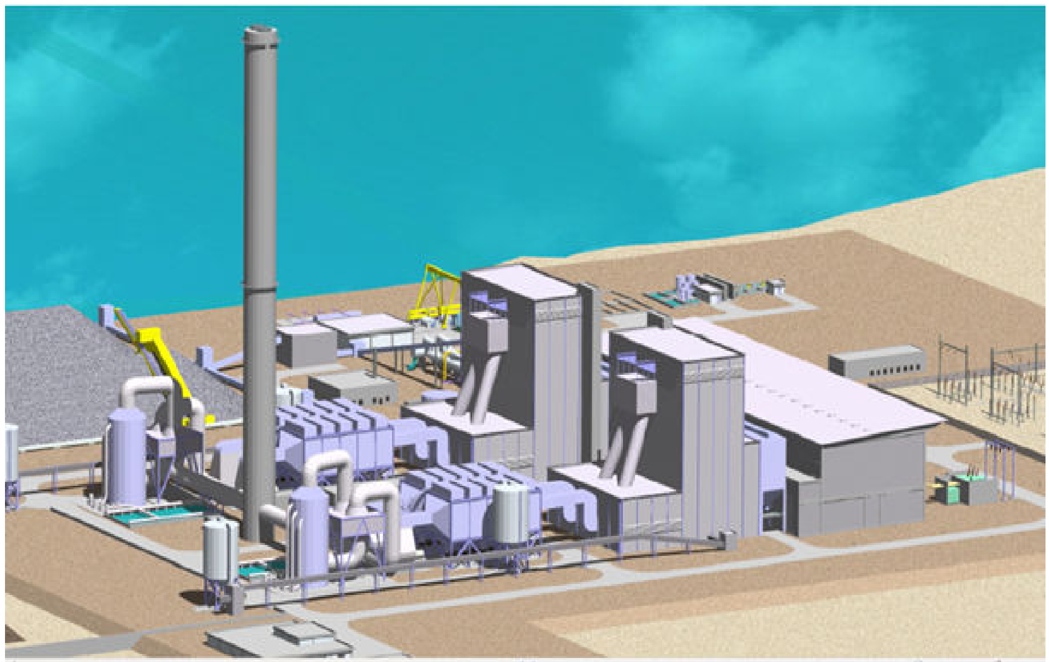
2013

REVISED FEASIBILTY STUDY for

RED SEA COAL FIRED POWER PLANT



Pulverized Coal Fired Boiler
2 X 300 MW Power Station

Sudanese Thermal Power Generating Company
Khartoum – Sudan

Projects Planning Directorate

May 2013

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MINISTRY OF WATER RESOURCES AND ELECTRICITY

Sudanese Thermal Power Generating Company – Khartoum – Sudan

Projects Planning Department

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Executive summary

As part of the current energy policy for the country, the Government of Sudan (GoS) is planning to increase the overall national electrification ratio to at least 80% by 2031 to achieve the following targets:

1. Connect all states of Sudan to the national grid by 2031 - as far as practicable;
2. Utilize a high share of domestic energy sources - as far as practicable;
3. Utilize a high share of renewable energy sources considering economic and technical limitations;
4. Diversify the energy sources - as far as practicable - in order to increase security of supply and reduce dependency;

The Government of Sudan (GoS) is committed to expand the generation capacity in the medium term (4-years) plan with a total of 1,839 MW (gross capacity) between 2012 and 2016/2017. 1,505 MW or 82% of such committed gross capacity will be provided by thermal plants and 334 MW or 18% by hydropower sources.Red Sea coal fired Power Plant Project is representing one of the essential committed power projects in Sudan for which the studies are finalized and for which financing is in the process for acquisition.

Red Sea Power Plant consisting of two independent units with a total capacity of 2 x 300 MW. The plant will basically consist of boiler system, steam generator, flue gas and ash handling systems, harbor facilities and housing area. The produced steam actuates steam turbine generators for electric power generation. The electric power will be transferred into the electric grid via a 220 kV and 500 kV substations. The Red Sea Coal Fired Power Plant is designed to include a Coal Berth with a capacity of 70,000DWT. The Project is located in the state of red sea in eastern Sudan – about 70 km to the north of Port Sudan.

The project studies define that candidate plant should be of a type and size that can be repeatedly added to the system over a 20 year planning period with no practical restriction on the number of units required or availability of fuel. Within these criteria a number of candidate plants were assessed, but the study recommended that thermal generation by coal fired boiler is the most appropriate options to have the following characteristics and benefits:

1. Generation of additional electric power at reduced cost compared with the existing thermal system
2. Quick and radical solution for Port Sudan power and water problems and the consequential economic development
3. Employment of over 1000 local workers during construction period and about 150 for operation thereafter.
4. The location of the power plant near to the area that had been allocated and licensed for cement industry and limestone quarries will give a good chance to accelerate the development of these industries by supplying power.
5. The ash will be consumed by cement factories which is the best environmental solution.

INTRODUCTION

Introduction

Preamble:

Coal is the world's most abundant and widely distributed fossil fuel with reserves for all types of coal estimated to be about 990 billion tonnes, enough for 150 years at current consumption (BGR, 2009).Coal fuels 42% of global electricity production, and is likely to remain a key component of the fuel mix for power generation to meet electricity demand, especially the growing demand in developing countries. Compared to oil and gas, coal is the most abundant of the fossil fuels. According to Planete Engeries, the world reserves will last at least 200 years at current rates of use. The United States, which is that largest energy-consuming country in the world, also has the largest coal reserves of any other nation.

Coal has been used as an energy source for a long time. The systems used to transport coal from mine to power plant are well established. Coal is delivered to power plants primarily by the train load. Coal is also relatively easy to mine for compared to other fossil fuels such as oil and gas. According to Energy Literacy, half of the current reserves in the United States are mineable using current technologies. Coal is also the cheapest fossil fuel option because of its abundance and ease of mining. Many countries are turning to coal as a means of producing electricity because of the increase in costs for oil and gas.

The major disadvantage of burning all fossil fuels is the release of the flue gases oxides, however the overall necessary environmental measurements in impacts defining, mitigating and monitoring accompanies with an efficient advance technical design can guarantee the economical, viable, safe utilization of coal fired power plant.

Red Sea Coal Fired Power Plant Project Background

Sudanese Thermal Power Generating CO. (STPG) is planning to construct a 600 MW coal fired power station composed from two generating units with a capacity of 300 MW for each unit , the plant is associated with desalination plant on the Red Sea Coast north of Port Sudan. In addition to the power and desalination plant the Project will include a number of infrastructure elements including the construction of a coal handling jetty, construction of a 220 kV transmission for the power interconnection with Port Sudan.

The Red Sea Coal Fired Power Plant and Desalination Project (hereafter referred to as the Project) is being developed in recognition of the fact that there is a shortage of both electricity and water to satisfy the needs of the population of the Red Sea State. Furthermore, the Project forms part of the whole country represented in the Ministry of Water Resources And Electricity a wider aim of increasing security of electricity supply and to meet the targets of grid expansion to cover the overall country un-interconnected areas with the National Grid.

Sudanese Thermal Power Generating CO. (STPG) Overview:

STPG is state owned company incorporated in 2010 after the restructuring of Sudan power sector, by dissolving of the formerly state monopoly entity National Electricity Corporation (NEC-Sudan) into a number of companies for power generation, transmission, and distribution.

STPG took the full responsibility of thermal power generation for a system of about 1,200MW as installed capacity in addition to a capacity of more than 1,000 MW in a number of projects currently are under construction.

Sudanese Thermal Power Generation Company Ltd. (STPG), is responsible for operation of all fossil fuel based power plants of Sudan power grids currently, as it is detailed here below:

Table 1-1: Existing thermal power generation facilities

Plant name and location	First year	Fuel oil type	Installed capacity
Khartoum North 1+2 ST	1984	HCGO	60 MW
Khartoum North 3+4 ST	1994	HFO & (HCGO)	120 MW
Khartoum North 5+6 ST	2011	HFO	200 MW
Khartoum North GT 1+2	1992/ 2001	GO	50 MW
Garri-1 Block 1+2 CCGT	2003	GO (LPG)	180 MW
Garri-2 Block 1+2 CCGT	2003/ 2007	GO (LPG)	180 MW
Garri 4 U1+2 ST	2010	Sponge Coke	110 MW

Table 2: Under construction projects of thermal power generation facilities

Plant name and location	First year	Fuel oil type	Installed capacity
Kosti ST	2013	Crude	500 MW
Al Fula ST	2015	AG/NG	405 MW

Table 3: Existing thermal capacity in isolated grids

Isolated grid (name of town)	Location (state)	First year of operation	Generation type / fuel	Number of units	Capacity installed (gross) MW
Neyala	South Darfur	1985	Diesel engine / gasoil	7	29
Al Du'ane	East Darfur	1985		2	8
Al Fashir	North Darfur	2000		11	15
El Genena	West Darfur	1989		4	9
Wadi Halfa	North	1993		5	3
Kadogly	South Kordufan	2004		6	8
El-Nuhood	North Kordufan	2004		4	4
Total					**76**

Site Description

The Project site is situated approximately 75 km north of Port Sudan at Marsa Arakiyai- (Arakiyai Harbour) on the Red Sea Coast. Port Sudan itself is located in north-eastern Sudan as shown in figure S-1 below, approximately 1 000 km from the capital city, Khartoum.
Land between Port Sudan and the Egyptian border to the north is undeveloped semi-arid desert scrubland.

