 which been constructed in 1983 by an England company so both of the units generate around 60 MW. Units 3 and 4 which generate 120 MW and they were also constructed by a British company in 1994. Finally the units 5 and 6 generate 200 MW and they were a gift from the Chinese government.

Figure: illustrates the location of Bahri thermal power station

Garri Combined Cycle Power Plant:

Garri thermal power plant is located at 80 kilometers away from the capital city (Khartoum). It has two units. The first one was commissioned at 2003, and the second one was on 2007. And the overall generation of this station is around 460 MW, which is covering 34.3% from the overall Sudan thermal power generation. Therefore it is supplying 220 KNA line to the capital city and the rest goes to the national grid so this line was completed in December 2013. On the other hand the other configuration of 4+2 turbines been completed since July 2007.

Figure: Shows the map location of Garri thermal station

Kosti Thermal Power Plant:

Kosti Power station is located 350 kilometers away from the capital city, therefore the location had been selected according to some reasons, and such are: the station will be so close to the water supplier which is the White Nile. In addition it's also near to the petroleum pipe line, so that they will be saved the transportation fees of the petrol. And the important thing that this power station considered as the largest and the huge power thermal station in Sudan. So that the overall capacity of kosti power plant is around 500 MW (125×4). Consist of four units, two of them been completed and already operated. The unit number three is now under commissioning. The last unit which is unit one is under construction these days.

Figure: Shows Kosti power plant project

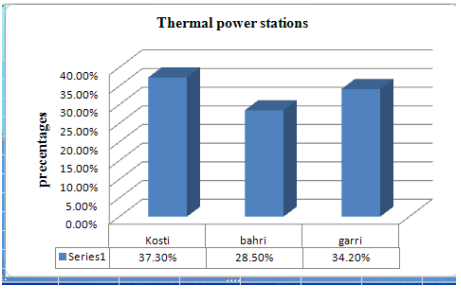


Figure: Shows the thermal generation percentages

Hydropower generation:

There are five large dams in operation. The two largest dams are Merrawi and al Rosaries. So most of these dams are multipurpose structures.

Table: Illustrates the dams in Sudan

Project	Place	Completed units	Units under commissioning	Capacity in MW	Percentages
Merrawi	North of Sudan (merrawi)	10 units	_	1250	78.6%
Alrosaires	damazeen	7 units	_	280	17.6%
Sennar	Sennar (blue Nile state)	2 units	_	15	0.94%
Gabel awleya	South of Khartoum	80 units × 380 KW	_	30	1.8%
Khashm alGirbah				15	0.94%

Merrawi dam:

Merrawi dam is located in the northern Sudan about 220 miles away from the capital city Khartoum. And because of its huge dimensions it becomes the largest dam in Africa. So the purpose of constructing this huge dam is for to generate electricity. The overall generated power is said to be around 1250 Mega watts. And as known to all that merrawi project cost was 1.2 billion Euros. Therefore the annual generation of the dam used to be around 5.5 TW.

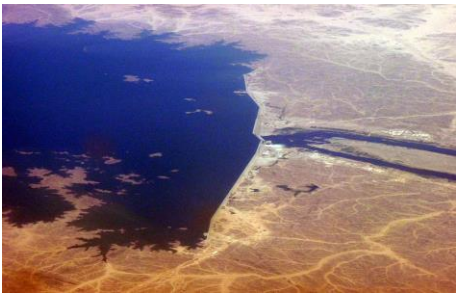


Figure: Shows the satellite view of merrawi dam

Sennar dam:

Sennar dam is the construction which been built by a pure British experience since 1925. The dam situated at the Blue Nile state in Sudan. So that the main purpose of building this dam is to irrigate the cotton and the crops agricultural projects at the area in the last century. The dimensions of the dam are: a length of 3025 meters with a height of 40 meters. Related to the power generation, the dam produces 15 mega watts which mean that each one of the units used to generate around 7.5 mega watts.

