The Tsate HPP - Starting Signal to overcome the Energy Scarcity in Central Mozambique

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Introduction

The last relevant Hydropower project that has been realised in Mozambique is the well-known 2,075 MW Cahora Bassa HPP on the Zambezi River in the Northern Tete Province of Mozambique. This hydropower scheme has been commissioned in 1975. Of the energy produced in the Cahora Bassa scheme some 75% are sold to South-Africa which has been established in a long-term treaty. The remaining 25% are allocated to the local market which represents about 90% of the energy demand in Mozambique.

Due to the difficult political situation and the civil conflict until the early 1990's no other large hydropower schemes have been realised in the country. The difficult economic situation after the civil conflict has impeded the implementation of new hydropower schemes until today. However, as new significant coal and gas resources have been discovered in the Northern part of the Country there are new hopes on a long lasting economic growth which also resulted in resuming ideas for new hydropower schemes.

The hydropower potential in particular in the Northern and central part of the country is significant and there are plenty of projects that have been identified for an economic operation. At the same time the demand for electrical energy for a competitive price is rising enormously. International funding agencies as well as private developers are currently active to identify the most profitable projects and to start with the realisation.

The Tsate HPP site, located about 50 km south of the city of Chimoio in Central Mozambique on the Revue River is one of the schemes that has been selected for further investigations. Due to the existing Chicamba HPP with its large reservoir upstream of the planned scheme, the Tsate HPP is predestined for further investigations. Together with the existing Mavuzi HPP downstream of the Tsate HPP site a relevant cascade on the River can be established with the goal to overcome the scarcity of energy generation in the region.

The Tsate HPP with an installed capacity of 49 MW is significantly smaller than many other much larger schemes being identified for realisation in the country. However, due to the fact that there is only little national expertise on the hydropower sector left, this project found the strong interest of international donor agencies to act as a trial project with the potential to become a starting signal for further and larger hydropower developments in Mozambique.

1. Background

1.1 Short Outline on the History of Hydropower Generation in Mozambique

Significant hydropower generation in Mozambique goes back to the late 1950's when the 52 MW Mavuzi hydro-power scheme on the Revue River has been commissioned, some 10 years later followed by the 38 MW Chicamba HPP upstream on the same river. Although these two schemes are the country's oldest, the history of hydropower in

Mozambique is intrinsically tied to the 2,075 MW Cahora Bassa HPP on the large Zambezi River in the Northern province of Tete completed in 1979. The Cahora Bassa HPP is the second largest hydropower scheme on the African continent and therefore well known.

In 1987 the 16.6 MW Corumana HPP on the Sabie River coming from South Africa and close to the capital Maputo has been commissioned. Apart from a number of small hydropower plants (e.g. Lichinga and Cuamba HPP's) no other hydropower scheme has been realised in Mozambique, although the country provides a huge potential for hydropower, in particular in the Northern and Central provinces. Main reason for the non-realisation of other hydropower schemes was the civil war between 1977 and 1992 and the difficult process of reconstruction thereafter.

1.2 Present Situation

75% of the energy produced by the Cahora Bassa HPP is exported to South Africa, which is guaranteed until 2027 by a long-term treaty. The 25% of the energy remainig for the Mozambican market currently cover 90% of the demand. Fig. 1 shows the development of the electricity supply between the years 1955 and 2013. As can be seen from the below graph the main producers of electrical energy are HCB (Hidroelectrica de Cahora Bassa) generating at Cahora Bassa HPP and EdM (Electricidade de Mocambique) generating mainly hydropower but also some thermal power. Since about 2011 the energy market has been opened for independent power producers (IPP's) which already after some years significantly contribute to the Mozambican power generation.