Alternatives Considered

In December 2003 the Research and Consultancy Centre (RCC) of Port Sudan undertook a site selection study for (NEC) to propose the best site for this Project. The conclusions of the study indicated that locating the Project on the Red Sea coast will offer NEC significant economic advantages in terms of fuel purchase, transportation and delivery. It is also imperative that the Project site is close enough to Port Sudan to enable cost-efficient water supply via pipeline to the city if it is required as an option for water supply to the city. An additional consideration is the proximity and abundance of limestone supply to the site. Also one of the justifications for Locating the Project at Arakiyai Harbour will, involve removal of the less some coral during the construction of the jetty. Arakiyai is found to be likely the most favorable option to have of the minimum ecological impacts upon terrestrial fauna as well as marine and terrestrial vegetation, Among the proposed three sites alternatives which are considered for the project siting.

New build coal fired boiler in Port Sudan represents the most favorable option, in particular, in the medium term based on the overall considerations and studies for generation expansion plans of Sudan power generation capacity. Red sea coal fired power plant have the privilege of relatively near position from the coal supply market moreover this is accompanied with the less overall cost for the project based on its favorable levelized cost among the other options of the power plants globally.

Project status

STPG signed an EPC turnkey contract with Harbin Electric International Co. LTD, (HEI) - China on 27th December 2011 for a project construction period of 36 month.

COUNTRY PROFILE

Country Profile

Background:

With some 1.9 million square kilometres, Sudan is the third largest country in Africa, after the secession of South Sudan in July 2011.Based on a recent census conducted in 2008 the population of Sudan is estimated at 35 million people for 2012. The main demographic characteristics of Sudan with a strong impact on power demand are a high population growth, high share of rural, nomadic and displaced population, a low population density and unequal distribution of its population among its states and landscapes. The correlation between electricity consumption (total and by sector) and economic growth in Sudan is very high. The economy in Sudan experienced a long period of growth during the past decade. It is dominated by the exploration of crude oil, agriculture and private services. The importance of the crude oil can be seen in the actual development in Sudan where oil production decreased considerably due to the secession of South Sudan. This caused a shortage of foreign currency and the resulting devaluation of the Sudanese Pound and soaring inflation.

Geographic frame

The Republic of Sudan[9] lies in North East Africa: In the northeast, it has access to the Red Sea providing one major entry point for trade and transport. In the east, it shares borders with Eritrea and Ethiopia where the major share of Sudan's Nile water flows into the country through the Blue Nile and the Atbara and their tributaries. In the south, it shares its longest border with South Sudan where the remaining water inflow occurs through the White Nile. In the west, Sudan shares relatively short borders with the Central African Republic in the South and Libya in the North and a longer border in-between with Chad reaching from desert land in the north to bush land further south. In the north, Sudan's second longest border passes mainly through the desert land with Egypt. It crosses the river Nile carrying all water outflows. The Nile basin is the largest landscape, which lies mostly in the eastern half of the country reaching from the north to the south. The river Nile and its tributaries with several thousand kilometres of river courses and reservoirs have shaped this landscape and dominated the historic and present development of the country. Hence, the majority of the population and most of the agricultural and economic activities are located in this area. Vast desert areas of the Sahara - sparsely populated or uninhabited - extend in the north and east of the country. Savannah and bush lands constitute the remaining areas.

Political and administrative frame

Sudan is sub-divided into 17 states[11] and more than 130 localities. The largest states by size are the North, Northern Darfur, Northern Kordufan and Read Sea; by population Khartoum, Al Gezira, South Darfur and North Kordufan. In general, the Sudanese government and administration is centralised. However, various administrative issues are regulated on lower levels. For instance, the expansion of the distribution grid happens on state level.

Demographic frame

Based on a recent projected census[13] conducted in 2008 the population of Sudan is estimated at 35 million people for 2012. The main demographic characteristics of Sudan with a strong impact on power demand are a high population growth, high share of rural, nomadic and displaced population, a low population density and unequal distribution of its population among its states and landscapes.

Population growth and migration:
The annual population growth is 3.2% (about 1.1 million in absolute terms) which makes Sudan one of the fastest growing countries in the world. The growth is expected to slow down to 3.1% in 2015 and 2.9% in 2019 leading to 38 million in 2015, 44 million in 2020 and 55 million in 2030.

Economic frame

The correlation between electricity consumption (total and by sector) and economic growth in Sudan is very high as detailed in section 4.2.1 making a thorough analysis of the economy necessary as an input for the demand forecasting. The economy in Sudan experienced a long period of growth during the past decade with growth rates averaging at 7%. This was driven by high growth rates in the sectors oil exploration (7%, between 2000 and 2005 double digit growth with an average of 15%), industry (9%) and governmental services (10%). But also private services and agriculture contributed on average 6% and 5% per year respectively.
The economy in Sudan is dominated by the exploration of crude oil, agriculture and private services. According to the official statistics, agriculture has contributed a stable third to the national gross domestic product (GDP) during the past 10 years deriving partly from large agricultural schemes. Private services have a similar share of the economy with finance, insurance and real estate contributing most ahead of transport and communication.
Although the exploration of crude oil contributes only 5 to 10% to the total GDP, it has a very strong influence on the overall economy. The crude oil and petroleum products are the basis for several industries. Further, the crude oil revenues supply foreign currency to the economy and cover a part of the national budget, thus allowing the government for the provision of services as well as cross-subsidies. The importance of the crude oil can be seen in the actual development in Sudan. In 2011, the oil production decreased considerably due to the secession of South Sudan, a 27% decrease as part of GDP.

Power system in Sudan – historic, actual and outlook

The power sector in Sudan went through considerable developments in recent years as follows:
 Demand for energy has increased through the demographic as well as economic development of Sudan and is expected to further increase;
 Ambitious targets for the electrification of the people of Sudan are set;
 Generation capacity has tripled during the past seven years and several new projects are under construction or in the planning stage considering the enormous domestic energy potential;
 The power sector has undergone a major reform.
 The latest power system planning study dates back nearly five years.

As part of the current energy policy of the country, it is the aim of the Government of Sudan (GoS) to:

Increase the overall national electrification ratio to at least 80% by 2031;
 Connect all states of Sudan to the national grid by 2031 - as far as practicable;
 Utilize a high share of domestic energy sources - as far as practicable;
 Utilize a high share of renewable energy sources considering economic and technical limitations;
 Diversify the energy sources - as far as practicable - in order to increase security of supply and reduce dependency;
 Utilize all hydro potential in the country - as far as practicable.

Power system in Sudan – consumption

Presently electricity only accounts for 2% of the total energy use in the country due to a low electrification ratio. This is mainly because the Sudanese national power grid covers only a small portion of the country. For instance, the greater Khartoum area accounts for two thirds of the total energy consumed in the country. Regions not covered by the national grid rely on isolated grids (fuelled by fossil fuels), small gasoil-fired generators or energy substitutes such as kerosene lamps. In mid-2011 there were nearly 1.7 million customers connected to the national power grid of which more than 85% (1.5 million) were domestic. The electrification rate for the whole country is about 30%. During the past six years, the number of customers doubled (both total and domestic) with an annual average increase of 12% indicating that the electrification advances. However, the electrification ratio has increased at a slower path due to the population growth of about 3%. These characteristics of a slowed down electrification are expected to prevail since the population growth will not diminish and the number of new connections is limited by technical and economic constraints. These restrictions have to be taken into consideration when planning for the aim of the Government of Sudan to increase the electrification to 80% by 2031. Figure 1-1 shows this effect by comparing the actual electrification ratio during the past 5 years and the ratio if no population had occurred.

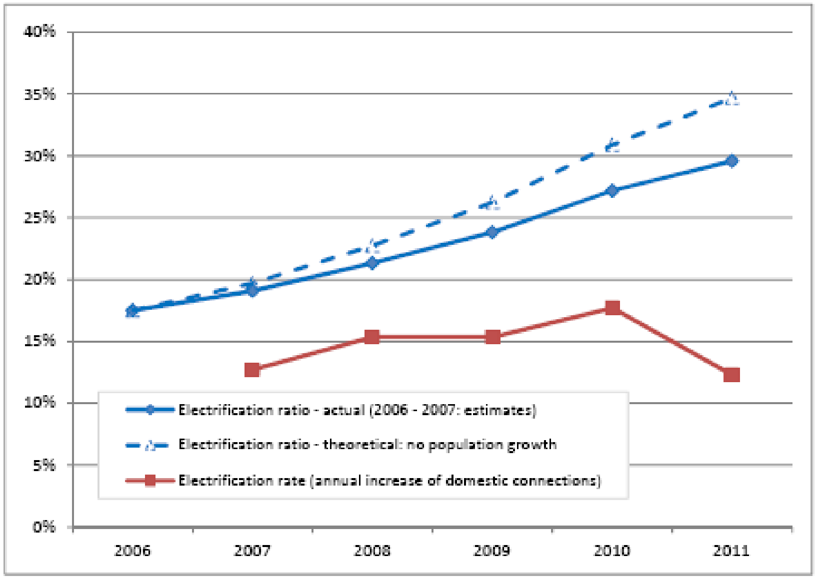

Figure 1-1: Electrification ratio (national grid) and rate (2006 - 2011)

During the past decade the consumption increased by an average of 14% per year, slightly above the growth of connections. While the share of domestic and governmental consumption of total consumption remained stable at about 50% and 14% respectively, the industrial share decreased from 22% in 2000 to 16% in 2011. In the same period, the share of agricultural consumption doubled to nearly 5% and the commercial consumption increased from 12% to 15%. There is a strong correlation between economic growth, as growth of GDP, and the consumption of electricity in total and by consumer group, the strongest for commercial, governmental, domestic consumption and total annual consumption.

