REPÚBLICA DEMOCRÁTICA DE SÃO TOMÉ E PRINCIPE

FIRST FEASIBILITY STUDY ABOUT THE INFRUSTRUCTURES RELATED TO THE ELETTRIFICATION OF SAO TOME ISLAND

Udine (Italy) , June 2007

ing. Gianni De Cecco

INARCO
UDINE-FRIULI V.G. - ITALY

GUINEA ECUATORIAL ENGINEERING CONSULTING

CONTENT:

1 PREMISE

The present elaborate derives from a **first analysis** about the feasibility of the electrification of the island of Sao Tome which will guarantee the electricity supply to the entire territory of the Island.

The electrification includes the production plants and the electricity primary and secondary distribution lines.

The analysis starts with the examination of the projects and studies already produced about the specific topic, takes into account the 2001 population census survey and the considerations aroused from a preliminary survey of the intervention area.

Once there will be an agreement about the general idea all the interventions that will need to be realized will be defined and organized by phase according to the available financial resources.

2 ELECTRICAL ENERGY NEEDS ASSESSTMENT

The electrical energy needs of the island of Sao Tome have been calculated in the following way:

⇒ Average power used per household (lighting, household appliances, air conditioning, TV, external lighting, etc..) 5,7 kW

⇒ Simultaneity coefficient = 0,4

⇒ Maximum simultaneous power per household = 5,7 x 0,4 = 2,3 kW

⇒ Average number of members per household = 6

⇒ Population estimation in 2010 (survey 2001)= ~ 160.000

⇒ Number of households (dwellings) = 160.000/6 = ~ 27.000

⇒ **Total maximum power = 2,3Kw x 27.000** households**62.100 kW**

⇒ **Power needs for public facilities** (airport, hospitals, media centres, press centres – TV and radio, government palaces, public services, police services and civil protection, etc.) = 2.000 kW x 0,7 (simultaneity coefficient) = **1.400 kW**

⇒ **Hotels and tourism=**

50 units x 20 kW x 0,7 (simultaneity coefficient) = **700 kW**

⇒ **Public lighting** (considering a light point every 25 m for a total of 50 km of lighted roads)

= 50.000/25 = 2.000 points x 0,75 kW = **1.500 kW**

⇒ ***Total simultaneous power*** = ***65.700 kW***

As a check we can confront this value with the one obtained considering the average needs per capita.

The average daily consumption per capita of an Italian region for civil uses amounts to 0,462 kW per person.

By multiplying this value by the population assessed in 2010 for the island of Sao Tome, a value of ca 74.000kW is obtained.

This value is comparable with the one previously determined.

This amount is referred only to civil usage, excluding the industrial one.

Considering a population of ca 160.000 persons and an expected industrial and economical development of the island in the near and medium term future, a need of ca 80 MW is assessed, of which 1/3 concentrated in the area around the capital.

3 EVALUATION OF THE AVAILABLE PRODUCTION

The power produced by the hydroelectric plants that can be realized on the island is, as deduced from the study conducted by Hidrorumos, nominally equal to 28 MW in case of spate rivers and 6MW in periods of low flow.

Hence the power that will have to be produced with other energy sources varies as follows:

- 80 - 28 = 52 MW when the rivers have got the maximum flow;
- 80 - 6 = 74 MW in case of low flow.

Currently a power of 8MW is available and it is produced by the following plants:

- 1 MW (2MW theoretical) hydroelectric plant
- 7 MW diesel plant in Sao Tomè.

The first phase project, that will be soon contracted, together with some eventual private investments, will bring to the realization of two power plants working with generator sets that will provide 12MW:

- 1 Plant in Sao Tomè (in the immediate outskirt):
  - two 2MW generator sets for a total of 4MW
  - and the setting for the future installation of an extra generator set with the power of 2MW.
- 1 Plant near Rio Grande with 6MW power produced by 3 generator sets. This plant is planned near the outfall of the Rio Grande river in such a way that in the future, when the hydroelectric plant will be realized (produced power estimated by HIDRORUMO: maximum 6,9 MW, minimum 1,5 MW) it will compensate the power produced in the low flow periods.

Once realized the interventions above mentioned, a produced power of 20MW will be reached.

