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THE REPUBLIC OF GUYANA

Moco-Moco Hydropower Plant: Site Assessment for Restoration

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CHAPTER 1 Introduction

The Moco-Moco Hydro power station developed as a run-of-the-river project was commissioned in May 1997.The site is located on the Moco-Moco Creek, Region 9, Cooperative Republic of Guyana. Moco-Moco creek is a part of the Amazon River System originated from the north of Kanuku Ranges converging into Kakutu River which is a boundary river between Guyana and Brazil at 1 km south of Lethem. Total length of Moco-Moco Creek is 26 km and a natural water drop of about 400 m. The length of section of Creek which is developed as a hydro power project is about 1.5km and has a natural drop of about 225 m. The purpose of this project is to provide electricity to Lethem, the administrative Head Quarter and surrounding villages.

Moco-Moco hydropower station is designed to generate electrical power of about 500kW, with a gross head of about 219.32 meters (net head of 210 meters) a design water flow of 0.34m^3/s. The installed capacity of this power station is 2x250 kW. Estimated annual generation is 2913 MWh which corresponds to a plant load factor PLF) of 66.5%. The main components of this hydro power station are

- Retaining dam
- Headwork
- Low pressure water transmission pipe line
- Fore bay
- Penstock line
- Power house with Petlon type generating units
- 13.8 kV transmission line

The Moco-Moco hydro project is financed by Govt. of China and constructed by China National Complete Plant Import and Export Corporation (Group).

It is reported that there was sudden and heavy rainfall on 5th July 2003 resulting in landslide which damaged the penstock on 6th July 2003. This damage in penstock resulted breakdown of penstock causing outflow of water in the form of jet which resulted in mountain slide in a large area between upstream of thrust pier 2 and thrust pier 5. After this accident fore bay gate was closed and power generation was stopped.

The Government of Guyana requested The Energy and Resources Institute (TERI) to study the existing situation at the Moco-Moco hydropower generation and assess the scenario to bring back power station operational. The TERI technical team visited site along with GEA engineers on 6th October 2013 to assess the current situation. This brief report summarizes the existing situation at site and recommendation for further action.

1.1 Moco - Moco Facility

The Moco - Moco Hydro power station has 2X250 kW generating units with Pelton type turbines. The summary of design specifications and details of hydro turbine-generator equipment are given in table 1.1.

Table 1.1 Summary of design specifications

Parameters	**Design values**
Name of River:	Moco-Moco River
Mean discharge of river:	Q_{mean}= 0.61 m^3/s
Rated discharge of MMHPP:	Q_r = 2 x 0.17 m^3/s - 0.34 m^3/s
Availability of flow:	P_{flow}= 90 %
Rated head of MMHPP (net head):	H_r = 210 m
Annual plant output: (Energy)	E = 2,913 MWh; PLF: 66.5%
Elevation of weir crest:	370.98 m asl
Width of weir ogee:	21.5 m
Dam height:	3 m
Length of headrace pipeline:	1,349 m
Diameter of headrace pipeline:	600 mm
Average slope of headrace pipeline:	0.40%
Material of headrace pipeline:	GRP (Composite plastic, inside plastic coated)
Water level at top of penstock:	365.55 m asl
Elevation of Fore bay inlet centre at top of penstock	364.215 asl
Length of penstock:	577 m
Diameter of penstock:	438 mm
Diameter of bifurcation pipes	325 mm
Average slope of penstock:	38%
Material of penstock:	Welded steel plates
Thickness of penstock pipe:	9.75 mm
Elevation at centre of branch pipe at inlet to power house	146.415 asl
Equipment of the Hydro power plant	
Turbines:	
Number	2
Type:	Horizontal Pelton
Model:	CJ22-W55/1 x 5.8
Manufacturer:	Fuchin Ind., China

Parameters	Design values
Rated discharge:	0.166 m^3/s
Rated head:	210 m
Rated capacity:	273kW
Efficiency at rated data:	eta = P/ (Q x H x 9.81) = 0.80
Speed:	900 rpm
Generators:	
Numbers:	2 nos.
Model:	SFW *250-8/850*
Speed:	900 rpm
Runaway speed:	2160 rpm
Voltage:	480 V
Frequency:	60 Hz
Power factor:	0.8
Efficiency:	93.2%
Transformer:	
Model:	S-630/13.8

Though the annual generation is estimated to be 2913 MWh, it is reported that the actual generation before the stoppage of the powerhouse due to major breakdown, is lower due to some problem and simultaneous flow of water is not happening in both the branches of penstocks.