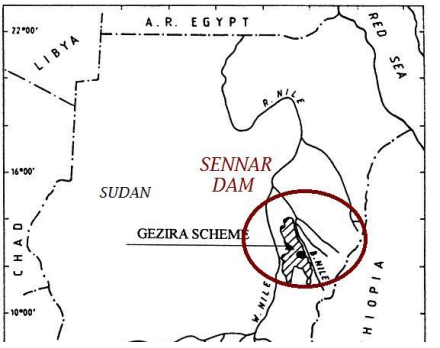


Figure: Shows the dam map Location

Alrosaires dam:

Alrosaires dam is located in dmazeen city at the south of the capital city of Khartoum. So this dam was completed 1966 for the irrigation purpose. And the capacity of the dam is around 280 mega watts, includes seven units, each one produce around 40 mega watts. On the other hand the length of the dam been extended to 25 kilometers in 2013.

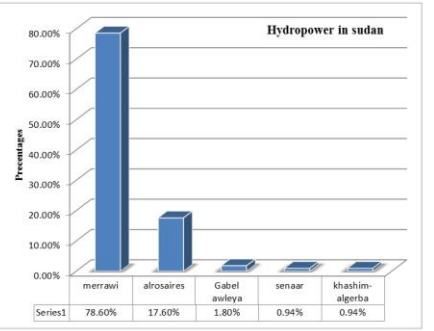


Figure: Shows the hydropower percentages in Sudan

The Diesel Generation in Sudan (Out of the Grid)

Project	Place	Number of Units	Capacity	Actual power
Port Sudan station	red sea state	4 Units (A_B_C_D)	36.5 MW	_
Elgenena station	Darfur state	5 Units	14.7 MW	3.7 MW
Eldeain station	North kordofan state	4 Units	6.5 MW	_
Elnehood station	North kordofan state	6 Units	6 MW	4 MW
Kadogli station	South kordofan state	3 Units	7.7 MW	3 MW
Neyala station	Darfur state	5 units	14.3 MW	11.5 MW
Elobaeed station	North kordofan state	8 units	17.4 MW	_
Elfasheer station	Darfur state	14 unties	19.6 MW	17 MW

Port Sudan Diesel station:

Port Sudan diesel station is situated at east side of Sudan beside the red sea. This diesel station consists of four units, each one of these units having a various capacity. The units been named as: A, B, C, and D. firstly the unit A: unit A has 26

machine, so that the overall generation of these unit is 840KW×26 is equal to 12.5 MW. Secondly unit C which consists of three units generates a power of 17.1 MW, because each one these units used to give a power of 5.7 MW. And finally the unit D which is consists of three units also. Each one of these units generates a power of 2.3, So that the total generation of unit D is 6.9 MW. Put in consideration that the unit B is out of service nowadays because of the annually maintenance.

Elgenena station:

This station is located at the western Sudan at Darfur state, and it consists of five units. The machines of these units been exported from various countries. Such as: Germany, China and America. The units one is consist of two German machines. And it produces 3.2 mega watts out of 3.6 mega watts. The second one is unit two which is a Chinese machine, and it also consists of two units. Each one of these units generates 300 KW out of 3.5 mega watts. The final unit is an American and it consists of one machine. This machine is generating 150 KW out of 500 KW.

Eldeain station:

This diesel station is situated at the western side of Sudan, in north kordofan state. So this station is consists of two units, each one of these units have a different made machines such as: the Chinese machines and the Cheeks ones. The first unit which is the Chinese made having two machines, each one of these machines produce a power of 750 KW and a total power of 1.5 mega watts. On the other hand the unit number two which is a cheeks made, is having also two units, each one of these units produce a power of 2.5 mega watts. So that the total power of this station is around 6.5 mega watts.

Elnohood Station:

Elnohood station situated at the west of Sudan. This station consists of six units, four of them are working and producing a power of 4 mega watts and the rest of the units are still under commissioning.