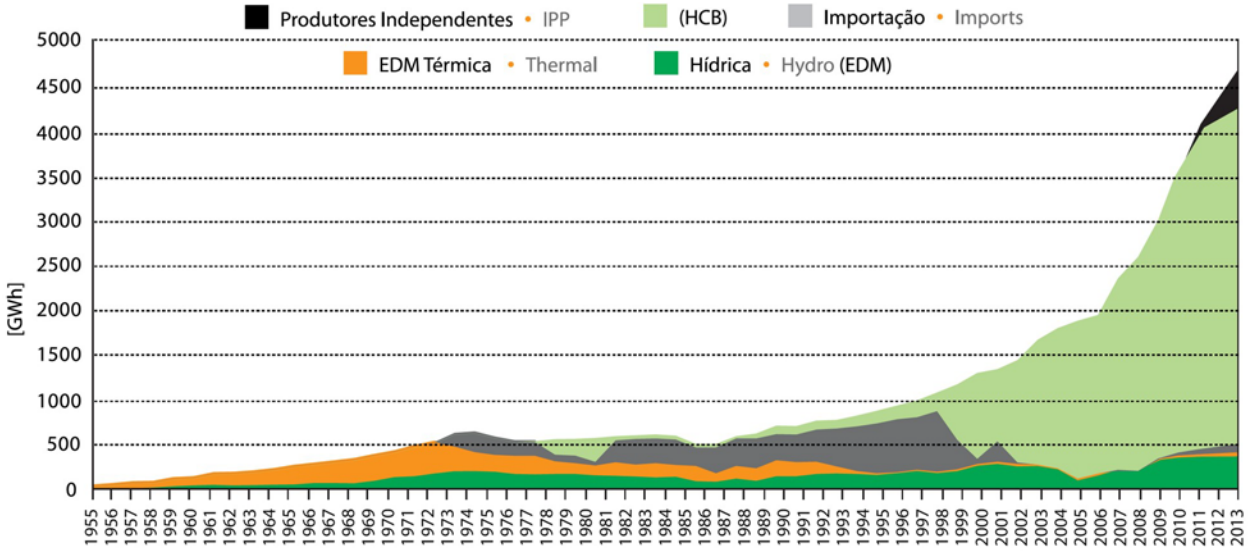

Fig. 1. Annual energy consumption in Mozambique between 1955 and 2013 (taken from Annual statistical report 2013 of EdM)

Fig. 1 also shows that the increase in demand has been significantly accelerated since about the year 2005. The average increase since 2005 is some 13%. It can be concluded that nowadays Mozambique faces problems in providing enough energy during all seasons and daytimes and therefore must often rebuy energy from South Africa (imports) for a comparatively high price.

1.3 Future Developments

As in the future the expected scarcity to be covered by imports is increasing due to the limited potential of the existing generation facilities, it is obvious that new generation sources must be urgently explored in order to continue with the ongoing electrification of rural areas for an improvement of living conditions on the one hand and to avoid jeopardising the economic growth in the country on the other hand. One of the main important factors of the economic growth are new significant on-shore and off-shore coal and gas resources which have been discovered in the Northern part of the country, resulting in well justified hopes on a long lasting economic growth.

Without additional generation capacities, the exploration of these resources will not be possible, which also resulted in resuming ideas for new hydropower schemes. As the coal and gas resources were found in the Northern provinces and the large hydropower potential also lies in the Northern part of the country the boundary conditions for the exploration of these resources can be considered being very beneficial.

2. Hydropower Potential in Mozambique

As already stated above there is a significant hydropower potential available in Mozambique. There is different information in different sources about the hydropower potential in Mozambique ranging from 12,000 MW to 15,000 MW. Only about 2,200 MW have been developed so far (schemes as indicated above). The Government of Mozambique has identified about 100 locations for possible hydropower developments. Many of them are known since decades already.

Due to the increasing dynamic in the developments through EdM but also significantly through the IPP's there is a high number of project names circulating among experts. Some of the relevant projects are listed in the following table which however must not be considered being complete.