CHAPTER 2 Observations

2.1 Power scenario at Letham

Letham Power Company is responsible for power generation and distribution in this region. At present power requirement of Letham city and surrounding villages are catered from diesel generator (due to stoppage of Moco-Moco hydropower). Letham Power Company has three diesel generator sets of rated capacity 1X 600kW, 1X500 kW and 1X270kW. From the Letham power company official it was learn that normally two DG sets will be operated to cater the power demand. The peak load is around 600 to 650kW and average load is around 450 to 470kW. The average diesel oil consumption for diesel generator set is 20000 litres per day. Considering present diesel consumption and future power demand it is economically viable to restore the operation hydro power station.

2.2 Present infrastructure at Moco-Moco

Main dam, fore bay, intake and headrace pipeline

No major damages are observed in the main dam, fore bay, intake and head race pipeline. However, the intake gate requires cleaning to remove rust and painting.

Penstock

The total length of the penstock is 577 meters, arranged along the slope from fore bay to the power house. The total elevation difference from fore bay to power house is 217.8 meters (difference in centre line of penstocks). The penstock has an internal diameter of 457.2mm with wall thickness of 9mm and 7mm. There are 8 thrust piers and 570 buttresses are arranged along the penstock. During the site visit it was found that the weir structure at the upper end of the Moco-Moco falls at the Moco-Moco River is in good shape. The land sliding mass is located between buttress 302 upstream of thrust pier - 2 and buttress 514 of downstream of thrust pier – 4, with a total length of about 215 meters, which accounts 37% of the total length of the pipe alignment is distributed. The major displacement of penstock starts from buttress -201 to 514. The penstock pipe line from buttress – 302 to 514 got displaced and deformed. The penstock between the thrust pier – 3 and thrust pier – 5 got bent and offset from the buttress with maximum displacement of about 4 to 6 meters from the original alignment. The pictures of the existing penstock are shown in Figure 2.1.

Figure 2.1 Images of Damaged penstocks

Power house

Power house has two horizontal Pelton turbines directly coupled to synchronous generators complete with auxiliary equipment and a separate electrical panel room. The pictures of turbine hall and electrical room are given Figure 2.2.

Figure 2.2 Damaged turbines and Generators

Internal structural parts of turbines and turbine speed governor systems are damaged condition. There is no water flow meter at the turbine inlet, installed inlet pressure gauges are damaged conditions. Turbine runner wheel should be inspected for traces of abrasion.

The copper winding coil of generators is missing generator is in completely damaged condition. The entire turbine-generator units of both the units need to be replaced. The damaged synchronous generator is shown in figure – 2.3.

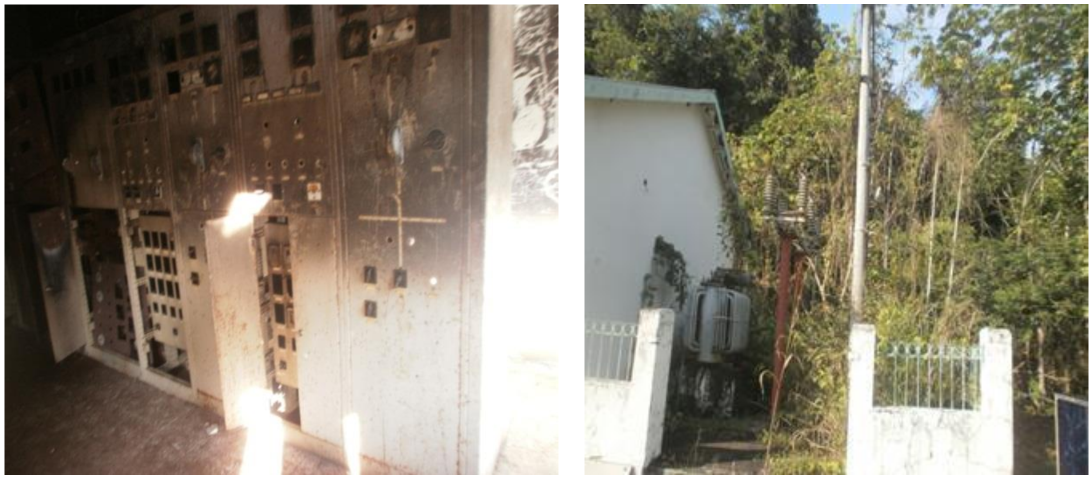
Figure 2.3 Damaged synchronous generator

It is opined that repair of existing generator will not be economical. All the control and protection systems of turbine-generator systems are in breakdown condition and require replacement.

Electrical System

In the Electrical System room, it is observed that all the switchgear, control, protection, metering and auxiliary systems are in damaged condition. It was reported that after the incidence of landslide, transmission line was being charged by supplying power from diesel generator. During this process, power was fed from Letham diesel generator station to the transmission line and as there was no isolation/protection between electrical system of hydro-power station and transformer, fire resulting from a fault in the system, destroyed the entire switch gear panel including transformer. The picture of destroyed electrical switchgear panel and transformer is given in Figure – 2.4.