Kadogli station:

This diesel station is situated at south kordofan state at the west of Sudan. And it consists of seven units, the first unit is consisting of four Chinese machines and their total generation is 4 mega watts. The unit number two is related to Caterpillar Company so it produces a power of 1.350 mega watts. The last unit is out of the service nowadays and it used to generate a power of 1 mega watts. Finally the total generation of Kadogli station is not more than three mega watts.

Notice:

The diesel stations used to be out of the grid all along the year, and it used to be inside the grid during the winter session because of the maintenance services. In addition the dams used to be effected by the flood so that why the diesel energy is said to be an alternative solution for the hydropower energy.

Elfasheer station:

This diesel station is situated at the west side of the Sudan at Darfur state. It is consisting of two stations. They are classified into two different stations known as the old and the new. Firstly the old station which having A, B and C units. Unit A there is seven caterpillar machines their total generation is around 6.5 MW. Secondly the unit B is consisting of two units inside it, each one of them generates 2 mega watts. The third one having two Chinese machines and the total generation is supposed to be 4 mega watts for both. And the actual power is around 700 to 80 KW.

The new station which is a German made is consisting of three different units, each one of them generates a power of 3.7 mega watts. So that the maximum power generation are 11.1 mega watts.

Neyala station:

Nelaya station is located at the west side of Sudan in Darfur state. And it consists of five units, classified as: A, B, C, D, and E. the first unit (A) is a French made, been constructed since the last century in 1984 and it still working at the moment. This unit has four machines generating power as:

2 ×3.5 MW = 7 mega watts
2 ×1.5 MW= 3 mega watts

Notice:

The total power of this unit had been reduced to five mega watts, because of the cooling problem.

Secondly unit (B) which is a British made. The unit got 5 machines each one generate a power of 0.8 MW and it been also reduced to 0.6 MW because of the cooling maintenance.

The third unit (C) has five machines, each one produce a power of 1.8 MW. The fourth unit (D) is a German made (NTU company) and it is generating 5.4 mega watts per hour with the help of three machines. The last unit (E) consists of three caterpillar machines (American made) so the total generation is 4 mega watts.

Elobaeed station:

This power station is located at the western Sudan in north kordofan state. There are three units at this station, Classified into A, B and C. the first unit (A) is Netherlands made and it consists of four machines each one produce a power of 3 mega watts and the total generation of this unit is 12 MW. The second unit (B) is an American made (caterpillar company) and

is consists of two machines each one generate 1.5 MW. The last unit (C) is generating a power of 2.4 MW. Finally the total power generation of this station is around 17.4 MW.

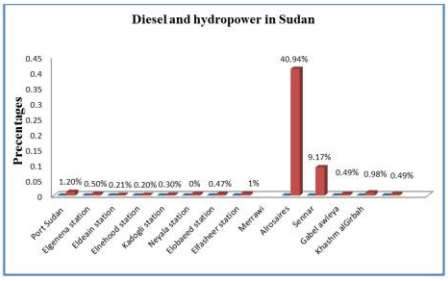
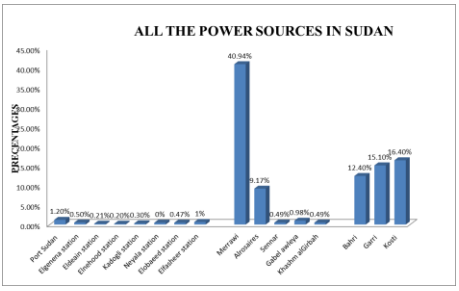


Figure: Illustrates the diesel and the hydropower in Sudan



Future of electric power in Sudan:

There is no doubt that the move of the national economy of the country's electric power needs, and that the division of the country within the framework of the Federal rule requires States to develop, which confirms the need for this energy.

The aim of the overall national strategy to double production:

Electricity ten times the current output of 500 Mega watts to become the 5000 Mega watts during her years ten, estimated demand for electric power in Sudan in the period between 1990 to 2020 at about 11.8% annually which means that he will grow from 1,700 Mega watt hours in 1990 to 15,500 Mega watt hour

in 2010, while demand will grow on the load of 270 Mega watts to 2,000 Mega watts in these same years mentioned.