Various forms of suppressed demand exist, mainly curtailed demand due to poor security and quality of power supply and non-served demand due to insufficient ability to pay for connection and electricity and insufficient coverage of power grid. The overall suppressed demand in Sudan is estimated at three to four times the current demand, i.e. the existing power system only serves between a fourth and fifth of the potential demand. This rough estimate can serve as a reference point for the current electricity supply and as an indication for the potential future demand for electricity in Sudan.

Power system in Sudan – load characteristics

During the past ten years, the annual peak load in Sudan grew steadily at around 13% per year, similar to the growth of energy consumption (both displayed in the next figure). In 2011, the annual peak load was 1,517 MW (gross, at generator output), nearly double the peak load in 2006. Determined by the annual temperature profile, the development of peak loads throughout

the year show one to two maxima, one during the period April to June and one between August to October The load curve of the national grid varies between seasons as well as between weekday and weekend day. It shows a rather flat minimum between midnight and 7am in the morning and two peaks, one at midday around 2pm and the second in the evening around 8pm. The absolute maximum load depends on the season and day of the week. While the evening peak dominates the months November to March and the midday peak dominates the period April to October, caused by the higher temperatures and higher air condition use.
The load factor varied between 67% and 59% during past decade, as shown in the figure below.

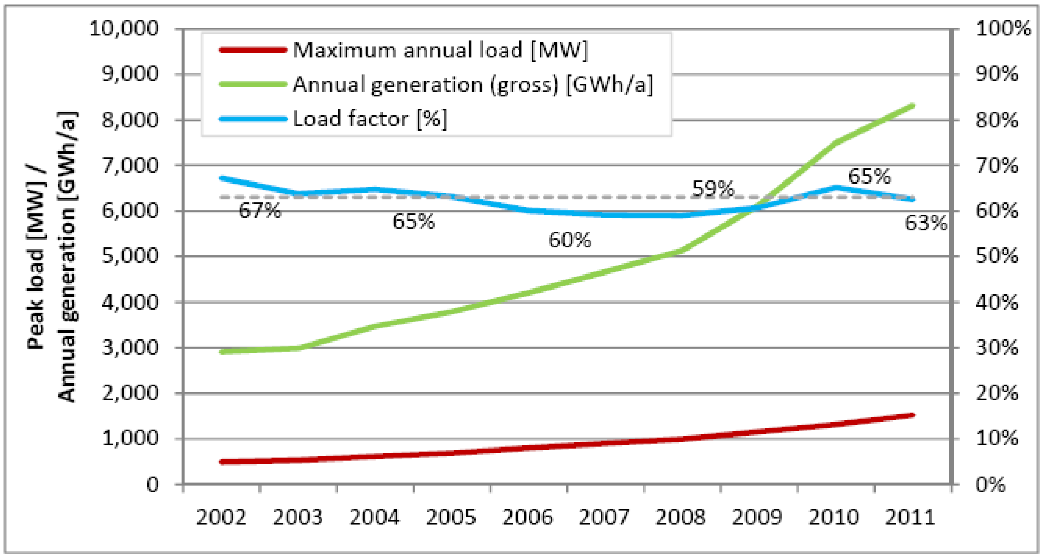

Figure 1-3: Annual generation, peak load and load factor (2002 - 2011)

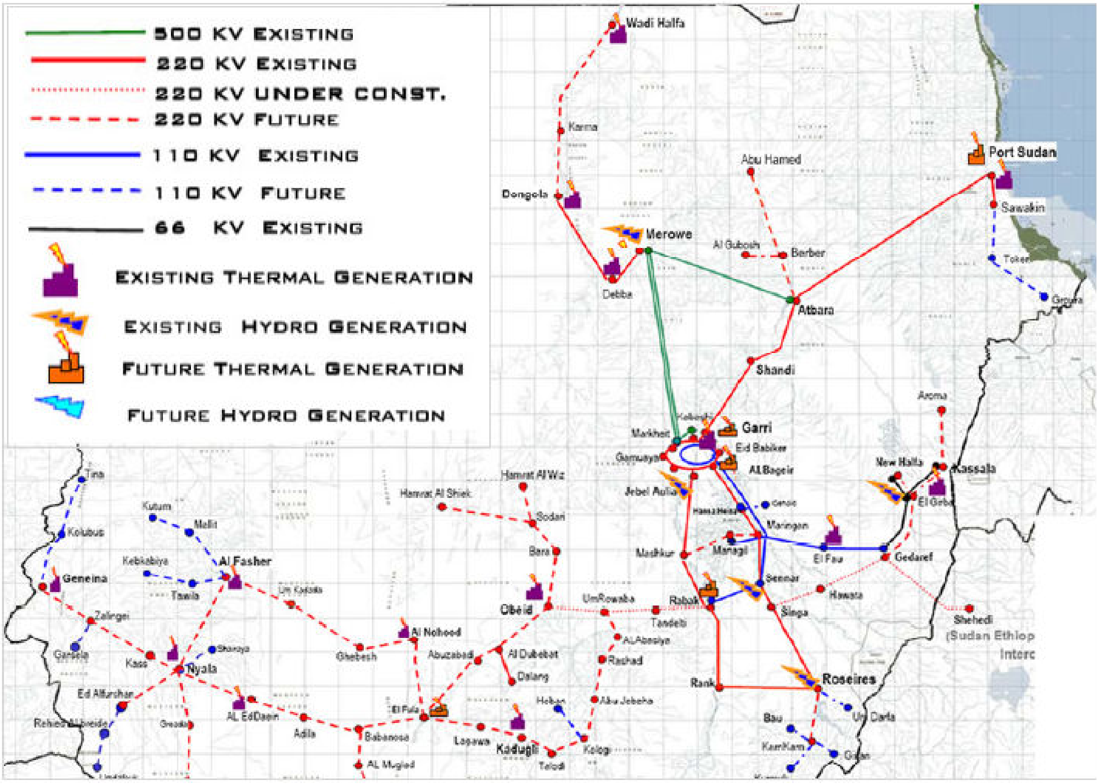

Figure 1-4: Schematic network topology Sudan 2010 (Source: SETCo)

Power system in Sudan – generation

The generation sector in Sudan is determined by two main factors:

- The high share of hydropower through low operational costs; and
- The fluctuation of the underlying water source throughout the year requiring additional thermal generation.

The map below shows the location, type and capacity of existing (*circle*) and committed (*square* & expected first year of operation) power plants.

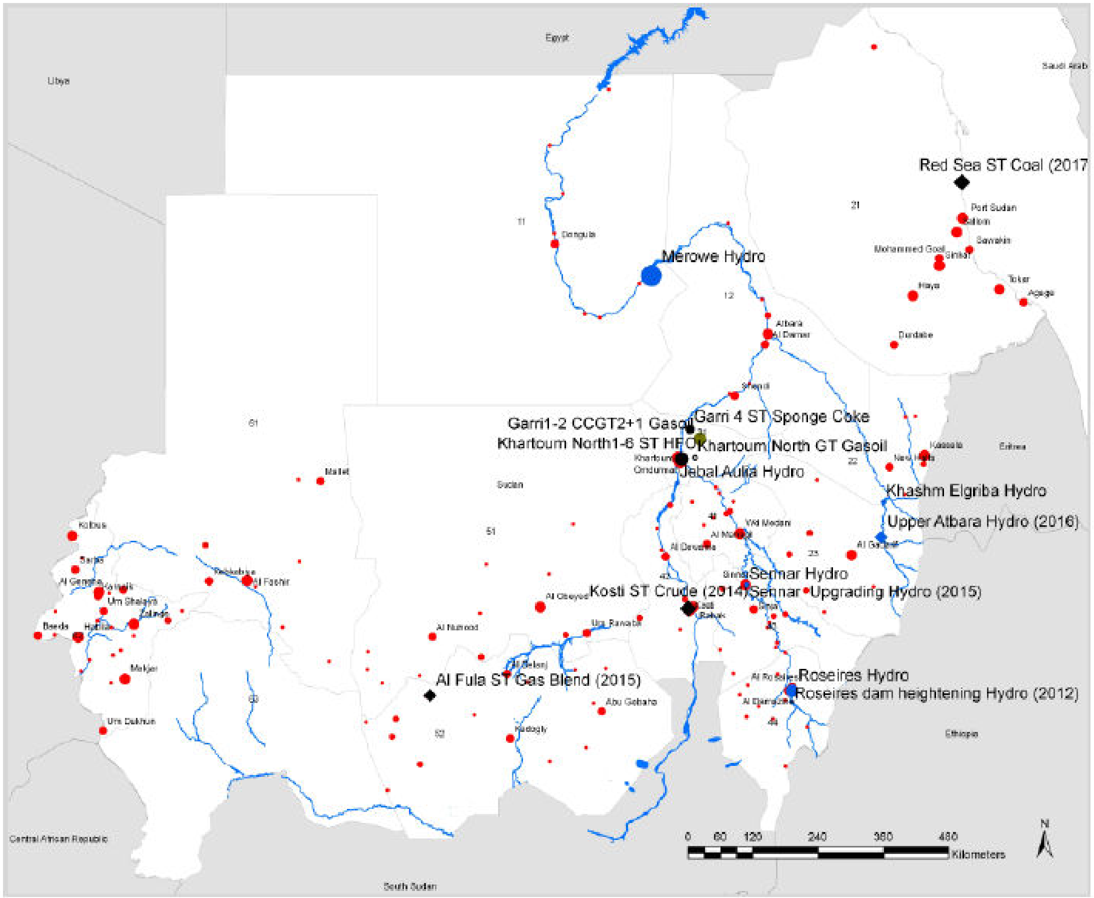

Figure 1-5: Map of Sudan – existing and committed power plants[2]

Long and Medium Term Power System Plans

In 2011, the Ministry of Electricity and Dams (MED) has contracted Lahmeyer International (LI) for the consultancy services for the development of:

1. A long term power system planning study to cover the period 2012-2031; and
2. A medium term plan for the period 2012 – 2016.