A **thermoelectric power plant** will also have to be realized in order to cover the total needs of the island of Sao Tomè. Such a plant, which has got a better performance compared to the generator sets, will possibly be methane-fuelled and will produce a minimum power of:

80MW – (8MW current+12MW planned+6MW minimum hydroelectric power) = 54 MW

In this calculation we assume that the plants realized with the generator sets will compensate the difference of power produced by the hydroelectric plants in the different periods of the year: 28MW - &MW=22MW ca.

It is obvious that when the investment for the thermoelectric plant will be programmed, an increment of its power could be considered in order to reduce the power produced by the generator sets, which is much more expensive.

4 THE THERMOELECTRIC POWERPLANT

As already mentioned in the previous chapter, a thermoelectric plant will also have to be realized, fuelled with methane or petrol, and situated in the vicinity of the planned new harbour.

The one fuelled with methane is less complex and less expensive, in terms of construction, operating phase and maintenance.

In fact while in the petrol one it is necessary to build a heat absorption unit, in the methane-fuelled one it can be omitted.

The petrol-fuelled plant uses steam or diathermic oil as expansion fluid in the turbine for the production of electricity.

For this reason it is necessary to have a system to dissipate the produced heat trough an absorption unit which produces refrigerated water using the exhaust saturated steam from the turbines and the cooling water.

A system of regeneration and production of refrigerated water at 7 °C, with evaporation tower, could be installed for this purpose. The water could then be used as cooler in the harbour (air-conditioning, refrigerating cells).

Such a system requires a modest quantity of fresh water, which could be taken from the nearby Rio do Ouro.

The thermoelectric plant would provide the basic energy necessary to the island; the difference could be obtained with the construction of more powerful hydroelectric power plants.

The energy produced by the thermoelectric power plant will be brought to the capital, the centre of higher consumption, through a 130kV line; a transformation station 130/30 kV will be set around the capital for the connection to the existing net.

From this station more 30kV lines will depart for the distribution in the entire island.

5 ANALYSIS OF THE COSTS NECESSARY FOR THE REALIZATION OF THE HYDROELECTRIC POWER PLANTS AND THE THERMOELECTRIC ONE

The study produced by HIDRORUMO includes also the construction costs of the hydroelectric power plants which are planned to be built.

The following tables show the costs reported in the HIDRORUMO study, and their updating for 2007:

Construction costs for the hydroelectric power plants in US$ - year 1996

				Works for the civil construction			Mechanic works				
n.	Plant Name	Min. production	Max. production	provisional works (a)	intake works	plant	hydraulic circuit	plant	sub-total (b)	other costs (c)	total cost
		[MW]	[MW]	[MUS$ 1996]	[MUS$ 1996]	[MUS$ 1996]	[MUS$ 1996]	[MUS$ 1996]	[MUS$ 1996]	[MUS$ 1996]	[MUS$ 1996]
3	Ouro 5	0,312	1,139	0,456	1,608	0,214	0,851	0,402	**3,531**	1,347	**4,878**
8	Ouro 4	0,167	0,873	0,603	1,273	0,214	0,683	0,134	**2,908**	1,106	**4,013**
15	Ouro 3	0,122	0,780	0,643	0,992	0,228	0,878	0,724	**3,464**	1,320	**4,784**
13	Ouro 2	0,299	0,486	0,643	1,219	0,214	0,683	0,456	**3,216**	1,226	**4,442**
2	Man.Jorge 4	0,185	0,898	0,643	0,462	0,201	0,925	0,637	**2,868**	1,018	**3,886**
9	Man.Jorge 3	0,330	0,517	0,456	0,449	0,228	0,864	0,147	**2,144**	0,817	**2,961**
7	Man.Jorge 2	0,190	0,818	0,456	1,065	0,228	0,958	0,201	**2,908**	1,112	**4,020**
14	Man.Jorge 1	0,285	0,443	0,456	1,327	0,214	0,543	0,456	**2,995**	1,199	**4,194**
1	Abade 3	0,300	1,842	0,603	0,777	0,295	1,474	0,992	**4,141**	1,521	**5,662**
5	Abade 2	0,440	2,382	0,456	3,290	0,221	1,213	2,171	**7,350**	2,854	**10,204**
11	Abade 1	1,100	2,358	0,603	5,313	0,261	1,434	1,796	**9,407**	4,643	**14,050**
6	Iô Grande 2	0,640	5,889	3,397	13,199	0,328	2,305	1,159	**20,388**	6,801	**27,189**
12	Iô Grande 1	1,500	6,879	0,878	3,424	0,496	3,196	9,574	**17,567**	14,941	**32,508**
4	Lemba 2	0,210	2,829	22,619	5,682	0,275	1,494	0,375	**30,445**	3,203	**33,647**
10	Papagaio 1	0,025	0,563	0,456	0,764	0,161	0,891	0,348	**2,620**	0,998	**3,618**
	TOTAL	6,105	28,696	33,366	40,843	3,779	18,392	19,571	**115,95**	44,106	**160,06**