Figure 2.4 Burnt electrical switch board and damaged transformer



From the site visit it is clear that entire electrical switchgear, electrical control, protection, metering and auxiliary systems need to be replaced with new systems.

2.3 Review of existing project reports

There are four studies carried out by different international organisations during the period 2004-2011 to assess and make the Moco-Moco hydro power station operational.

1. Assessment by China Water Resources Beifang Investigation, Design & Research Company Ltd., March – 2004
2. Assessment by Incomex (Industria Commercio e Exportacao Ltda
3. Indalma (Indalma Industria E Commerico Ltda) – Report of Site visit, August -2010
4. Deutsche Gesellschaft Internationale Zusammenarbeit (GIZ) Germany, Aug – 2011.

Brief summary of recommendations from above reports are given in table 1.2.

Table 1.2 Summary of recommendations

Assessment by China Water Resources Beifang Investigation, Design & Research Company Ltd., March – 2004	Solution A : Simple treatment • Assuming that landslide is stabilized, the original penstock could be restored by adopting some simple engineering measures, including slope excavation, earth back filling, providing drainage system and application of flexible joints, pipes etc. In this way water supply and power generation could be recovered with in short time • Estimated total cost for the solution A is 420,000 to 540,000 US dollars Solution B: Comprehensive restoration of the original alignment • Re built the thrust piers 2, 3 and 4 and rehabilitate the destroyed penstock • Cutting the upper section of the slope to flatten the slope • Setting up surface and ground water drainage system along penstock alignment • Reinforcement of the thrust piers and butters • Treatment of fore bay stability • Treatment of upstream slumping crack of sliding mass • Replacement of bulked penstock • Replacement of expansion joints in penstock • The time period for the solution B is 8 – 9 month • Estimated cost for the solution B is 1.8 to 2.4 million US dollars Solution C : New Penstock Alignment • Since part of the existing penstock is located on the sliding mass rehabilitation is technically difficult and inefficient economically, in addition it cannot guarantee a safe operation of the power house. Hence it is suggested to new penstock alignment solution should be taken in to consideration • The project cost and magnitude of fall in elevation cannot be ascertained at present All the work investigation, design approval and project implementations will require a period of 6 to 12 months, necessary maintenance work should be taken by Guyana side to prevent the project site and facilities from further destruction.
Assessment by Incomex	Incomex proposes to rehabilitate and operate the Moco Moco hydro power plant in 4 phases. Phase – 1 • Phase – 1 of the project involves the negotiation, approvals and constructional arrangement between the government of Guyana and Incomex. Phase – 2 • Phase – 2 of the project involves restoration of the Moco Moco small hydro power station. • Excavation of unstable landmass around thrust pier – 2 to 4 • Complete restoration of the penstock. • To guarantee slope stability and prevent the impact of materials damaging the penstock, Incomex intends to construct reinforced walls along the penstock to act as barriers between the overburden and penstock. • Construct a drainage system along the length and area surrounding the penstock to drain surface water and to reduce seepage into surrounding landmass thus, reducing the impact on the pipes. • Reinforcement of the fore bay and construction of the buffer to maintain the pressure on the pipes. • Restoration of the transmission lines • Cleaning the area around the transmission lines • Replace components in the transformers • Replace and repair electrical panels in the power house

	• Repair the turbines and generators Phase – 3 • Proposing an operational contract of twenty five years, with a guarantee of electricity supply to current and future market of Lethem and its surroundings. • In case of an increased demand in the region, Incomex will be interested to assess and further develop other hydrological potential close to Moco Moco. Phase – 4 • After 25 years the company may engage the government for an extension of its constructional arrangement based on the satisfaction of the parties. • The company will transfer the operations of the Moco Moco Small hydro power plant to the government of Guyana at the end of its contractual period based on conditions negotiated in phase – 1 of the project. The total value for the works for rehabilitation of the Moco Moco station is 430,000 US dollars. However, this amount may increase depending on the current state of the site. Power Purchase Agreement: Incomex is proposing a price of US dollar 95/MWh for electricity generated by SHP Moco Moco.
Indalma – Report on Visit of site t, August - 2010	Solution – 1 : Possibility of recovery of the hydro power Moco-Moco • Technically, the recovery of hydro power Moco-Moco is possible, through reforms in the construction, in the repair of the some equipment and in the purchase new equipment that can be not be repaired. However, the cost of the reform of hydropower is extremely high and the amount of generated power of 450 kW and continue the risk of new landslides. Solution – 2 : Possibility to build another power house • Another alternative was diagnosed by Indalma, reusing some existing structures and building a new engine room and new pipe forced. The site identified for the construction of new plant avoids places with instability on the slopes, or would not have the risk of landslide damaged structures. With the installation of more modern equipment, cheap and efficient, the power to be generated reaches 1 MW. With this model, where some structure of the old hydropower would be reused, the cost installation would be around R$6000,000.00 to $3,335,000.00 (exchange rate 1.80).
Deutsche Gesellschaft Internationale Zusammenarbeit (GIZ) Germany, Aug – 2011	Option – 1 : Maintaining the current installed capacity • The original designs and materials should be reused as much as possible in order to minimize costs • The penstock should be re-aligned, cradles be repaired and replaced wherever necessary and damaged and non repairable pipeline should be replaced. • The slope should be protected properly against future landslides including drainage system and slope protection measures • Synchronizing equipment would be used in order to operate the diesel station and the hydropower station in parallel • Cost estimation for the proposal US dollar 819,775.00 Option – 2: Upgrade the station to 1 MW • Reportedly there are plans from interested development groups to extend the installed capacity of the MMHPP to 1 MW. • Estimated annual energy benefit is 4409 MWH/annum • Cost estimation for this option is US dollar 2,350,590.00 • Considering static financial model, the payback time is estimated to be 6.8