Objectives and planning criteria

the following planning criteria and objectives were taken into consideration as a basis for the plan works:

Table 1-1: Planning criteria for expansion planning in Sudan

Economic and political criteria

1.1. Least cost	The power system plan will consider least economic costs by arriving at the expansion plan with the lowest net present value of total costs during the study period (2012 – 2031). However, other criteria and assumptions are taken into consideration such as limits on finance for investments to arrive at reasonable overall annual investment budgets and technical criteria as listed below.
1.2. Electrification rate - population	The target for the electrification ratio is 80% of the population in 2031. Within the demand forecast, three scenarios were developed which reach this target through grid-connected electrification only (high scenario) or have to be supplemented with rural electrification (base and moderate scenario). The balancing of demand and supply for each scenario provides the respective supply gaps which have to be filled with adequate generation candidates.
1.3. Electrification - states connected to the main power grid	All states of Sudan should be connected to the power grid by 2031. Within the demand forecast, three scenarios were developed which reach this target at different years of this study. The balancing of demand and supply for each scenario provides the respective supply gaps which have to be filled with adequate generation candidates.
1.4. Electricity for opti-mum industrial development	The grid connection of large energy consumers with at present own power supply was considered in the demand forecast, in particular for Port Sudan and Atbara/River Nile.
	A high share of domestic energy sources

1.5. Domestic resources / increase domestic added value	should be aimed at as far as practicable.
1.6. Share from renewable energy sources (RES)	A high share of renewable energy sources should be aimed at considering economic and technical limitations. Within this study and parallel studies on renewable energy LI will advise on potential and suitable shares for renewable energy sources
1.7. Diversification of energy sources	A diversification should be aimed at - as far as practicable - in order to increase security of supply and reduce dependency.
1.8. Pricing of domestic energy sources	Domestic energy sources (e.g. crude oil) will be priced at world market prices.
2. Technical criteria	
2.1. Reliability (security and quality of power supply), reserve margin	The total reserve margin is set at 15% of the peak load. In addition, a spinning reserve of the largest unit dispatched in the system but at least 150 MW will be applied. For power transmission an adequate ratio of reliability and cost will be applied on a case by case basis during the transmission development exercises.
3. Environmental criteria	
3.1. Pollutant emissions	World Bank standards will be applied as minimum criteria (for e.g. CO_2, SOx, NOx, particulate matter).
3.2. Other local impact	Criteria applied in previous projects in Sudan will be considered for other local environmental and social impact (e.g. noise, land use / re-settlement).

Here below the study results are summarized for the network expansions and developments:

1. A moderate scenario - assuming an expansion and demand growth similar to the recent years;
2. A high scenario towards the grid-connected electrification of 80% of all households in 2031, which requires a considerable increase of electrification efforts compared to the past; and
3. A base scenario in-between the above scenarios. It is forecasted to reach the electrification target of 80% mainly by grid-connection supplemented by off-grid rural electrification.

They key results and findings for each scenario are prescribed as follows:

Moderate scenario

For the moderate scenario, demand for energy and peak load are forecasted to grow by an average annual rate of 10.5% for the period until 2021, 4.5% for the period 2021 to 2031 and 7.5% for the whole study period. On average 250 MW of load and 1,400 GWh of energy consumption at generation sent-out level is added every year. Energy generation (sent-out), energy consumption (billed) and peak load will reach 35,000 GWh, 29,000 GWh and 6,400 MW in 2031, respectively. For this scenario, some 1.3 million of new connections, 90% domestic, would be necessary until 2016. The electrification ratio is forecasted to grow by nearly two percentage points per year. It will reach 62% in 2031.

Base scenario

For the base scenario, demand for energy and peak load are forecasted to grow by an average annual rate of 12% for the period until 2021, 4.5% for the period 2021 to 2031 and 8% for the whole study period. On average 280 MW of load and 1,600 GWh of energy consumption at generation sent-out level is added every year Energy generation (sent out), energy consumption (billed) and peak load will reach 40,000 GWh, 33,000 GWh and 7,100 MW in 2031, respectively. For this scenario, some 1.6 million of new connections, 90% domestic, would be necessary until 2016.The electrification ratio is forecasted to grow by an average of two percentage points per year. It will reach 71% in 2031.

High scenario

For the high scenario, demand for energy and peak load are forecasted to grow by an average annual rate of 13% for the period until 2021, 4.5% for the period 2021 to 2031 and 9% for the whole study period. On average 330 MW of load and 1,800 GWh of energy consumption at generation sent-out level is added every year. Energy generation (sent out), energy consumption (billed) and peak load will reach 45,000 GWh, 38,000 GWh and 8,100 MW in 2031, respectively. For this scenario, some 1.9 million of new connections, 90% domestic, would be necessary until 2016, i.e. the overall connections would have to more than double within five years. The electrification ratio is forecasted to grow by an average of six percentage points per year during the first five years. It is forecasted to decrease when most states are connected and electrification will be more difficult to achieve. The electrification ratio is expected to grow by less than half percentage point towards the end of the period and will reach 80% in 2031, the envisaged electrification target.

Institutional and political frame of the power sector

Based on the Federal Cabinet of Minister's decision in 2010 the competencies of the National

Electricity Cooperation (NEC) have been transferred in real estates and tasks ownership, under the umbrella of the MED. Accordingly, MED converted the electricity sector into five companies as follows:

- Merowe Dam Company Ltd, operating Merowe hydro power plant (HPP);
- Sudanese Hydropower Generation Company Ltd. (SHGC), responsible for operation of the remaining HPPs;
- Sudanese Thermal Power Generation Company Ltd. (STPG), responsible for operation of all fossil fuel based power plants;
- Sudanese Electricity Transmission Company Ltd. (SETCo), which is operating, maintaining and extending the transmission grid;
- Sudanese Electricity Distribution Company Ltd. (SEDCo), which is operating, maintaining and – in cooperation with the states – extending the distribution grid.

All the above five companies are under full control of the Ministry which is responsible for the general policy, planning and for supervising the above utility companies.

In 2012 MED changed into the Ministry of Water Resources and Electricity (MWRE).

Other state institutions involved in the power sector are:

- Dam Implementation Unit (DIU) as part of the MED, responsible for the planning of new HPPs;
- Ministry of Finance, providing financing sources for projects and operational budgets;

Institutions of each state, for instance responsible for the extension of the distribution grid in their area

- Electricity Regulatory Authority: providing regulation and supervision of the electricity sector.

As part of the current energy policy it is the aim of the Government of Sudan (**GoS**) to:

- Increase the overall national electrification ratio to at least 80% by 2031;
- Connect all states of Sudan to the national power grid by 2031 - as far as practicable;
- Utilize a high share of domestic energy sources - as far as practicable;
- Utilize a high share of renewable energy sources considering economic and technical limitations;
- Diversify the energy sources - as far as practicable - in order to increase security of supply and reduce dependency;
- Utilize all hydro potential in the country - as far as practicable.

Electricity in Sudan is subsidised through fuel subsidies and the provision of investment costs for new power plants, which are not passed through to the customer.

Electrification rate (national grid) and connections by sector

Presently electricity only accounts for 2% of the total energy use in the country due to a low electrification ratio. This is mainly because the Sudanese national power grid covers only a small portion of the country.

Power system in Sudan - summary

Below the Sudanese power system is briefly described as follows:
The existing electrical network in Sudan has been designed for an operating voltage level up to 500 kV. This fact is giving the network the capability to transfer available generated electricity from remote hydropower plants like Merowe HPP, and Roseires HPP to the main load centres of the country that are located at relative long distances of up to 500 km like the greater Khartoum area with 60% of the total load. Several other production sites are locally supporting the load demand, especially in Khartoum itself and sites in the east-ern states, i.e. Sinnar, Al Gadarif and Red Sea region.
The transmission grid system is divided into Khartoum, Al Gezira, Eastern, White Nile and Northern areas. The electrical system comprises the 500 kV National Grid branched to the 220 kV and 110 kV level to the West and 220 kV / 110 kV / 66 kV at the East of Sudan. The transmission of electricity takes place through two interconnected electrical grids -- the Blue Nile Grid and the Western grid – covering geographically a portion of the country. The distribution of electricity is performed on 33 kV and 11 kV voltage levels. Isolated power systems rely on small gasoil-fired generators and the voltage level's implementation of 33 kV and 11 kV for local distribution.

