Back

Adding Value at Existing Hydropower Dams in Tanzania: A Conceptual Analysis for Establishing a Dam based Mini Hydropower Plant Utilizing Lower Kihansi Dam Environmental Bypass Flows

Leonard B. Kassana

Dept of Research & Development, TANESCO Ltd, Box 9024, Dar es Salaam. Tanzania

Email: *leokassana@yahoo.com*

ABSTRACT

This work looks at the possibility of utilizing the already allocated bypass water flow to generate electric power without impending environmental requirements for specially designated Lower Kihansi environmental area, which is located in South east of Tanzania. This project has a double added value i.e it earns revenue for TANESCO as well as contributing to CO_2 emissions cut. It also reduces deforestation rate by supplying energy to consumers who would otherwise have used charcoal or firewood for cooking and heating purposes.

The small hydropower potential to be harnessed from this scheme utilizing mandatory environmental water bypass flow is 266 kW potentially able to earn about US$ 150,000.^{00} annually.

From environmental point of view, the scheme has the following added benefits namely ***Kyoto protocol compliance on Climate Change****. By developing this scheme Tanzania will be cutting CO_2 emissions that would have been emitted by the equivalent fossil fuel generator. Also by increasing this* ***green energy*** *in the country, there are further environmental benefits that come along with this. Charcoal which is a burnt wood product enhances deforestation rate as people use a lot of it for cooking and other heating business and more usage of it contributes to the environmental degradation leading to more desertification.*

Tanzania hydro plants have been very unlucky as far as hydrological conditions are concerned, with large parts of the country experiencing low hydro storages over the last three to five years. The country's largest hydro power reservoir, Mtera, reached its minimum supply level of +690 m.a.s.l, exhausting live storage that would normally operate Mtera and Kidatu power plants, which together have an installed capacity of 280MW. The loss of these power plants meant that 31% of the country's entire installed capacity was unavailable.

Although this situation was helped slightly thanks to supplies from the Ubungo/Songas and IPTL natural gas and Jet-A fuel fired power plants, there were still severe economical repercussions as the country had to invest in expensive emergency IPP projects. These emergency gas fired power plants included rental based plants totaling approximately 200MW capacity involving Aggreko, Alstrom & Dowans companies. In addition the Government of Tanzania contracted Wartsila to install a 100MW natural gas fired power plant that will be fully owned by Tanzania Electric Supply Company Limited (TANESCO). All these plants began coming on-line gradually in 2005 and are expected to be fully available by the end of 2007.

One important difference between electricity produced using hydropower and electricity obtained from burning fuel is that hydro energy is lost if not tapped while unburned fuel can be saved and used in another day. Therefore it is wise to make use of any hydro potential available from wherever that may be. For

example the mandatory water discharges through the Lower Kihansi dam could be utilized more effectively with the development of a mini-hydro plant. This is the subject of this paper.

Thus this paper looks at the possibility of utilizing the bypass flow at Kihansi to generate usable energy without impending environmental requirements for the mandatory bypass flow. It will further highlight benefits available if this scheme is built. This presentation is based on the original published work by the same author in the International Water Power & Dam Construction, Volume 59 Issue 8, August 2007.

1 BACKGROUND

TANESCO's Lower Kihansi hydro power plant was commissioned in late 1999 on the Kihansi River Falls, a tributary of the Kilombero River. The hydro power plant, located in the Ududzungwa escarpment, utilizes a head of 850m with an installed capacity of 180MW. It currently produces about 32% of Tanzania's hydro generation.

The existing system at Kihansi includes a 25m high concrete gravity dam, which impounds a small reservoir with total water storage of 1.6 Million m^3. The intake connects to the 2.2km inclined 1:7 headrace tunnel of 34-37.5m^2 via a 25m^2 circular unlined 500m vertical headrace shaft. The power house cavern (12.6m wide, 98m long and 32m high) connects to the 2km tailrace tunnel and 1.9km access tunnel. Total tunnel length is in the order of 10 km.

Plate 1: Lower Kihansi Dam with Bypass Flow

As part of the environmental requirement compliance, Lower Kihansi Hydropower System is required to discharge a constant water flow through the dam to maintain an ecosystem downstream of the existing dam. The mandatory discharge is about 2 m^3/s all year long. This is the energy this paper is proposing to tap!

