Proposal for Improve the Electrical Power Supply in Port Sudan Town

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Abstract

This study discusses the lack of electrical power generation at Port Sudan (Sudan) and suggests solution to this problem. Information on the existing power plant and the grid at the town was analyzed, in addition to estimation of the power demand on the current grid and its future expansion for ten years were made. Different economical measures such as annual, internal and external rate of return were taken and the economical feasibility is proven to be within standard prescribed measures.

Keywords: *Port Sudan, power consumption, proposed power plant, economical analysis*

1. Introduction

Port Sudan is the second important city in Sudan due its strategic location as the major Sea Port of Sudan and its unique outlet to the outside world. It is lies at latitudes 190 35/ north and 370 13/ east in northeastern Sudan. The main sources of electricity generation in region (until year 2005) are the four power stations named A, B, C and D with 54.7MW of total available capacity [1]. However due to some problems and unforeseen factors which can be classified as mechanical and electrical, the generation will not reach the designed capacity stated above. The mechanical and electrical factors can be summarized as:

1.1. Although the action of humidity on engine performance is not affected by change of air pressure (altitude) or air temperature, the effect of humidity is to decrease the engine indicated power.

1.2. High relative humidity accelerates the rate of corrosion and leads the plant to mechanical failures that increase the cost of maintenance and increase the time of intermittent stoppages of the plant and hence reduce available power.

1.3. During to high humidity and during the dusty, and rainy season most of the over load lines have been experience many problems and disturbance which appears as short circuit or line to line which means that the insulation layer have been broken down.

2. Power Consumption

The electricity consuming groups are divided into five main groups. These groups include the residential, commercial, industrial, agricultural and government sectors. The annual power consumption of the above, mentioned sectors in GWH illustrated in Table 1 shown below [2]:

Table 1. The Power Consumption of Different Sectors (year 2004) in GWH

Month	Residential sector	Commercial sector	Industrial sector	Agricultural sector	Government sector	Total Demand
January	2.239	0.317	0.687	0.005	0.162	3.41
February	2.428	0.384	0.718	0.004	0.176	3.71
March	2.416	0.387	0.681	0.004	0.194	3.682
April	2.3	0.376	0.658	0.005	0.178	3.517
May	2.294	0.381	0.699	0.005	0.196	3.575
June	1.977	0.314	0.653	0.005	0.192	3.141
July	2.074	0.301	0.628	0.005	0.195	3.203
August	2.3	0.381	0.69	0.004	0.193	3.568
September	2.07	0.3	0.611	0.004	0.192	3.177
October	2.416	0.384	0.681	0.004	0.195	3.68
November	2.3	0.381	0.687	0.004	0.193	3.565
December	2.416	0.387	0.686	0.004	0.194	3.687
Total	27.23	4.293	8.079	0.053	2.26	41.915
Percentage (%)	64.965	10.242	19.275	0.126	5.392	

The Figure 1 above shows that the residential sector is the biggest consumer. It consumed more than 60% of the power in the town during year 2004.

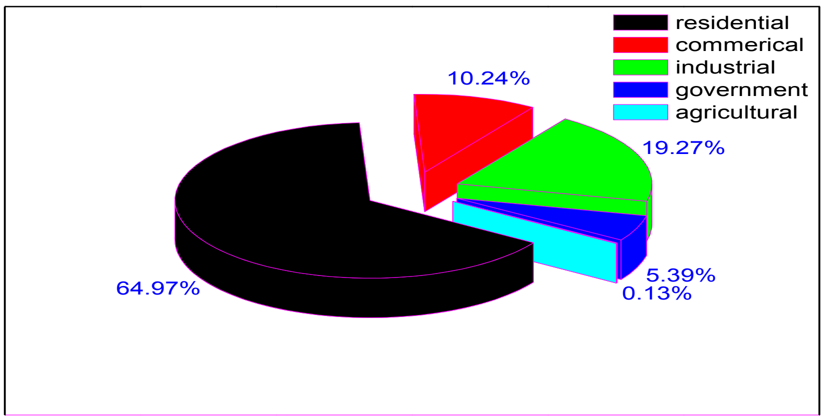

Figure 1. The Percentage of Power Consumed in the Town (year 2004)

The power generation from the power station A, B, C and D for the year 2004 is shown below in Table 2 [3].