Interconnections with neighbouring countries

Interconnection with Ethiopia

In 2011, an interconnection of the Sudanese system via Gedaref-220 kV to Ethiopia has been realized and started commercial operation in 2012. It consists of a 220 kV double circuit transmission line of total economical transmission capacity of 200 MW.

Interconnection with Egypt

A connection with Egypt is under investigation. A recent feasibility study, conducted in August 2012, revealed two feasible options to interconnect the electrical networks of Sudan and Egypt:

- Option 1: 220 kV double circuit transmission line form Toshka 2 substation in Egypt to Wadi Halfa 220 kV substation in Sudan with a total lengths of 162 km and maximum power flow of 200 MW.

- Option 2: 500 kV double circuit transmission line from new North West High Dam substation in Egypt to new Algoreair 500 kV substation in Sudan with a total length of 767 km and maximum power flow of 1000 MW..

Both countries agreed to start implementation of the first option (220 kV) in 2012. The commercial operation is envisaged for the beginning of 2014. The consultant considers this a challenging time schedule. The second option (500 kV) may be implemented in future. No information on the future power purchase agreement between Egypt and Sudan was available at the time of this study.

Interconnections with other countries

Further interconnections and energy exchange might be feasible in future (e.g. with Chad, South Sudan and Saudi Arabia). However, no other interconnections are considered in this study.

Renewable energy sources (other than hydro)

Sudan holds abundant renewable energy sources (RES). Its hydro resources are already being utilized or are under development, as described in section 5. Besides the hydro re-sources, there is further RES potential through solar and wind energy, biomass and bio-gas, and geothermal energy. A detailed assessment of the physical, technical and economic potential of these sources as well as the implementation opportunities and barriers in Sudan is covered by the Renewable Energy Master Plan (REMP). This study is under preparation by Lahmeyer International for the MWRE, in parallel to the Long and Medium Term Power System Plans (LMTPSP).

In summary, large-scale expansion of solar photovoltaic power plants (close to the main load centre in the Greater Khartoum Area) and wind farms (in regions of preferable wind regimes) are technically and economically feasible in the Sudanese power system. Due to their potential to save fossil fuels at existing thermal power plants the extent of utility scale solar and wind power plants can be in the range of several 100 megawatts during the next decade. In addition, biomass and small hydro power plants provide additional feasible options to use renewable energy, though at a lower scale but with a higher reliability.

The following graphs show the developments of RES installed capacity for the next ten years according to the assumptions detailed above and summarized in the table as well as estimated annual generation for the next twenty years, to be considered in the successive expansion modelling. For these assumptions the contribution of electricity generation from RES (large hydro not included) to the overall electricity consumption will increase from currently zero to around 5 to 7% in 2016, 7 to 9% in 2021, and 9 to 11% in 2031 de-pending on the demand scenario.

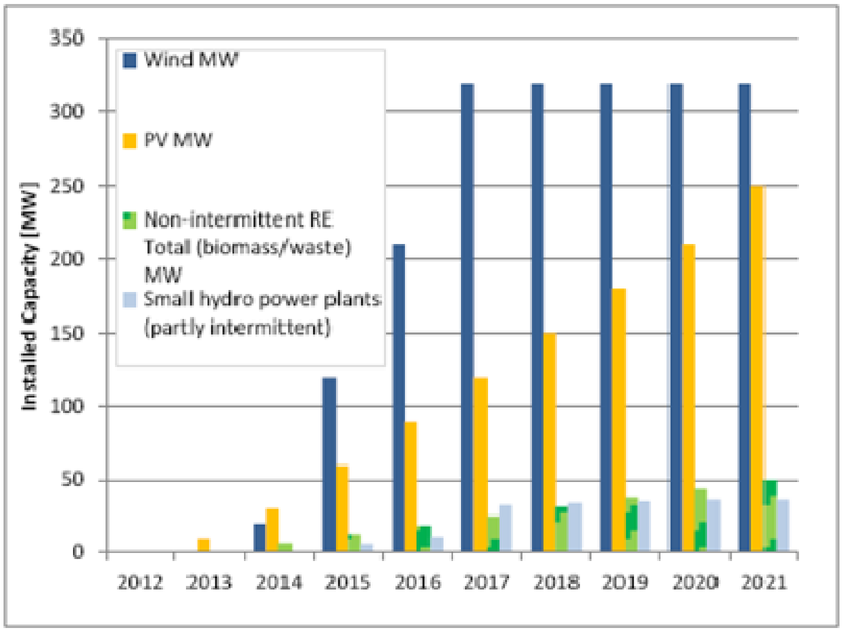

Figure 6-1: Cumulative installed capacity by RES assumed for 2012–2021

Table 7-4: Existing hydro and thermal power generation facilities

Plant name[34]	Operation		Fuel type[35]	Capacity			Energy
	First year	Last year (expected)	(secondary fuel)	Installed (gross)	Available (net) high	Available (net) low (August)	Firm annual
				MW	MW	MW	GWh
Hydro							
Merowe	2009	beyond study period[36]	Hydro	1,250	1,240	872	5,450
Roseires	1966			280	270	164	1,050
Sennar	1962			15	12	7	50
Jebal Aulia	2003			30	19	0	55
Khashm Elgirba	1964			10	10	9	67
Sub-total				1,585	1,551	1,052	6,672
Thermal							
Khartoum North 1+2 ST	1984	2015	HCGO	60	28[37]	28	212
Khartoum North 3+4 ST	1994	2031	HFO (HCGO)	120	110	110	840
Khartoum North 5+6 ST	2011	2041	HFO	200	190	190	1,408
Khartoum North GT 1+2	1992/ 2001	2015/ 2028	GO	50	34	34	265
Garri-1 Block 1+2 CCGT	2003	2028	GO (LPG)	180	170	170	1,346
Garri-2 Block 1+2 CCGT	2003/ 2007	2028	GO (LPG)	180	170	170	1,346
Garri 4 U1+2 ST	2010	2028	Sponge Coke	110	100	100	708
Sub-total				900	801	801	6,124
Total				2,485	2,352	1,853	12,796

Plant name[34]	Operation		Fuel type[35]	Capacity			Energy
	First year	Last year (expec pec-ted)	(second-ary fuel)	In-stalled (gross)	Available (net) high	Available (net) low (August)	Firm annual
				MW	MW	MW	GWh
Hydro							
Merowe	2009			1,250	1,240	872	5,450
Roseires	1966			280	270	164	1,050
Sennar	1962	beyond study period[36]	Hydro	15	12	7	50
Jebal Aulia	2003			30	19	0	55
Khashm Elgirba	1964			10	10	9	67
Sub-total				1,585	1,551	1,052	6,672
Thermal							
Khartoum North 1+2 ST	1984	2015	HCGO	60	28[37]	28	212
Khartoum North 3+4 ST	1994	2031	HFO (HCGO)	120	110	110	840
Khartoum North 5+6 ST	2011	2041	HFO	200	190	190	1,408
Khartoum North GT 1+2	1992/ 2001	2015/ 2028	GO	50	34	34	265
Garri-1 Block 1+2 CCGT	2003	2028	GO (LPG)	180	170	170	1,346
Garri-2 Block 1+2 CCGT	2003/ 2007	2028	GO (LPG)	180	170	170	1,346
Garri 4 U1+2 ST	2010	2028	Sponge Coke	110	100	100	708
Sub-total				900	801	801	6,124
Total				2,485	2,352	1,853	12,796

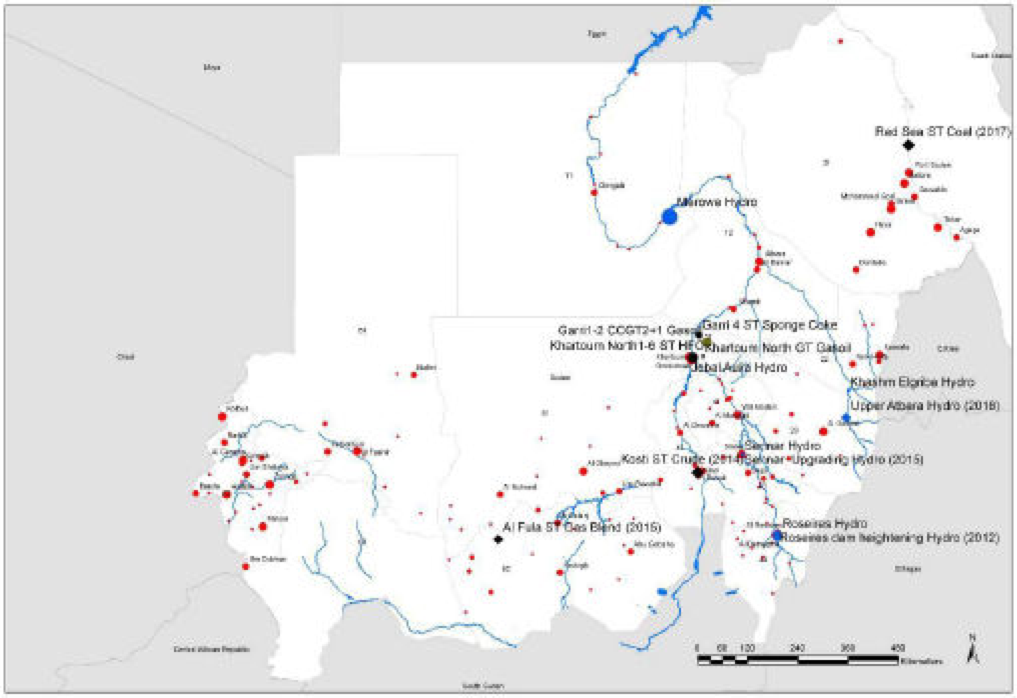

Figure 7-2: Map of Sudan – existing and committed power plants

Transmission lines and ratings

A complete list of existing line connections for the transmission system including main electrical parameters and its rating available for simulations is attached in Annex 2. De-tailed information on the transmission system is provided in the Demand Forecast Report - WP III – Evaluation of Existing Facilities.