This generation has reached the maximum in 1995, about 340Mega watts, while generating capacity aqueous vehicle maximum about 308 watts (with the nature of the seasonal fall in the summer and fall seasons to less than 100Mega watts. And the composite thermal generating capacity in the year 1995 was 340 watts, which is available only 160 watts and only reason for this is due to the end of the life span of some machinery and need a complete overhaul to other parts or basic. It seems here the large deficit in supply compared with demand, especially in the summer and autumn seasons, which fall in which water generation capacity and to some extent thermal generation to the lowest levels.

The National Authority for electricity within the framework of the preparation of its plan for the development of the energy sector.

This market study of electric energy supply and demand, and then expectations are processing this request for several years to come, goes to twenty years in the case of a long-term plan and to five years in the case of a medium-term plan in addition to the annual plan.

Accordingly, and despite the fact that the National Electricity moving within the framework of a long-term plan, which showed the possibility of generating water and entered in a solid forecast generation in the context of the construction and expansion of the national network geographically with the development of thermal generation and increase in certain years.

Future plans:

1 - The introduction of two units steaming capacity of 90 * 2 station thermal Kosti.

2 - Introduction of two units steaming capacity of 125 watts

hydro-power Ahamdab 2007.
3 - Insert gas unit Bbhry capacity of 100 watts in 2007
4 - Introduction of eight additional units capacity 125 Mega watts.

And thus the total energy added until 2015, about 1530 Mega watts, the plan developed in 1993 and under which is expected to reach production of electricity by the year 2015 to 1530 Mega watts plan is limited too but do not meet the aspirations of the country in the process of development, such as Sudan, with its bounties and plentiful underground and above ground, and that this plan and put in the time and the authors are not taking into account that Sudan will become the oil state, especially after the influx of Sudanese oil in the late nineties of the last century and is now on the rise steadily. Therefore emerged thinking here to visualize the output terminal electrical energy capacity of relatively large to accommodate the surge of development which began harbingers to enter a lot of investors to the country to invest in all service areas, agricultural and industrial, where is the safety valve for these investments and the presence of energy and ample and stable.

Some models of proposed projects:

Electricity Project Waterfall:

* Goals:
Project aims water waterfall fifth to generate hydro-electric power to cover the needs of the River Nile State's current and future in addition to achieving a surplus can be connected to the neighboring States .

* Location:
The proposed site for the establishment of the reservoir and the

power plant is about 143 kilometers north of the city of Atbara and partner south of the village about 5 kilometers, where the reservoir basin extends south through the mountainous area population almost uninhabited until the outskirts of the village, about 65 kilometers Mberekh south of the reservoir site. The site is proposed to establish the nature of the reservoir geology is suitable where there are basic rocks near the surface of the earth with the availability of local building materials and abundant quantities.

Attributed to design Supreme 334 meters

Attributed to the reservoir behind the summer period 324 meters

Attributed to the period of the reservoir behind the 328-meter floods

It ranges teams balance of power between 7-11 meters

*** Electric power for the project**:

Power generation depends on this project on the natural behavior of the Nile River without any storage. Ranges where the disposal of the river in the summer after the flood between 1,000 to 1,200 cubic meters / second which design a power plant in accordance with this behavior and it can define the parameters of electric power generated from the project are as follows:

Plant capacity ranging from 100 to 120Mega watts. The average annual high power about 800 Mega watts.

Electricity problems in Sudan:

Generation problems:

1 - The generation water seasonality in Albladozlk for irregular rates of water contained in the reservoir due to a decrease azimuth available for turbines.

2 - In many cases the primary purpose of the building is an

irrigation reservoir (Sinnar) Therefore, we find that the production of electricity depends on the quantity to be withdrawn from the reservoir to fulfill the requirements of irrigation.

3 - Decrease the ability of water turbines in Roseires and Hojtha urgent maintenance.