(a) costs for the construction site arrangement: access roads, digging excavations and embankments
(b) sub-total determined summing all the civil and mechanic works
(c) technical expences, geological campaign, funding management
(d) total cost obtained summing the sun-total b) and other costs (c)

civil work costs updating - from 1996 to 2007	**149,000**	**%**
mechanic works costs updating - from 1996 to 2007	**158,000**	**%**
technical expences updating - from 1996 to 2008	**111,000**	**%**

Construction costs for the hydroelectric power plants in US$ - updated 2007

				Works for the civil construction			Mechanic works				
n.	Plant Name	Min. production	Max. production	provisional works (a)	intake works	plant	hydraulic circuit	plant	sub-total (b)	other costs (c)	total cost
		[MW]	[MW]	[MUS$ 2007]	[MUS$ 2007]	[MUS$ 2007]	[MUS$ 2007]	[MUS$ 2007]	[MUS$ 2007]	[MUS$ 2007]	[MUS$ 2007]
3	Ouro 5	0,312	1,139	0,679	2,396	0,319	1,344	0,635	**5,374**	1,495	**6,869**
8	Ouro 4	0,167	0,873	0,898	1,897	0,319	1,080	0,212	**4,406**	1,227	**5,633**
15	Ouro 3	0,122	0,780	0,958	1,477	0,339	1,387	1,143	**5,305**	1,465	**6,770**
13	Ouro 2	0,299	0,486	0,958	1,817	0,319	1,080	0,720	**4,894**	1,361	**6,255**
2	Man.Jorge 4	0,185	0,898	0,958	0,689	0,299	1,461	1,006	**4,413**	1,130	**5,544**
9	Man.Jorge 3	0,330	0,517	0,679	0,669	0,339	1,366	0,233	**3,286**	0,907	**4,193**
7	Man.Jorge 2	0,190	0,818	0,679	1,587	0,339	1,514	0,318	**4,437**	1,235	**5,671**
14	Man.Jorge 1	0,285	0,443	0,679	1,977	0,319	0,857	0,720	**4,552**	1,331	**5,883**
1	Abade 3	0,300	1,842	0,898	1,158	0,439	2,329	1,567	**6,391**	1,688	**8,080**
5	Abade 2	0,440	2,382	0,679	4,902	0,329	1,916	3,430	**11,256**	3,168	**14,424**
11	Abade 1	1,100	2,358	0,898	7,917	0,389	2,265	2,837	**14,307**	5,154	**19,461**
6	Ilô Grande 2	0,640	5,889	5,061	19,667	0,489	3,642	1,831	**30,690**	7,549	**38,239**
12	Ilô Grande 1	1,500	6,879	1,308	5,101	0,739	5,050	15,127	**27,325**	16,585	**43,909**
4	Lemba 2	0,210	2,829	33,703	8,466	0,409	2,361	0,593	**45,531**	3,555	**49,086**
10	Papagaio 1	0,025	0,563	0,679	1,138	0,240	1,408	0,550	**4,015**	1,108	**5,123**
	TOTAL	6,105	28,696	49,715	60,856	5,630	29,059	30,922	**176,18**	48,958	**225,14**

ratio €/US$ 0,742 (07/06/2007)