The number of transmission lines and total length by voltage is provided below:

Table 7-5: Transmission system length by voltage level

Voltage level kV	Number of lines #	Total length approx. km
500 kV	4	970
220 kV	74	7000
110 kV	51	1180
66 kV	8	320

A geographical configuration overview about the present infrastructure for the transmission network including existing, under construction and planned transmission lines is en-closed as a schematic network topology in the figure below.

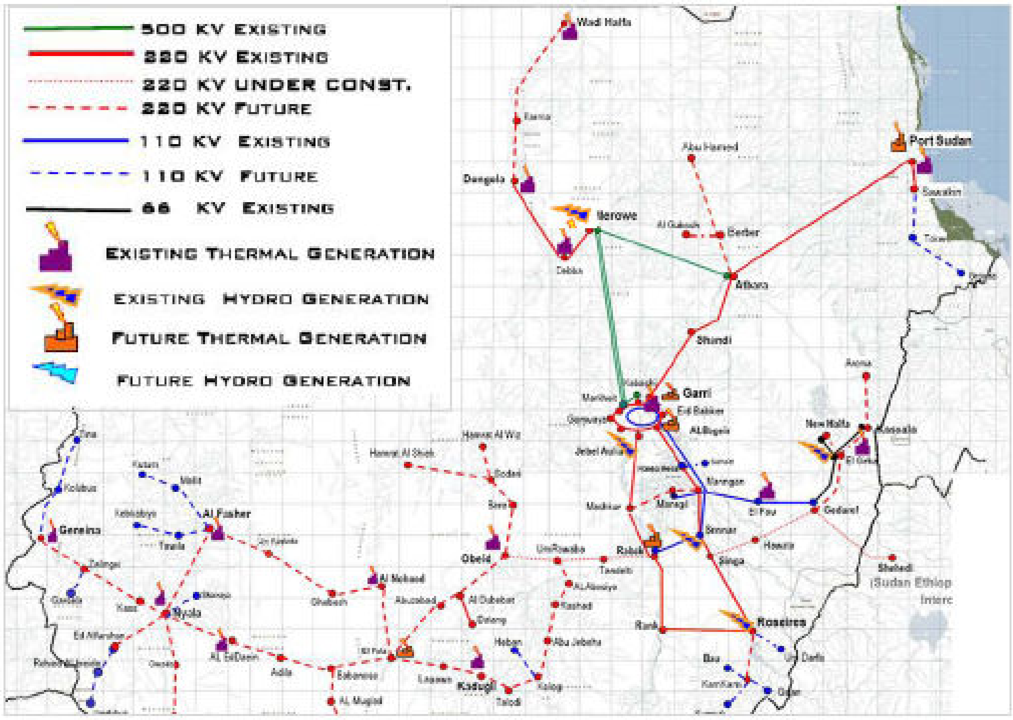

Figure 7-3: Schematic network topology Sudan 2010 (Source: SETCo)

Voltage and frequency

Presently, the national electrical system of Sudan operates on the transmission level with standard tensions of 66 kV, 110 kV, 220 kV and 500 kV; furthermore on the distribution levels the standard tension of 11 kV and 33 kV have been implemented in the networks scheme. The nominal fundamental system frequency for the electrical network is 50 Hz.

Committed projects and generation retirements until 2016

This section describes the committed projects in Sudan for which the studies are finalised and for which financing was or is in the final process for acquisition.
Furthermore, the section lined out projects, which evoked in the collected documents and/or during the discussions carried out during the data collection missions in the country. The studies of prefeasibility of these projects were not started yet or are in hand.

Generation capacity development until 2016/2017

A total of 1,839 MW (gross capacity) is committed to be installed between 2012 and 2016/2017, about the period underlying the medium term (4-years) plan. 1,505 MW or 82% of such committed gross capacity will be provided by thermal plants and 334 MW or 18% by hydropower sources.

The corresponding numbers expressed in terms of available capacity (net capacity sent out) total 1,719 MW, with 1,385 MW (or 81%) generated from thermal and 334 MW (19%) generated from hydropower sources. The corresponding numbers expressed in terms of
Lowest monthly available capacity (sent out) total 1,665 MW (about 12% below the in-stalled capacity), with 1,385 MW (or 86%) generated from thermal and 280 MW (14%) generated from hydropower sources.
The following tables provide an overview of the committed hydro, thermal and renewable power generation facilities in the country including years of plant commissioning and ex-pected retirement as well as installed and available capacity parameters, and firm annual energy value projections.

Table 7-18: Committed power generation facilities 2016/2017

Plant name[41]	Operation		Fuel type[42]	Capacity			Energy	Remark
	First year	Last year (expected)	(secondary fuel)	Installed (gross)	Available (net) high	Available (net) low (August)	Firm annual	
				MW	MW	MW	GWh	
Hydro								
Upper Atbara	2016	beyond study period[43]	Hydro	320	317	225	710	Peaking plant
Roseires Dam Heightening	2012			(280) 280[44]	(270) 270[44]	(164) 214[44]	(1,050) 1,410[44]	For irrigation scheme; no additional capacity but energy
Sennar Upgrading	2015			(15) 26[45]	(12) 25.7[45]	(7) 12[45]	(50) 105[45]	Replaces existing Sennar units
Sub-total				331	331	280	1,125	
Thermal								
Red Sea ST	2017	2043	Coal	600	534	534	4,079	
Al Fula ST	2016	2046	AG/NG (Crude)	405	381	381	2,908	Gas sources not secured yet
Kosti ST	2013/ 2014	2043	Crude (HFO)	500	470	470	3,590	Fuel supply uncertain
Sub-total				1,505	1,385	1,385	10,577	
Total				1,836	1,716	1,665	11,702	

Additionally renewable energy sources (RES) in form of wind and photovoltaic in utility scale shows high potential for the integration in the generation plan. The table below indi-cate available information about planned and committed projects and respective stage together with the expected installed capacity.

Table 7-19: Renewable energy power generation facilities 2016

Plant name*'	Operation		RES	Capacity		Energy	Remark
	First year	Last year (expected)	(renewable source)	Installed (gross)	Available (net) high-low (for August)	Firm annual	
				MW	MW	GWh	
PV-Solar Plant Khartoum	2013	n.a.	Solar energy	90	Analysis on-going	n.a	Tendering
Wind Farm Dongola	2014	n.a.	Wind energy	100	Analysis on-going	n.a.	Tendering
Wind Farm Khartoum	2015	n.a.	Wind energy	20	Not available yet		Planning stage
Wind Farm Red Sea	2016	n.a.	Wind energy	90	Analysis on-going	n.a.	Feasibility stage
RES Total				300			

Electrical network development until 2016/2017

Regarding network extension, several projects across the country are on planning stage or even committed as the figure below indicates

Table 8-1: Overview generation expansion candidates

#	Candidate plant	Gross capacity
Hydropower plant (HPP) candidates		
1	Shereik HPP	420 MW
2	Kajbar HPP	360 MW
3	Dagash HPP	312 MW
4	Mograt HPP	312 MW
5	Dal Low[53] HPP	648 MW
6	Sabaloka HPP	205 MW
	Dinder HPP / Atbara Irrigation HPP [54]	60 MW / 60 MW
Generic thermal power plant (TPP) candidates (fossil fuelled)		
1	Coal fired steam power plant (Coal SPP)	2*300 MW
2	Crude oil / HFO fired steam power plant (Crude / HFO SPP)	2*300 MW
3	LNG (Liquefied Natural Gas) fired combined cycle gas turbine (LNG CCGT)	2*497 MW (Red Sea) 2*414 MW (Nile)[55] (2+1 Configuration: 2 gas turbines + 1 steam turbine)
4	Natural gas (Red Sea) fired combined cycle gas turbine (NG CCGT)	

Table 8-18: Recollection of generic TPP candidates (fossil fuelled)

#	Candidate plant	Gross capacity	Remark
Generic thermal plant candidates (fossil fuelled)			
1	Coal fired steam power plant (Coal SPP)	2*300 MW	Plant location at Red Sea or Nile - to be determined (see scenario T 2)
2	Crude oil / HFO fired steam power plant (Crude / HFO SPP)	2*300 MW	Plant location to be determined (see scenario T 3)
3	LNG fired combined cycle gas turbine (LNG CCGT)	2*497 MW (Red Sea) 2*414 MW (Nile) (2+1 Configuration: 2 gas turbines + 1 steam turbine)	Plant location at Red Sea or Nile - to be determined (see scenario T 4)
4	Natural gas (Red Sea) fired combined cycle gas turbine (NG CCGT)		Plant location at Red Sea or Nile - to be determined (see scenario T 4)