Table 2. Port Sudan Power Generated (MWH), year 2004

station	A	B	C	D
January	1435.79	80.82	2545	2010.8
February	1080.98	10.28	2415	2046.48
March	1746.72	0	3099	1905.2
April	2203.229	46.354	3391.6	1721.72
May	2608.52	94.85	4945	2042.92
June	2430.79	60.43	4457.3	1785.64
July	3643.63	14.128	4743	1547.6
August	4022.07	0	5323	784.8
September	4675.83	10.396	4532	669.2
October	5462.92	34.19	4905.5	0
November	4287.34	0	5900.3	0
December	1545.06	0	4900.3	0

It is clear that the power generated was very low in comparison with the installed capacity; some of the power stations are cut off during summer and high humidity season, in addition to, the failure of overhead lines effect in transmission, which take along time for maintenance.

The maximum expected generation of the grid is estimated as 77.775 GWH during year 2004 and the actual generation in the power stations is only 59.403 GWH. Table (3), show that there is an obvious lack in power generation in the town.

Table 3. Estimate the Expected Generation, Actual Generation and Lack of Power Generation in the Town (year 2004)

Month	Expected generation	Actual generation	Lack Deficit
January	5.12	5.002	0.118
February	6.605	5.002	1.603
March	6.605	4.605	2
April	6.605	5.513	1.092
May	6.605	3.605	3
June	6.605	3.841	2.764
July	6.605	4.727	1.878
August	6.605	5.156	1.449
September	6.605	4.298	2.122
October	6.605	4.483	1.775
November	6.605	6.756	0
December	6.605	6.415	0.19
Total	77.775	59.403	18.372

3. Estimation the Power Demand in the Future

The field surveys of studying the urgent needs and the future expansion of private and governmental institutions has encountered great many obstacles. This is due to the poor statistical data and the lack of past records of population size.

3.1 Estimation of the Expected Load

In this study, it is assumed that the region concerned (Port Sudan) will be provided with electricity in two stages.

The first stage includes the first years of operation in which all the sectors will be joined to the grid. In the second stage, an annual incremental rate will be proposed to cover the future.

3.2 Consumer's Groups

The consumers are to be classified into five main groups as commercial, industrial, agricultural, government service and residential areas. Table 4 illustrates the annual future demand from the year 2005 to the year 2015 with a percentage growth rate not constant and depends on the sectors concerned.

Table 4. Peak MW Demand

year	residential	government	industrial	commercial	agricultural	total
2005	30	20	60	15	5	130
2006	33	22	69	17	6	147
2007	36	24	78	19	7	164
2008	39	26	87	21	8	181
2009	42	28	96	23	9	198
2010	45	30	105	25	10	215
2011	48	32	114	27	11	232
2012	51	34	123	29	12	249
2013	54	36	132	31	13	260
2014	57	38	141	33	14	283
2015	60	40	150	35	15	300

4. Classification of Proposed Power Plant

The proposed combined cycle power plant includes two gas turbine generating units of 100 MW each with their individual heat recovery steam generators (HRSGs) and a common steam turbine generator unit to produce an additional 100 MW. Figure 2, shows the plant diagrammatically and Figure 3 and 4 shows the plant on a T-S diagrams.