Table 1. List of possible future hydropower developments in Mozambique (in alphabetical order)

Project name	Installed capacity	River	Province
Alto Malema	60 MW	Malema	Zambezia
Boroma	210 MW	Zambezi	Tete
Cahora Bassa North Bank (extension)	1,245 MW	Zambezi	Tete
Chemba	1,000 MW	Zambezi	Tete/Sofala
Lupata	612 MW	Zambezi	Tete
Lurio	180 MW	Lurio	Nampula/Cabo Delgado
Mapai	40 MW	Limpopo	Gaza
Massingir	25 MW	Rio dos elefantes	Gaza
Mavuzi 2	8 MW	Revue	Manica
Mavuzi 3	50 MW	Revue	Manica
Moamba	15 MW	Incomati	Maputo
Mphanda Nkuwa	1,500 MW	Zambezi	Tete
Muenezi	25 MW	Revue	Manica
Pavua	120 MW	Pungue	Sofala
Tsate	49 MW	Revue	Manica

The projects listed in table 1 comprise approximately 5,000 MW of additional hydropower generation potential, which would more than triple the hydropower generation capacities if realised. It can easily be observed that most of the additional hydropower potential is related to the Zambezi River, which is the far biggest river in Mozambique.

Although there are many ideas about exploring the hydropower potential in Mozambique resulting in a multitude of activities in form of masterplans, feasibility studies etc. the local knowledge on the realisation of hydropower projects of significant size is very limited as the last hydropower scheme to be commissioned goes 30 years back to the year 1987. For this reason, comparatively small schemes like the Tsate HPP are of utmost interest in order to learn about the administrative process for the implementation of such a hydropower project in Mozambique. Such a relatively small scheme therefore can be considered acting as both a pilot project and a starting signal for further hydropower developments. Once that HPP is realised and commissioned, larger schemes might follow.

3. The Tsate Hydropower Project

3.1 Project Location

The Tsate HPP is located on the Revue River about 50 km South of the city of Chimoio in the Manica province in central Mozambique. Some 70 km upstream of the dam site of the Tsate HPP there is the large Chicamba HPP reservoir which allows to control about half of the reservoir inflows to the Tsate reservoir. In a distance of about 12 km downstream of the Tsate dam site there is the weir structure of the Mavuzi HPP forming a small reservoir. The location of the Tsate HPP is depicted in Fig 2.