PROJECT OVERVIEW

Project overview

Project studies

As a part from the project preparation the following studies were carried out:

1. Site selection study by Research and Consultancy Centre (RCC) of Port Sudan Alahlia Colleague - December 2003
2. Preliminary feasibility study by NEC - Aug, 2004
3. Red Sea Power Project & Desalination Plant – Preliminary Environmental Impact Assessment - Mott MacDonald - June 2005
4. Coal market survey - Mott MacDonald - Aug, 2007
5. GEOTECHNICAL INVESTIGATION REPORT FOR PROJECT OF COAL BERTH OF RED SEA POWER PLANT AT ARKEYAY, SUDAN (FOR FEASIBILITY STUDY STAGE) by FHDI ENGINEERING CO., LTD - NOVEMBER 2007
6. Topographic Survey Report for Project of Coal Berth of Red Sea Power Plant at Arkeyay, Sudan By FHDI ENGINEERING Co., LTD - NOVEMBER, 2007
7. SEAWATER TEMPERATURE MEASUREMENT REPORT FOR RED SEA POWER PLANT PROJECT AT ARKEYAY, SUDAN by SOUTHSOUTH CHINA UNIVERSITY OF TECHNOLOGY - NOVEMBER 2007
8. Bathometric hydro graphic survey for Marsa Arkeyay by Sudan Navy – February 2009.
9. Specification Tender documents
10. Project Contract documents with Harbin international (HEI) December 2011.
11. EIA Updating of Red Sea Power Plant Project - SMEC International 2012/2013.

Analysis of Alternatives

This section summarises alternative project options in terms of both project site and power generation type.

Project Site

Locating the Project on the Red Sea coast will offer NEC significant economic advantages in terms of fuel purchase, transportation and delivery. Proximity of the Project site to Port Sudan would enable more cost efficient water supply via pipeline to the city. An additional consideration is the proximity and abundance of limestone supply to the site for use in the emissions abatement technique to be adopted.

In December 2003 the Research and Consultancy Centre (RCC) of Port Sudan undertook a site selection study for NEC to propose the best site for this Project. The considerations and findings of the RCC's report are summarised below.

Harbour Selection

Three harbours along the coast were considered as possible sites for development of this power and desalination project:·

1. Figa Harbour (Arous area): Arous is nationally and internationally valued for its aesthetics, having very clear waters and clean, sandy beaches. Figa Harbour is located close to some of Sudan's best preserved coral reefs (Swadi and Romi). Arous and Figa Harbour, therefore, hold great potential for ecotourism development. The area is located approximately 40 km from Port Sudan and is, therefore, quiet and free from polluting activities. Sea grass beds are common within the shallow waters here, and a rich vegetation of halophytic species is present behind the cliffs.
2. Arakiyai Harbour :Arakiyai Harbour is located 75 km north of Port Sudan and is a semi-enclosed lagoon with cliffs bordering the shoreline. Sea grasses are present in the shallow part of the lagoon, the beach is relatively clean and sandy with a large number of crab mounds. Mangrove trees are present in the lagoon and are some of the oldest mangroves in Sudan. The area is popular for picnicking and Kokian collecting (shells used to make perfume).
1. Sheikh Ibrahim Harbour Located around 95 km from Port Sudan, this harbour is a flat coastal plain with no cliffs, and is used as a landing site by fishermen. The bay is delineated by a dense and well-established mangrove stand, seagrasses and algae, and is home to a large number of sea birds. There are plans to establish a shrimp-culturing project in the vicinity of the bay.

RCC's study, by using a very simplified selection assessment methodology, concluded that Arakiyai Harbour would be the best location for the Project. NEC has, therefore, proceeded on this basis.. It is not possible for the harbour, in its current state, to receive ships of up to 80 000 dry weight tonnage (DWT) bulk cargo, one of the justifications for its selection.
Locating the Project at Arakiyai Harbour will, therefore, involve removal of some coral in construction of the jetty. Ecological surveys undertaken for this assessment indicated a lack of terrestrial flora and fauna and lack of marine flora, therefore, in terms of limiting ecological impact to marine fauna Arakiyai may be more favourable.

Generating Technologies

Electricity demand has been suppressed by available generation capacity for a number of years. Unsuppressed demand is forecast to continue to exceed generation capacity if NEC does not expand installed generation.

A study undertaken by PB Power in 2003 on generation planning reviews the development options for additional generation connected to the grid. Whilst the Red Sea State was not connected to the National Grid at that time, extension of the grid will connect the area by 2007, so the conclusions of the study are relevant. The study defines that candidate plant should be of a type and size that can be repeatedly added to the system over a 20 year planning period with no practical restriction on the number of units required or availability of fuel. Within these criteria a number of candidate plants were assessed, but the study recommended that thermal generation and hydroelectricity were the most appropriate options. To strength that recommendation other factors such as the availability and reliability, existing infrastructure, land use planning requirements, environmental impact and socioeconomic impacts are considered in the EIA study of MML in 2007 to have a high level analysis of alternative for the generating options.

This analysis takes account of the other factors noted above and the outcome of the analysis is summarised in Table [1]. The generating technologies considered in this analysis were:

· New build coal fired boiler and steam turbine plant
· New build HFO fired steam generation plant
· New build HFO fired slow or medium speed diesel engine plant
· New build distillate fired gas turbine plant
· New build liquefied petroleum gas (LPG) fired combined cycle or open cycle plant
· New build hydroelectric plant
· New build wind turbines
· New build photovoltaic (single site)
· New build photovoltaic (domestic/commercial application).
· New geothermal plant.

Timing of New Generation

The assessment of need for further electricity generation carried out in 2007 concluded that maximum demand was not being matched by the generation capacity at that time in the Red Sea State. Additional capacity of 165 MW is already required with an expectation of further demand once supply restrictions are eased.

For the purposes of that assessment, the timing of new generation was considered in terms of:
Short term availability: new plant to be commissioned and operational by 2008
Medium term availability: new plant or contracted generation available by 2012
Long term availability: new plant or contracted generation available after 2012.

Availability and Reliability

The availability and reliability of different generating technologies is an important consideration in generation planning. Whereas thermal power plant such as boiler plant and diesel engines generally have a high availability and reliability, hydroelectric plant may be just as reliable but less available due to water level fluctuations. Any restrictions in availability of certain generating technologies such as rainfall for hydroelectric plant and wind for wind turbines will limit their application in providing base or semi-base load generation. New generation must be able to assist in providing base or semi base load.

Existing Infrastructure

The provision of new generating plant also includes utility connections, not least to export the power.
Other considerations include fuel supply infrastructure. The extent of new infrastructure must be considered in assessing different technologies.

Socio-Economic Impact

The socio-economic impact of power generation facilities of the size being considered is generally limited to the construction phase. Overall, for most technologies the impacts are considered neutral if managed carefully through local liaison with the community, but may even be positive when issues in relation to job creation and economic development are considered.

Alternatives Analysis of the Powering Technologies

(i) Background
A review of available technologies can essentially be considered under two generic headings: fossil fuelled and renewables. Examples of some of the possible technologies are discussed in detail in the following subsections and all possible technologies are compared in Section (iv) below.
(ii) Fossil Fuelled
Coal-fired CFB Boiler and Steam Turbine Plant
The key factors associated with the use of coal fired Circulating Fluidised Bed (CFB) boilers combined with steam turbines as a generating option in Sudan are as follows:

Lower emissions to air as a result of pollution abatement techniques incorporated in CFB boilers when compared to other thermal generating technologies.
· Lower cost of fuel compared to gas.
· Good level of plant efficiency (~38%).
· Use of coal, which is a relatively cheap fuel and could be cheaply transported by ship, but can have associated environmental problems associated with sulphur content causing elevated emissions of sulphur dioxide. The CFB boilers will, however, remove up to 90 % of sulphur dioxide emissions.

HFO-fired Steam Generation

The key factors associated with the use of heavy fuel oil fired steam boilers combined with steam turbines as a generating option in Sudan are as follows:
· Well established technology used for current power generation at Khartoum North Power Station and well understood by NEC staff.
· Robust generating technology capable of providing large increases in installed generation.
· Good level of plant efficiency (~37%).
· Use of HFO, which is a relatively cheap fuel, but can have associated environmental problems associated with sulphur content causing elevated emissions of sulphur dioxide. Imported oil has high sulphur levels but expanding supply of Sudanese HFO with low sulphur content is available. LFO can be used but is significantly more expensive than HFO.

HFO-fired Internal Combustion (Slow or Medium Speed Diesel) Engines

The key factors associated with the use of medium speed diesel engine plant as a generating option in Sudan are as follows:
· Well established technology used for some power generation in Sudan at other sites and well understood by some NEC staff.
· Robust, well established small-scale generating technology.
· High level of plant efficiency (~40%).
· Can install several small engines to create flexible plant able to respond rapidly to changes in demand.
· Requires fewer operations and maintenance staff than compared to other thermal generating processes.
· Use of HFO, which is a relatively cheap fuel, but can have associated environmental problems associated with sulphur content causing elevated emissions of sulphur dioxide. Imported oil has high sulphur levels but expanding supply of Sudanese HFO with low sulphur content is available. LFO can be used but is significantly more expensive than HFO.