4 - Considerable need for boilers and machinery in thermal Freight Station for maintenance.

5 - Palaces line carrier between Alrasirs and Sennar and Hassahissa and baggier and Omdurman and Alazerkab in accommodating the storage capacity of the turbines, which rose from 210 to 280 megawatts.

6 - stations filled up stings to reduce the effort and do not accommodate the current demand growth in the circles of the country to industry (sugar - Cement Lord - projects ration - and industrial areas in Khartoum and baggier and civilian and either station Haj Abdullah stopped due to a fault in the transformer.

7 - Control Center present needs efficiency and it is not available without the system, information and reading for the generation, transmission and distribution hour by hour, in order to optimize the management of obstetrics.

8 - double the spending on additions and amendments art that raises the efficiency of transport and lack of spare parts and maintenance requirements during the operating period.

9 - generating small (diesel plants) need to qualify and most in need of reconstruction.

There are also losses electrical energy which is the difference between the stomach and the distribution of energy actually sold to consumers.

Divided into:

1 - losses art:

Losses a natural result of a specific passage of electric current

in transformers and conductors and be Losses of iron, copper, Losses in transmission and distribution lines, as well as losses which occur due to electrical current leakage in the distribution networks and poor connections.

2 - Administrative losses:

They Losses other unrelated technical losses workers as a result of mistakes in reading the measurements of electricity consumption and manipulated, or linking to third-party distribution networks uniform (thefts).

Proposals for solving the problem of electrical power:

1 - the provision of spare parts and maintenance to maintain the continuity of Obstetrics and thinking about the possibility of local manufacturing of spare parts.

2 - Work on the stalled rehabilitation units and low operating efficiently In contrast, work on the development of new units to rise generation.

3 - Work on the rehabilitation of generating medium to help at peak times.

4 - Raise the efficiency of generating water.

5 - Work to reduce losses art in the network using terrestrial networks for being more reliable than other networks.

6 - Implementation of electrical networks under the designs to accommodate modern electrical loads required for the long term.

7 - Improving the old networks and switched it with another small-sized wire fit the required growth.

8 - Handle all administrative losses by creating specialized cadres are good.

9 - raising awareness among consumers to reduce overtaking on the electric grid

Conclusion:

The study has a number of aspects of a study of the nature of electricity generation in Sudan and listed types of stations currently operating and proposed future stations and the problems faced by the generation with the development of possible solutions, as well as its future plans for production of electric power in the Sudan. In conclusion I appreciate all the supports and guidance which I have given from the engineers and the staffs in Kosti thermal power stations. And I specially appreciate engineer Ali for his greatest effort till I got this work.

Recommendations and suggestions:

1. Interest in the development of the electricity industry in Sudan so as to provide a great deal of energy for large projects, which will be the cause of the sizes it is not to save energy.
2. Water should pay attention to obstetric and development so as to provide water sources in Sudan and the lack of ongoing costs him.
3. To encourage investment in the electricity industry by providing the necessary guarantees for investors and the development of laws that help to do so.
4. You can export surplus electricity to neighboring countries and to benefit from the proceeds.

REFERENCES:

1. Electric power in Sudan problems and solutions (National Electricity Corporation - Planning Division).
2. National Electricity Corporation, statistical information, the

issuance of December 2003.
3. The third paper Scientific Conference - Energy and Development - the electric power crisis: causes and solutions (D. Yassin Haj Abdin, Director General of the National Electricity Corporation in April 1997 m).
4. Waterfall fifth Electricity Project Report (dam sheriek).
(TID Consulting to develop Khartoum in July 1996 m)
5. ENG. ALI AHMED MOHAMED ALI
6.ENG. KHIDDER ELTYEB KHIDDER ALI (EAST OF LONDON UNIVERSITY SCGHOOL OF ELECTRICAL AND ELECTRONICS ENGINEERING (POWER))
7.ELMAHI ABDALLAH ABDELGADEER (ELNELAIN UNIVERSITY -FACTUALY OF ELECTRICAL ENGINEERING