2 JUSTIFICATION FOR THE PROPOSED MINI-HYDRO PLANT

Bypass flows can have a serious impact on firm energy production because environmental requirements must first be satisfied before energy production can begin. A 1m^3/sec bypass release reduces Kihansi's annual energy capability by 16% while 2m^3/sec reduces it by 31%. The corresponding reduction in total system capability is 9% and 12% respectively. At 7m^3/sec flow bypass, the plant's firm energy is reduced by 100%. In other words, in a dry year, the plant will only be able to operate during the rainy season.

Since we can't fully utilize the bypass flow to generate power for the entire 850m head without compromising the environmental requirements, we could utilize the bypass flow as shown in figure 1. In this design the bypass flows could be utilized to generate power without causing a detrimental effect on the ecosystem. After generating power the water is released back to its originally intended route to nurture the ecosystem.

From the National Energy Policy document (2003), the government encourages energy projects by all stakeholders either governmental departments and/or private stakeholders.
At the moment, the government of Tanzania is expressly spearheading the energy sector reforms in Tanzania.

Currently, the OUTLOOK is that the electricity coverage in Tanzania is only about 10% while in rural areas the access is even lower to just over 1%. These low access rates are major constraints to economic development and alleviation of poverty. However, the government of Tanzania is committed to improve the situation and has set a goal to raise the access to electricity to 25% of the population by 2010. The population is now estimated at 36 million inhabitants.

To achieve such ambitious targets, several strategies have been conceived.

- Expansion of the present main grid to cover new areas (Grid Expansions)
- To promote Min Grid/Isolated grids to provide electricity to areas outside the main grid.
- Promote Rural Electrification by installing a Rural Electrification Agency (REA)
- Promote other renewable energy sources (solar, wind and small hydro plants)
- Promote private sector participation in the power sector

So looking at the proposed scheme in this paper you find clearly that it is conforming to the national energy strategy to achieve the ambitious targets set by the Government of Tanzania the overall goal towards energy sufficiency and energy security policy.

3 SOME EXPERIENCE FROM OTHER COUNTRIES

Such schemes do exist in several places around the world. Penche (1994), an editor to the Layman's Guidebook on how to develop a hydro site says "there is also the possibility of installing a power plant on an existing conventional multiple purposes dam, by either an existing conduit or outlet works or siphon intakes"

In India, according to Kumar (2007), there about 36 small hydropower stations that are Dam Toe SHP Stations. These are out of 984 small hydropower stations that include both operational and under construction projects to date. These small hydropower power stations have a total of 3259.882 MW. Thus the dam toe PowerStations contribute about 6% of the total small hydropower stations installed capacity in India to date.

The environmental requirements/awareness started picking up significant momentum not more than 20 years ago a period that has also seen a significant number of dams that are complying with this requirement of bypass water flows. Needless to say, such small hydropower systems like the one being proposed to develop in Tanzania are possibly attracting most of the hydropower stakeholders due to the added value that they can impart to the existing dams be it for generating hydropower or other purposes like irrigation.

4 POTENTIAL PROJECT BENEFITS

4.1 Financial Benefits:

The power and energy benefits calculations are based on the fundamental theory of hydro energy and power formulae as depicted in the given two equations:

- $E = ?*[9.807*Q*t*H]/[3.6*10^6] = [?*Q*t*H]/[367.1]$ in kWh
- $P = [9.81*Q*H* ?]$ in kW where
  - E = energy
  - ? = overall efficiency of turbine-generator assumed be in the range of 0.72- 0.87
  - Q = discharge in m^3/sec
  - H = head in m
  - t = time in hours
  - P = power in kW

Based on the above formula and the parameters as shown in the table below, the scheme is expected to generate about **TZS 150 Million** (US$ 150,000.^{00}) **annually** as per rough calculations shown below strengthening the Company' financial position:

Table 1: Preliminary Energy and Revenue Calculations Results

Item Description	**Value**	**Units**
FSL of the reservoir	+1146	m.a.s.l
MSL of the reservoir	+1141	m.a.s.l
Level at the bypass inlet in the dam	+1135	m.a.s.l
Level at the bottom of the dam i.e. bypass pipe outlet	+1125	m.a.s.l
Head (1141-1125 m.a.s.l)	16	m
Water Flow (1.5-2.0 m^3/s)	2	m^3/s
Acceleration due to gravity	9.81	m/sec^2
Water Density,	1000	kg/m^3
Power	266.8	kW
Annual Plant utilization	7500	Hrs/year
Annual Energy (kWh)	**2,001,240**	**kWh**
Energy unit price (Average to the consumer)	75	TZS/kWh
Revenue/year (TZS)	**150,093,000.^{00}**	**TZS**
Annual Revenues in TZS (Million)	**150**	**TZS in Million**

4.2 Capacity Building

internally: Since this is going to be done internally at more than 95%, our staff are going to enhance their technical capacity in Hydropower/Technical skills.

4.3 Energy Security:

This is towards the energy sufficiency efforts in line with national energy policy

4.4 Kyoto protocol compliance on Climate Change:

By developing this scheme you are cutting CO_2 emissions that would have been emitted by the equivalent fossil fuel generator. Further more, under Carbon Credits; TANESCO could get money from GEF for partly or full funding this scheme. **By the way TANESCO can start looking at carbon trading possibilities in the future!!**

By increasing this **green energy** in the country, there are further environmental benefits that come along with this. Charcoal which is a burnt wood product enhances deforestation rate as people use a lot of it for cooking and other heating business and more usage of it contributes to the environmental degradation, more desertification.

5 COSTS FOR IMPLEMENTATION]

5.1 Sunk Costs

Largely many costs are sunk cost as the following infrastructures are in place at the site and they will not be incurred for this installation:

- 33 kV transmission line exist at the dam
- dam and reservoir exists for constant water supply through the year
- Telecommunication exist at Lower Kihansi
- Penstock pipe

- Air strip exist just in case an emergency of charter plane is needed
- All weather road to the dam exist
- Technical human resources are available within TANESCO and we don't envisage a need for foreign experts to work on this at all as all work shall be done utilizing the indigenous professionals.

5.2 Major requirements for the Project installations:

The following are needed to be newly procured for the scheme implementation

- A small turbine and Generator set unit to be designed accordingly
- Transformer and Switch gear panel and protection
- Control Equipment
- Penstock material of less than 50 m
- Other construction requirements, etc

5.3 Installation/Implementation Costs

At this very preliminary stage, precise cost figures can't be obtained. However, the author's experience drawn from similar projects around the world show that such installation costs range from US$ 1,200.^{00} to US$3,000.^{00} per kW unit. Since we expect to generate 266 kW, then preliminary installation cost for planning purposes and thus by assuming US$ 1,200.^{00} per kW as the scheme will enjoy a lot more sunk cost that had been incurred during the construction of the Lower Kihansi Plant system, the proposed scheme would therefore amount to **US$ 319,200.00 .^{00}**. Again this is still a conservative figure and we may have a lower figure after the pre-investment study that is currently underway in TANESCO.

For preliminary guidance, the table below gives a number of the Indian cases highlighting installed capacity with their corresponding installation costs in rupees (x10^{6}).

6 RETURN PERIOD FOR THE INVESTMENT

At this very preliminary stage, the crude method that can be used to evaluate the investment is **the Payback Period Method.** The expected investment cost is US$ **319,200.00 .^{00}** and forecasted cash inflow (sales revenue) annually is **US$125,000.^{00}** at US$1.^{00} = TZS 1200.^{00} rate of exchange. Then this investment has a payback period of about **three years**. However, more work is needed for precise financial calculations and refinements to ascertain this figure during the pre-investment study that is currently underway.