Gas oil-fired Gas Turbines

The key factors associated with the use of gas oil fired Combined Cycle Gas Turbine (CCGT) plant as a generating option in Sudan are as follows:

· High plant efficiency (50 %+).

· Lower emissions to air depending upon fuel used and pollution abatement techniques employed when compared to other thermal generating technologies.

· Higher cost of fuel compared to heavy fuel oil.

· Limited technical experience of this technology amongst NEC staff in Sudan, although recent construction of a CCGT will introduce the necessary experience.

Gas-fired Combined Cycle Gas Turbine

The key factors associated with the use of gas fired Combined Cycle Gas Turbine (CCGT) plant as a generating option in Sudan are as follows:

· High plant efficiency (~50 %+).

· Lower emissions to air depending upon fuel used and pollution abatement techniques employed when compared to other thermal generating technologies.

· No natural gas in Sudan so gas would have to be liquefied petroleum gas (LPG). High operating costs associated with fuel.

· LPG produced in Sudan is used as a priority for cooking fuel to displace the use of wood.

· Very little experience of using LPG in gas turbines internationally.

· Limited technical experience of this technology amongst NEC staff in Sudan, although recent construction of a CCGT will introduce the necessary experience.

Gas-fired Open Cycle Gas Turbine

The key factors associated with the use of Open Cycle Gas Turbine (OCGT) plant as a generating option in Sudan are as follows:

· Moderate plant efficiency (~37%).

· Lower emissions to air depending upon fuel used and pollution abatement techniques employed when compared to other thermal generating technologies.

· No natural gas in Sudan so must use LPG. High operating costs associated with fuel.

· LPG produced in Sudan is used as a priority for cooking fuel to displace the use of wood.

· Very little experience of using LPG in gas turbines internationally.

· Limited technical experience of this technology amongst NEC staff in Sudan, although recent construction of an OCGT will introduce the necessary experience.

(iii) Renewables

Hydro

The key factors associated with the development of hydro plant as a generating option in Sudan are as follows:

· No emissions to air, environmental impacts limited to land take and water environment

· High capital cost but low operating cost

· No fuel cost

· Longer construction lead time
· Not a firm electricity generation source

Wind

The key factors associated with the development of wind turbines as a generating option in Sudan are as follows:

· No emissions to air, environmental impacts limited to visual impact
· Variable wind resource, but it is at risk of being subject to destructively high winds that would need to be taken account of in the wind turbine design
· Dependent on wind conditions, including gusting which would therefore lead to varying generating levels, including intermittent periods of no generation
· Suitability of potential sites including land availability, accessibility and grid connection.

Solar (Photovoltaic Panels)

The key factors associated with the development of solar (photovoltaic panels) either on a single site or as an individual building application as a generating option in Sudan are as follows:

No emissions to air, environmental impacts limited to visual impact
· Subject to intermittent generation due to nature of solar resource
· Expensive technology and poor efficiency resulting in large area of panels required, (and associated land availability for a single site) and suitability issues
· When installed on an individual building basis, there are grid connection issues.

Geothermal

The key factors associated with the development of geothermal in Sudan are as follows:

· No emissions to air
· High initial capital costs but low operating costs and zero fuel cost
· Geothermal resource located in remote location resulting in very high cost of transmission
· Geothermal capability not sufficient to provide base load plant

(iv) Analysis

For each technology reviewed the following key aspects were assessed:

· Cost · Land use planning
· Timing · Environmental impact
· Availability · Socio-economic impact
· Cost to upgrade existing infrastructure

The analysis of alternative generating technologies is summarised in Table: 1. For each factor described above, the technologies have been given a rating from 1 to 4. The ratings have been totalled for each technology with the lowest score representing the optimum technology. This review of alternative generation options is a high level analysis based on a number of key factors but does not constitute a detailed environmental feasibility study.

Table:[1] for the analysis of alternative generating technologies summary

Technology	Cost [a]	Timing	Availability	Cost to Upgrade Existing Infrastructure [b]	Land Use Planning	Environ-mental Impact	Socio-Economic Impacts	Score
New build coal fired boiler and steam turbine plant	2	2	1	4	3	2	2	16
New build HFO fired diesel	2	2	1	3	3	3	2	16
New build distillate fired gas turbine	2	2	1	3	3	2	2	15
New build hydroelectric	3	3	3	4	4	2	3	22
New build gas fired open and combined cycle plant	2	2	1	4	2	2	2	15
New build wind turbines	2	1	3	3	2	2	2	15
New build photovoltaics (single site)	4	2	2	3	2	2	2	17
New build photovoltaics (domestic application)	4	1	2	1	1	1	1	11
New build geothermal	4	3	2	4	2	2	2	19
Ranking								
1	Low	short	high	low	v. minor	v. minor	beneficial	
2	Medium	medium	medium	medium	minor	minor	neutral	
3	High	long	seasonal	high	major	major	neutral	
4	v. high	v. long	low	v. high	v. major	v. major	detrimental	

Note [a] Costs include capital and operational costs

[b] Existing infrastructure includes fuel delivery systems and extension to refinery for gas oil or LPG requirements

The above table is taken from Red Sea Power Project & Desalination Plant – Preliminary Environmental Impact Assessment Mott MacDonald June 2005

Further in-depth Economical Analysis is done for the determination of **the plant capacity and technology selection** as follow:

The Candidate Power Plants:

Three candidate Power Plants have been investigated for the Red Sea Power Project.
The options differ with regards to:-

Generation Technology:

Case (1): 2X120 MW Steam Turbine Power Plant Fired with coal and using the CFB technology for the steam generator.

Case (2): 2x120 MW Steam Turbine Power Plant Fired with H.F.O conventional type Steam generator.

Case (3): 2x120MWCombined Cycle Power Plant Fired with H.F.O having the configuration 4+4+2

Technical Data of Candidate Power Plants:

The technical data and operation data for the candidate Power Plants had been extracted from similar international practices and NEC experience with the existing Power Plants taking into consideration the site conditions and the flowing parameters:

1. The actual generation capacity of the candidate Power Plants and the auxiliary consumption.
2. The time availability, capacity availability and Plant factor related to each candidate power Plant.
3. The total investment costs, construction period and plant life time related to each candidate power plant.
4. Fuel type, price, low heat value, and the corresponding heat rate for each candidate power plant.
5. The annual maintenance and repair costs, variable costs related to the net energy generated output as per international practices.

Economic Parameter

Fuel Price

The most economic parameter is coal price; a market survey for the coal markets in South Africa and the East Asian Countries which are the main coal markets near Port Sudan; showed that the coal price is still much cheaper than the imported H.F.O prices in Sudan.

The first and best option for supplying the Red Sea plant with coal is South Africa, which is a major coal producer and exporter and is closer to Sudan than any other coal exporting countries. South Africa exports washed coal varieties of good quality for thermal generation. Richard’s Bay Coal Terminal, one of the biggest in the world, has the necessary infrastructure required for loading Panamax vessels destined for Port Sudan. Given current price levels, we estimate that the price of coal delivered to Port Sudan is currently in the range US$115-120/t, depending on the type of vessel chartered and the quantity of coal.

On this regard STPG was signed an MOU as an initial agreement for coal supply with a prominent coal supplying company in South Africa in 2008.

Evaluation of Candidate Power Plants

The results of the calculation and computation using the candidate power plant technical and economical parameters given above showed that the 2x120MW Coal Fired Power Plant has the lowest dynamic unit cost compared with the others in term of ($cent/kwh); this result was used by STPG to build on it for the plant size upgrading to be as 2x300MW Pulverized Coal Fired Power Plant for the Red Sea Power Project to match with network size and the planning for the balance between supply and demand for the power supply in the country.

CONCLUSION

Conclusion

Coal is the most common fuel for power generation and its use is currently growing faster than any other fuel. Coal reserves are geographically much more dispersed than gas and oil therefore coal trade is much more competitive for power generation purposes than any other fuel. In addition, coal is the most abundant of fossil fuels, with global reserve production ratio of approximately 150 years. Steam coal trade volumes are increasing at rapid rates, driven mainly by growing demand in the developing countries of South East Asia. Hence, steam coal trade accounts for a significant and ever growing fraction of world dry bulk shipping freight.

New build coal fired boiler and steam turbine plant for Sudan represents one of the more favourable options overall and, in particular, in the medium term. In the long term, wind turbines and photovoltaic could be considered to supplement thermal generation and for non-grid connected areas, although this is likely to require significant upgrade in the control of local distribution.

Sudan power system planning studies define that candidate plant should be of a type and size that can be repeatedly added to the system over a 20 year planning period with no practical restriction on the number of units required or availability of fuel. Within these criteria a number of candidate plants were assessed, accordingly it is recommended that thermal generation and hydroelectricity were the most appropriate options.

The important finding is that the coal fired power project in red sea is not sensitive to variations in capital investment and operation parameters; accordingly, the coal- fired power plant can be used as base load power station to supply Port Sudan city and the Red Sea Area and the National Grid during the hydro dry season, to meet the capacities requirements for the national grid, according to the forecasted demand.