Construction costs for the hydroelectric power plants in €- updated 2007

				Works for the civil construction			Mechanic works				
n.	Plant Name	Min. production	Max. production	provisional works (a)	intake works	plant	hydraulic circuit	plant	sub-total (b)	other costs (c)	total cost
		[MW]	[MW]	[M€ 2007]	[M€ 2007]	[M€ 2007]	[M€ 2007]	[M€ 2007]	[M€ 2007]	[M€ 2007]	[M€ 2007]
3	Ouro 5	0,312	1,139	0,504	1,778	0,237	0,998	0,471	**3,987**	1,109	**5,097**
8	Ouro 4	0,167	0,873	0,667	1,407	0,237	0,801	0,157	**3,269**	0,911	**4,180**
15	Ouro 3	0,122	0,780	0,711	1,096	0,252	1,029	0,848	**3,937**	1,087	**5,024**
13	Ouro 2	0,299	0,486	0,711	1,348	0,237	0,801	0,534	**3,632**	1,010	**4,641**
2	Man.Jorge 4	0,185	0,898	0,711	0,511	0,222	1,084	0,746	**3,275**	0,839	**4,113**
9	Man.Jorge 3	0,330	0,517	0,504	0,496	0,252	1,013	0,173	**2,438**	0,673	**3,111**
7	Man.Jorge 2	0,190	0,818	0,504	1,178	0,252	1,123	0,236	**3,292**	0,916	**4,208**
14	Man.Jorge 1	0,285	0,443	0,504	1,467	0,237	0,636	0,534	**3,378**	0,988	**4,366**
1	Abade 3	0,300	1,842	0,667	0,859	0,326	1,728	1,163	**4,742**	1,253	**5,995**
5	Abade 2	0,440	2,382	0,504	3,637	0,244	1,422	2,545	**8,352**	2,351	**10,703**
11	Abade 1	1,100	2,358	0,667	5,874	0,289	1,681	2,105	**10,616**	3,824	**14,440**
6	Ilô Grande 2	0,640	5,889	3,756	14,593	0,363	2,702	1,359	**22,772**	5,601	**28,373**
12	Ilô Grande 1	1,500	6,879	0,970	3,785	0,548	3,747	11,225	**20,275**	12,306	**32,581**
4	Lemba 2	0,210	2,829	25,007	6,281	0,304	1,752	0,440	**33,784**	2,638	**36,422**
10	Papagaio 1	0,025	0,563	0,504	0,844	0,178	1,045	0,408	**2,979**	0,822	**3,801**
	TOTAL	6,105	28,696	36,889	45,155	4,178	21,561	22,944	**130,73**	36,327	**167,05**

From the previous tables derives that the minimum guaranteed production of electricity from all hydroelectric plants of Sao Tomè amounts to 6.105-0.025= 6.08 MW and the maximum one, when the rivers have got the maximum flow, amounts to 28.696 – 0.563 = 28.133 MW.

The costs updated to 2007 for the realization of the hydroelectric power plants amount to 167,05 – 3,801 = 163,249 million euros or to 224,14 – 5,123 million US dollars.

The cost per MW produced amounts in 1996 to:

- with low flow rivers 156 M$/6.08MW = **25,65 M$**
- with high flow rivers 156 M$/28MW = **5,57 M$**

The cost per MW produced amounts in 2007 to:

- with low flow rivers 163 M€/6.08MW = **26,81 M€**
- with high flow rivers 163 M€/28MW = **5,82 M€**

A thermoelectric power plant with a power of 50 MW, has got an estimated cost which amounts approximately to the following values:

a) with a gas-fuelled turbine the building cost is circa 59.600.000,00 euro. To this value we can add the absorption unit, which is not essential for the functioning of the plant, but allows the regeneration of the heat that would be otherwise dissipated from the exhaust gas. The estimated cost of such a unit is circa 10.670.000,00 € for a rounded total of 70.270.000,00 €. The cost per MW amounts to:
   - for the power plant 59.600.000,00€/50MW = **1.192.000 €/MW**
   - with the installation of an absorption unit 70.270.000,00€/50MW = **1.400.000 €/MW**

b) with a steam turbine an absorption unit is always required and the total cost amounts to 65.640.000,00€. The cost per MW amounts therefore to 65.640.000,00€/50MW = **1.312.800 €/MW**

IN.AR.CO. srl

GEECO sa
ing. Gianni De Cecco