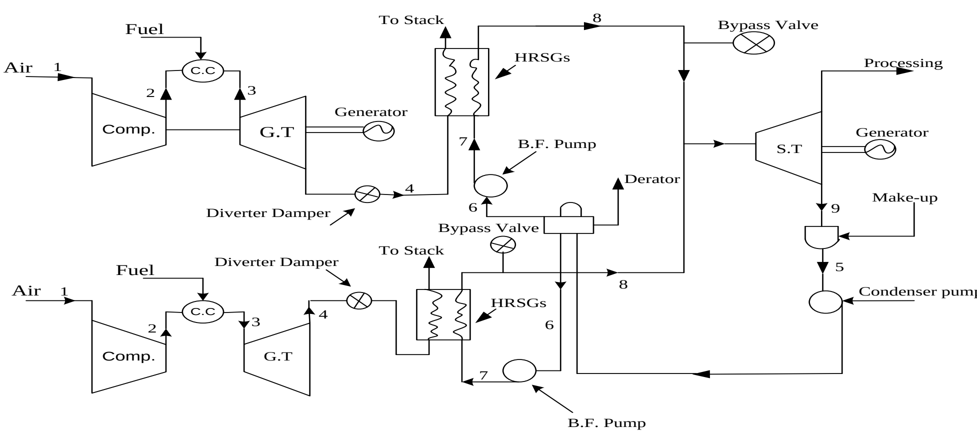

Figure 2. Proposed Power Plant Diagram

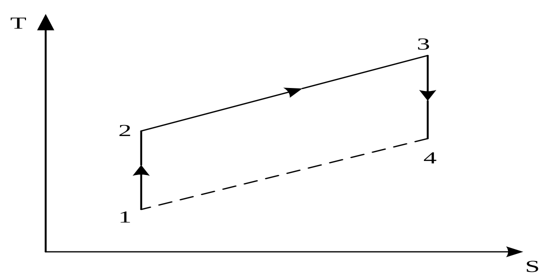

Figure 3. Gas Turbine on T-S Diagram

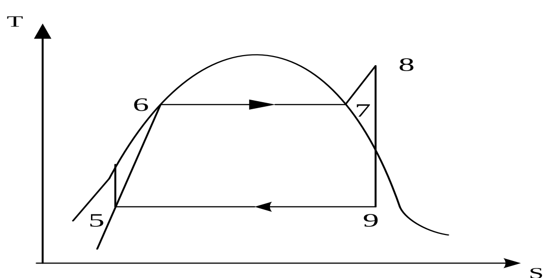

Figure 4. Steam Turbine on T-S Diagram

5. Crude Oil as a Power Generation Fuel

The use of crude oil as a power generation fuel recently has received considerable attention. The factors that have promoted this use are fuel availability, cost, safety, and environment aspects. The specification of crude oil is illustrated in Table 5 [4].

Table 5. Specification of Crude Oil

Type of Crude	Nile Blend
Place of sample	Crude oil tank
Density (15 ^{O}c), kg/m^3	849.4
Kinematics viscosity (100 ^{O}c), mm^2/s	6.232
API^0	35.1
Solidification point, ^{O}c	32
Carbon residue, m%	3.4
Salt content, mg Na CI/L	4
Acid number, mg KOH/g	0.25
Sulfur content, %	0.06
Nitrogen content, PPM	0
Water content, m%	0.15
Pour point, ^{O}c	40

6. Economical Analysis

The function of a power station is to supply power at minimum cost per kilowatt hour; the total cost consists of fixed charges with interest on the capital, taxes, insurance, depreciation and management, and operating charges such as cost of fuel, water labor, repairs and maintenance etc.

6.1 Cost Analysis

The cost of power generation depends upon two basic factors, which includes capital cost or fixed cost, and operational cost [5, 6].

6.1.1 Capital cost or fixed cost: The capital cost is the capital investment in the installation of a complete plant. It includes initial cost, taxes, insurance and depreciation. The type of proposed power plant used in this study is a combined cycles with the total capacity of 300 MW. The average cost of the plant is estimated about 214 million dollars, given that the generation of one MW costs about one million dollars, including the initial cost, interest, depreciation, taxes and insurance. Other fixed cost as engineering consultancy and civil works are estimated as 15% and 8% of the total capital cost respectively. Therefore, the total capital cost including the consultancy and civil work is estimated as 263 million dollars [5].