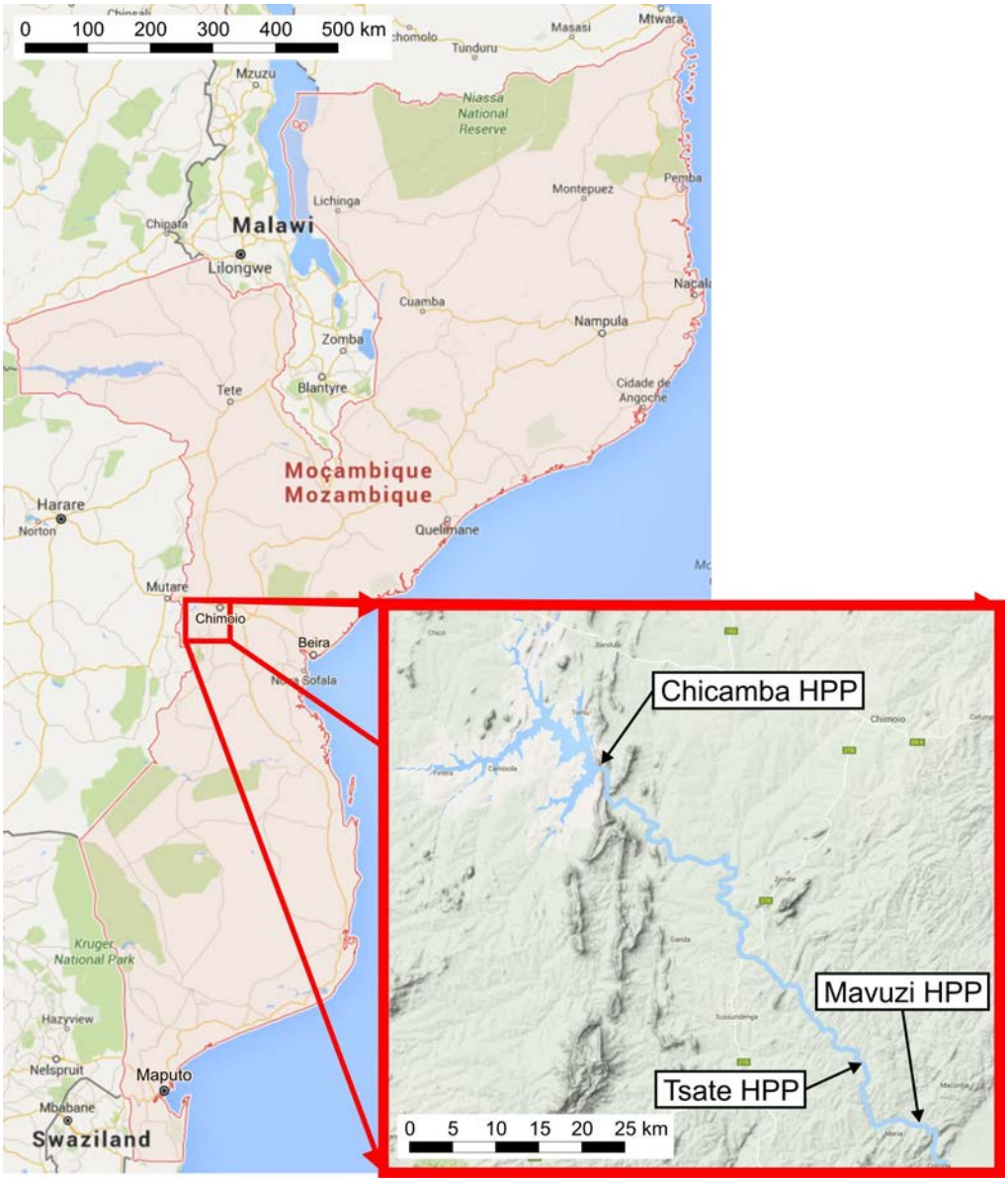

Fig. 2. Location of the Tsate HPP project area (background images taken from google maps)

3.2 Technical Aspects

In general, the Tsate HPP is planned as a run-of river scheme best operated with a constant water level. However, due to the size of its reservoir it also allows significant peaking options. In any case the operation of the Tsate HPP is strongly connected to the operation of the upstream Chicamba HPP and the downstream Mavuzi HPP. The cascade of three hydropower schemes can be operated very flexible in order to react on changing demands.

The Tsate HPP is a rather conventional hydropower scheme mainly consisting of the following main components:

- Dam structure with spillway
- Separate intake structure
- Headrace tunnel and pressure shaft
- Powerhouse and transformer caverns
- Tailrace tunnel with surge shaft
- Outlet structure
- Service building
- Switchyard

The most important salient features are listed in table 2.

Table 2. Most important salient features of the Tsate HPP (preferred 3 units alternative)

General				
Installed capacity	49.2 MW		Gross head	139.3 m
Average annual generation	263 GWh		Rated discharge	43.3 m³/s
Dam structure with spillway				
Dam type	ECRD		Type/no. of spillway gates	radial/2
Dam height	34 m		Dimensions of spillway gates (W/H)	15 m/16 m
Crest length	699 m		Type/no. of bottom outlet gates	radial/3
Dam geometry (u/s and d/s slope)	1v:2h		Dimensions of bottom outlet gates (W/H)	6 m/7,5 m
Dam volume	619,000 m³		Spillway capacity	6,900 m³/s
Reservoir volume	75 million m³			
Waterways				
Headrace tunnel (length/diameter)	127 m/3.65 m		Tailrace tunnel (length/diameter)	6,140 m/5.55 m
Headrace tunnel, lining	concrete		Tailrace tunnel, lining	unlined
Pressure shaft (height/diameter)	110 m/3.65 m		Surge shaft (height/diameter)	35.34 m/16 m
Pressure shaft, lining	concrete/steel		Surge shaft, volume lower chamber	3,220 m³
Powerhouse and transformer caverns				
Powerhouse cavern (L/W/H)	51.5/14.6/28.8 m		Turbine runner diameter	1.20 m
Transformer cavern (L/W/H)	32.2/9.0/8.6 m		Generator rated output/power factor	20 MVA/0.85
Type and no. of turbines	vertical Francis/3		Generator rated voltage	11 kV±10%
Rated speed	600 rpm		Transformer rated LV/HV voltage	11 kV/110 kV