Table : 2 Cost Details of Dam Toe SHP Stations

S. No.	Name of Project	State	Installed Capacity (kW)	Head (m)	Year of Commissioning	Total Cost (Rs in lacs)
1	Yeleru Reser SHP	Andhra Pradesh	3000	34	2002	1444.00
2	Mid Pennar MHS	Andhra Pradesh	2000	12.50		900.00
3	Singoor	Andhra Pradesh	15000	20.00	1999	4000.00
4	Somasila SHP	Andhra Pradesh	10000	17.00		0.00
5	Lower Ghagri Mini Hydro Electric Project	Bihar	400	258.00	1993	259.00
6	Sadani Mini Hydro Electric Project	Bihar	1000	101.00	1993	566.00
7	Nugu MHS (I & II)	Karnataka	3000	12 & 28	2000	1323.43
8	TB Dam SHP	Karnataka	8000	10.00		2220.00
9	Madhanmantri SHP	Karnataka	3000	4.70	2001	2134.50
10	Malaprabha SHP	Karnataka	2400	10.00		650.00
11	Deverebelekara	Karnataka	2000	10.90		810.00
12	Aanveri Mini Hydel	Karnataka	1500	21.70		726.00
13	Maddur	Karnataka	2000	13.20		743.00
14	Madhol	Karnataka	1000	13.05		474.00
15	Rajankollur MHS	Karnataka	2000	19.00	1999	1061.42
16	Devarabelakere Mini Hydel Scheme	Karnataka	2000	11.00	1993	558.00
17	Harangi	Karnatka	9000	24.00	1997	4450.00
18	Hemawathi	Karnatka	16000	16.00	1999	5505.00
19	Kadamane-1 SHP	Karnataka	9000	325.66		4450.00
20	Karikkayam St. 1&2	Kerala	15000	10.00		4249.00
21	Ullunkal	Kerala	7000	10.00		2184.00
22	Maniyar SHP	Kerala	12000	16.00		1900.00
23	Bhimgarh SHP	Madhya Pradesh	2400	10.00		559.95
24	Bhincrarh	Madhya Pradesh	2400	10.00	1998	610.57
25	Bhandardara SHP	Maharashtra	12000	69.00		5013.64
26	Majalgaon	Maharashtra	2250	5.25	2000	1138.97
27	Warna	Maharashtra	16000	29.50	1999	3416.78
28	Bhatgar	Maharashtra	16000	32.00	1977	1440.15
29	Bhatsa	Maharashtra	15000	70.00	1991	5248.00
30	Vaitarna	Maharashtra	1500	17.50	1987	128.00
31	Veer	Maharashtra	9000	15.00	1975	800.19
32	Harbhangi SHP	Orissa	2000	12.00		413.70
33	Pykara	Tamil Nadu	2000	27.31	1989	700.00
34	Mukurthy	Tamil Nadu	700	21.30	2000	382.67
35	Aliyar	Tamil Nadu	2500	30.00	2000	747.27
36	Perunchani	Tamil Nadu	1300	15.00	2000	623.05

Source: Kumar (2007)

7 DESCRIPTION OF THE PROPOSED PLANT

The figure and the photos below show how the proposed mini hydropower PowerStation will look like once built. This is a dam scheme type of power station that shall consist of a short length of penstock, power house and a very short tailrace open channel. See the overview in Figure 1.

The selection of the turbine is based on the empirical experience. Sayann, K.S (2003) suggests that the Tubular turbines with the following parameters are suitable for small hydro schemes:

- Head in meters = 2 to 15 m
- Discharges in cumecs = 1.5 to 40 m^3/s
- Capacity in kW = 50 to 5000 kW
-

Thus the proposed power scheme power characteristics fall within the suggested range and therefore at this stage, the selection of the turbine type will be Turbular.