6.1.2 Annual operational costs: It includes the following costs:

1) Fuel cost: the fuel used in the plant is crude oil. The fuel consumption estimated is about 0.185 Kg/KWh, which costs about 118,770,000 dollars per year as it is calculated in the following equation.

Annual fuel cost = rate of fuel consumption (Kg/KWh) *number of operating hours per day * price per kg * number of day per year (1)

=0.185*1000kg/MWh*24hour/day *(0.3$/0.864kg)*360day*214MW (2)

Annual fuel cost = 118,770,000 $

2) Maintenance cost: It is divided into to types as follows:

i) Fixed maintenance: it is estimated as 2400$/MW and which amounts to 513,600$.

ii) Overhead maintenance: it is estimated as 4$/MWh and which amount to 7,395,840$ per year.

iii) Annual depreciation: it is calculated using the following equation

Annual depreciation cost= C/N (3)

C = capital cost – engineering consultancy cost.

N = expected life time.

Therefore, annual depreciation = (263,000,000 – 32,100,000) / 30= 7,696,660 $ (4)

Therefore, the total annual operating cost amount to about 134376100$ and when adding a 10% of this value as an unforeseen expenses, the total cost reaches a value of 147,813,710$.

6.2 Annual Revenues of the Project

The price of kilowatt hour supply is taken as a common value and to all consumers croup equivalent to 0.14$. From Table 4, the generation of the plant increases yearly due to the increase of population and industrial, agricultural and commercial expansion. It increases with a rate of 10% yearly from value of 130 MW in 2005 to a maximum capacity of 300 MW in 2015. Therefore, an average value of 214MW per year is assumed through the life span of the project. The total revenues are determined using the following equation [5]:

Total annual revenues=average generation in MW*average sale's price in $/MWH * number of operation hour per day*number of operation day per years

=214*140*24*360=258,854,400$ (5)

6.3 Profit and Loss Account

Total annual revenues = 258,854,400 $
Total operation cost = 147,813,710 $
Gross profit = 111,040,690 $
Taxes (about 25%) = 27,760,172.5 $
Net profits after taxes =83,280,517.5 $
Therefore, the annual net profit is 83,280,517.5 $

6.4 Financial Evaluation of the Project

The following assumptions are considered to determine financial feasibility of the project

i) Discount rate will be used to determine the net present value through the useful life of the project which is determined to be 30 years

ii) The salvage value at the end of the 30th year will not be considered as revenue.

iii) Assume a discount rate of 30% which represents the available substitute opportunity for investing the capital.

iv) To determine whether the project is feasible or not the following methods of evaluating investment projects are used:

1. Accounting method: Annual rate of return (i.e. percentage profit) = (Net profit/investment capital) *100% = 31.7 (6)

2. Pay back period: Pay back period = (investment capital/ net annual profit) = (263,000,000$/83,280,517.5$) = 3.16 years ≅ 4 years (7)

Therefore, the project will recover its investment capital before the completion of four years of its age.

6.5 Internal Rate of Return (I.R.R)

It is the most used method of evaluating project, and it is defined as the discount rate that gives the project a present value of zero.

PW (30%) = -263,000,000+83,280,517.5 (P/A, 30%, 30 year)

= -263,000,000+83,280,517.5*3.3321 = 14499012.4 dollars (8)

PW(40%)=-263,000,000+83,280,517.5(P/A, 40%, 30year)=- 3,000,000+83,280,517.5*2.4999 = - 54,807,034.3 dollar (9)

Interpolation method is used to determine the suitable internal rate of return as follows:

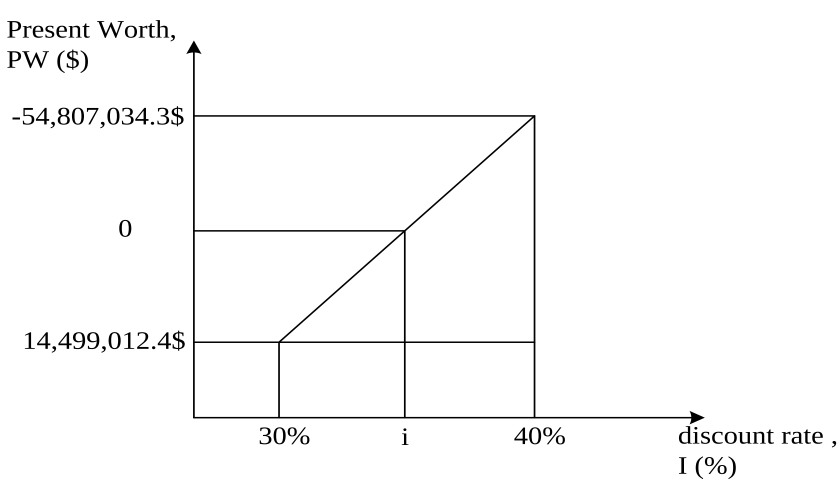

Figure 5. Internal Rate of Return (I.R,R)

i=30+ ((0-14,499,012.4) / (-54,807,034.3-14,499,012.4))*(40-30) =32.1% (10)

It is clear that the net present worth is equal to 14,499,012.4$ (Positive value) when using discount rate (I) equivalent to 30% and is equal to 54,807,034.3$ (Negative value) when using a discount rate equivalent to 40%.

Therefore, and due to the justifications mentioned above, the project is considered economically feasible.

6.6 External rate of return (E.R.R)

It determines the interest rate, which generates a future worth equivalent rate of return (MARR). Using the following equation:

$$\sum_{c=0}^{n} R_{jt}\left(1+r_t\right)^{n-t} = \sum_{t=0}^{n} C_{jt}\left(1+i\right)^{n-t} \quad (11)$$

Where:

I= external rate of return

C_{jt}, R_{jt} is the positive and negative net cash flows

For investment j during period t, respectively

R_t = reinvestment rate for positive cash flows occurring in period t and normally equals the minimum alternative rate of return (MARR)

n= useful life time of the project

$$83{,}280{,}517.5(F/A, 30\%, 30) = 263{,}000{,}000(1+i)^{30} = =30\ \% \quad (12)$$

Since, the external rate of return is equivalent to 30% which is the same as that of the minimum attractive rate of return (MARR), therefore, the investment is considered acceptable.

7. Cconclusion

In the present study, estimations of power demand have been prepared so as to determine the real needs of power of different consumers group, in addition to summarizing the problems of generation (mechanical and electrical), and estimating the peak MW demand for the year 2005 to the year 2015. Based in collected data a300 MW combined cycle power plant has been suggested for town. The economical analysis performed showed that the proposed power plant is feasible and it will pay back in a period of less than four years of operation.

References

[1] National Electricity Corporation (Khartoum), the study of Port Sudan power station (A) case. **(2004)** December.

[2] National Electricity Corporation (Port Sudan), “Technical specification for Port Sudan power station”, **(2004)**.

[3] National Electricity Corporation (Port Sudan office), monthly generation report.

[4] Khartoum refinery company, evaluation data, **(2004)** March.

[5] J. A. White, M. H. Agee, E. Kenneth, “Principle of engineering economic analysis”, published by John Wiley and Sons, **(1989)**.

[6] E. Elawad, “Discrete compound interest factors table”, Nile Valley University, **(2005)** April.

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Dr. Naeim Farouk was born in Sudan. He received his bachelor's degree in mechanical engineering from Red Sea University (Port Sudan) in October 1999, and a master degree in electrical power engineering from university of Khartoum (Sudan) in March 2006 and the Ph.D. degree in control theory and control engineering from Harbin Engineering University, China, in March 2012. He is member of the Sudanese engineering society. His research interest is in the intelligent control for marine power systems, electrical power plant. He is the author of more than ten journal and conference.