The Tsate HPP if viewed as longitudinal section is characterised by the design of the waterways, which comprise a very short headrace tunnel with pressure shaft but a comparatively long tailrace tunnel of more than 6 km length. Due to the length of the tailrace tunnel a d/s surge shaft is required. Basing on the results of the geotechnical investigations been carried out during the feasibility stage, the geology allows the execution of an unlined tailrace tunnel which is beneficial for costs as well as construction period. The tailrace tunnel can be driven from two faces, one starting close to the powerhouse cavern and one starting from close to the outlet structure.

The dam/spillway structure consists of the ECRD dam sections in the abutments and at about half of the rived bed width as well as the concreted spillway section at the left river bed side. The spillway consisting of two large radial spillway gates and three bottom outlet gates is designed to discharge floods up to 6,900 m³/s which represents the PMF. The bottom outlets can also be used for sediment flushing. However, the investigations carried out during the feasibility stage resulted in very little amounts of sediments.

The power intake structure is separated from the dam structure which allows an independent construction of dam/spillway structure and intake structure with the adjacent headrace tunnel. For the outlet structure a separate small site installation area is required as it is located off from the main site area.

Two scenarios for the powerhouse equipment have been investigated - 2 or 3 units, resulting in a slight preference for the 3 - units alternative. The units comprise of vertical Francis turbines coupled with the generators. The transformers are housed in the transformer cavern which is arranged parallel to the powerhouse cavern. For the power evacuation, a steep shaft leads from the transformer cavern to the switchyard. This shaft is also used as emergency exit and smoke exhaust (separate section).

Fig. 3 shows the general arrangement of the above listed main components without the outlet structure, which is not shown due to the length of the tailrace tunnel. The arrangement is quite compact as almost all structures are located in close vicinity of the dam structure and therefore allow effective construction activities not being too wide spread.

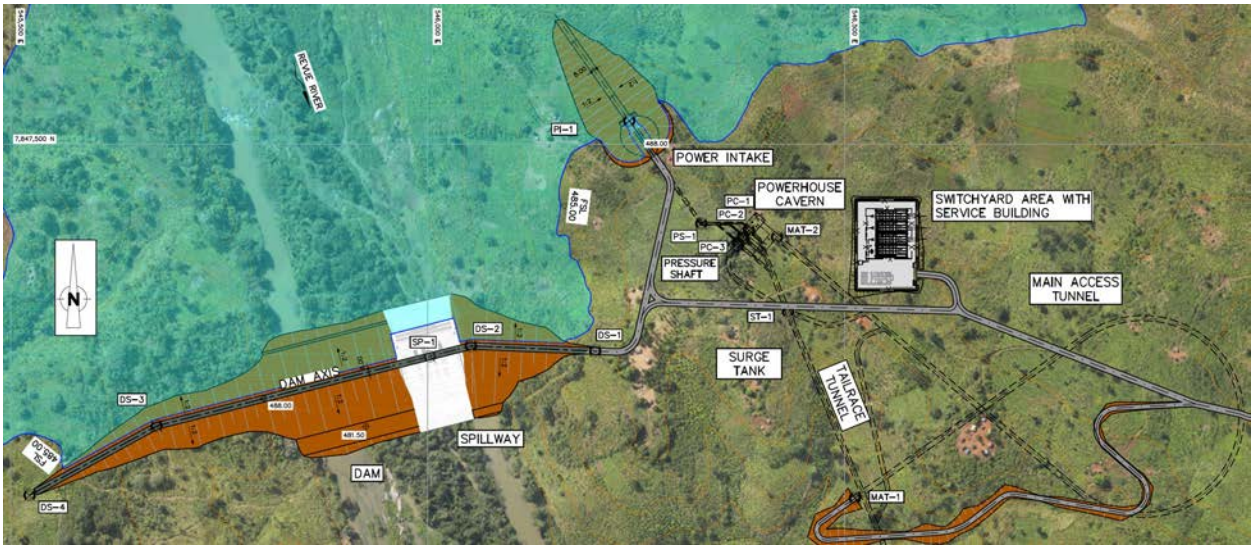

Fig. 3. Arrangement of the main structures of the Tsate HPP (without outlet structure)