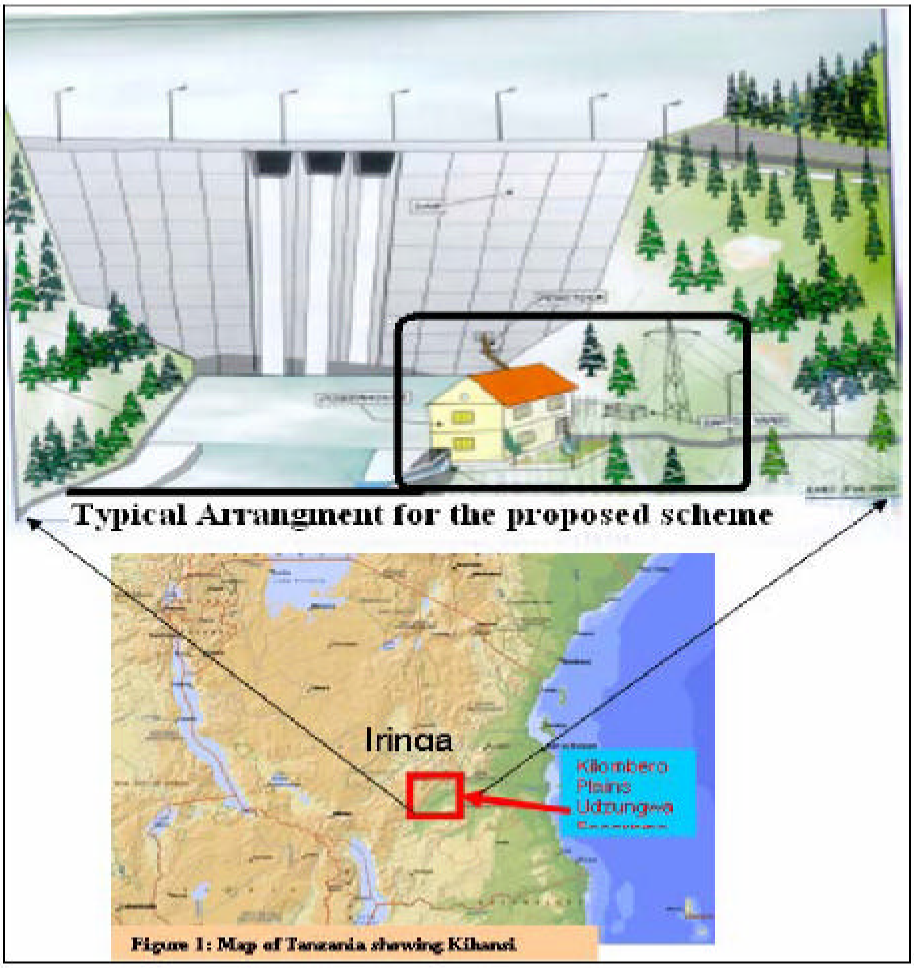

Figure 1: Map of Tanzania showing Kihansi

For heads under 100 m, the size of the power house size and its concrete volume are the functions of the turbine size. However when heads exceed 100 m, the size of the power house is governed by the diameter of the generator casing. Empirical equations permitting estimation of the turbine and generator casing sizes are available and can be used for a rough estimate of power house dimensions during the initial conceptual study. These are equations are elaborated in Gordon, J.L (1983).

However in this case, the pre-investment study will take care of sizing of the power plant and all other pertinent auxiliary works i.e the entire power house layout.

8 CONSTRUCTION SCHEDULE

The proposed power plant is envisaged to take about 6 to 8 man months of implementation from the turbine-generator procurement to the commissioning of the plant. The pre-investment study underway will ascertain a definite time frame for implementation. However, the implementation of the same is roughly composed of the following components:

Table 2: Proposed Construction Schedule

s/n	Item	M1	M2	M3	M4	M5	M6	M7	M8
1	Turbine-generator unit procurement								
2	Powerhouse construction								
3	Penstock and Tailrace channel								
4	Switchgear facility								
5	Transmission line connection								
6	Commissioning								

9 LESSONS FROM THIS SCHEME PROPOSAL

There are numerous dams in Tanzania and Africa as a whole that also mandatorily do discharge environmental flows and they also need to be reviewed for energy harnessing possibilities like this one at Lower Kihansi Dam in Tanzania. This can add value to existing dam structures while preserving environmental integrity.

REFERENCES

Gordon, J.L (1983).Power House Concrete Quantity Estimates, Canadian Journal of Civil Engineering, November 1983

Hangzhou Regional Center (2006). Small Hydropower. A Text Book Specially designed for Training Workshops in TCDC Program. Zhejiang University Press. China.

Kumar, Arun (2007). Personal Communication via email message

Penche, Celso (1994). Layman's Guidebook on How to Develop a Small Hydro Site. Part I & II, European Commission. European Small Hydropower Association. Brussels. Belgium.

Sayann, Kuldip Singh (2003): Hydraulic Turbines for Small Hydropower, International on Technology Selection for Small Hydropower Development. Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee. India