3.3 Environmental and social Aspects

During the course of the work on the feasibility study the environmental and social aspects of the construction and operation of the Tsate HPP has been investigated. Moreover, some public consultations for the affected local population as well as the involved stakeholders have been carried out (see fig.4).

In terms of flora and fauna environment there are no significant problems expected as there are no endangered species that could be found, neither during the multiple site visits nor in secondary information sources (literature). In any case mitigation measures need to be installed to compensate any potential adverse impacts on the environment.

Fig. 4. Public consultations with the local population carried out for the Tsate HPP

The conversations to the local people having hold during the multiple reconnaissance visits and the public consultations that have been carried out have all shown that the local population as well as the local authorities fully support the project Other than in many other hydropower projects the local population is keen on the realisation of the project. The main reasons therefor are:

- Expectation of more prosperity
- Access to electrical energy
- Hope for job opportunities

Against the background that by today most the local population has no access to electricity resulting in difficult living conditions with negative future developments this is considered being reasonable. Even the fact that some of the people need to be resettled does not seem to hamper the realisation of the project.

In general, it can be stated that the number of affected people/households for a project of this size (reservoir surface area of about 8 km²) is relatively low. Main reason for this is that the local people mainly live on the plateau and not on the slopes towards the river, which will be flooded once the HPP is in operation. The following rough relevant quantities could be derived from a study of detailed aerial images:

- There are about 200 affected households to be resettled and compensated, including 187 primary structures (houses, huts etc.) and 33 secondary structures (stables, coops etc.)
- Some 215 ha of cultivated land and 3.5 ha residential land need to be considered for compensation incuding approximately 4,250 banana trees, 205 other trees and respective crops
- Very roughly some 20 graves will be affected

These do not only include those which are permanently affected (e. g. due to required resettlement in the reservoir area) but also those who are temporarily affected as their agriculturally used land might be required during the construction phase.

4. Financing of the Project

4.1 The financing Institutions

The Swedish International Development Cooperation Agency (Sida) has financed the feasibility study on the Tsate project by a grant for the executing agency Electricidade de Mocambique (EdM). The feasibility study has been awarded to Lahmeyer International (LI) in JV with Tecnica Engenheiros Consultores after an international competitive bidding process in 2012.

Sida has indicated possible interest in providing financial resources for the further implementation of the project. Moreover, German Financial Cooperation through the KfW Development Bank as well as the European Investment Bank (EIB) show strong interest in financing the project together with Sida.

4.2 Timeline for the Implementation

The target is to start operation of the Tsate HPP in 2022. By today this target can still be achieved. However, it needs joint efforts of all involved parties (government, stakeholders, local population, donors etc.) to reach that target. Once this project will be in operation this will send out a positive signal for other hydropower developments in the country which are highly required for an economic growth.

5. Other required Developments

The exploration of Mozambique’s hydropower potential is of utmost importance for the economic growth of the country and its population. However, investments in the generation facilities is only one important component for the success. Another very important component is the transmission and distribution of the electrical energy. By today Mozambique is subdivided into four more or less separate grid sectors, namely:

- South (ATSU)
- Centre (ATCE)
- Centre-North (ATCN)
- North (ATNO)

The Tsate HPP can be integrated in the existing grid of ATCE with some adaptions. But bigger schemes to be realised require a substantial improvement of the grid for a reliable power evacuation. An integrated grid combining the four sectors would be an important step to achieve that. Investigation on that topic are ongoing.

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