	years, which seems to be well acceptable. • For economic analysis considering a discount rate of 9.5%, operation and maintenance cost of 5% of annual profit and cash financing, the calculated returns amounts to 13 years • The internal rate of return after 20years would amount to 13% at a net present value(NPV) of 350,000 US dollar

All the earlier study documents carried out during the period 2003 to 2011 except the report by Deutsche Gesellschaft Internationale Zusammenarbeit (being latest among these studies) assume that the original equipment like turbine, generator, governor control systems, switchboard and electrical panels are in good condition. However, at present all the equipment are in no condition to generate power.

CHAPTER 3 Recommendations

Based on the site visit, review of the available documents and discussions with various experts, the following options has been recommended for restoration of the Moco-Moco Hydropower station:

3.1 Option 1: Retaining existing installed capacity 2x250 kW)

Main dam, headwork, intake and headrace pipeline:

No major damages are observed and therefore these structures can be retained.

Water conductor system: Penstocks System

1. For restoration of penstock, geotechnical analysis is required to identify zones at risk to avoid landslide in future.
2. During the site visit it was observed that, small part of the penstock length is completely damaged, while most of the penstock length is displaced and deformed. It was estimated that, 75% length of the penstock pipe line is in good conditions 15% of penstock pipe line length is displaced and deformed around 10% length of penstock line need to be replaced with new pipeline. However, it is recommended to replace the entire penstock in order to have uniform design/ material as the cost of penstock is not significant in the total cost of replacement.
3. To avoid future landslides, the slope bordering the pipe line alignment must be cleared. It is recommended to provide rock anchors in rocky slope area.
4. Proper drainage system must be designed along the penstock line to divert rain water.
5. The penstock supporting structure should be designed properly by providing clamp with cushion (Teflon) pad, to allow free movement of the pipe in longitudinal direction.
6. All the existing gates valves need to be reconditioned for free operation.
7. Blocked trash-rack must be cleaned and curtain must be provided at the dam to avoid fall of leaves on dam water.
8. After restoring penstock, hydro tests to be carried out to check penstock conditions and to check turbine inlet pressure.

9. Further, the alignment has to be tested for ensuring simultaneous flow of water in both the penstocks which is reported to be not happening when the project was operational.

Powerhouse equipment

1. Power house equipment is tailor-made based on the site requirement. Repair of turbine, generator, governor system and switch board (including electric cables and panel) is not economical, original supplier need to be contacted for the repair, but it is highly unlikely that they will be able to provide spares as the plant is more than 10 years old.
2. It is recommended to replace all power house equipment with turbines, generators, governor, switchgear, control, protection, metering and auxiliary equipment complete with new equipment and latest control/protection/monitoring system with SCADA.
3. Discussions with the suppliers revealed that the cost of penstock restoration estimation will not be possible at this stage. It need to be defined based on the selection of new equipment.

Civil works

Contractor for civil works will be able to provide cost estimates after site visit. In this regard, with few Indian contractors are being approached.

3.2 Option 2: Upgrading the installed capacity to 1 MW

Another option is to install a new power house of total 1 MW generation capacity, (2 turbines of 500kW). Flow of 0.68 m^3/sec is required for the generating units which is available in the river.

By increasing the penstock pipe capacity from 0.5m^3/s to 0.75m^3/s, it possible to utilize the entire discharge for power generation of 1 MW. The estimated annual energy for this option is 4409 MWh which corresponds to a PLF of 50% according to report by Deutsche Gesellschaft Internationale Zusammenarbeit (GIZ) Germany, Aug – 2011

For this proposal

a. The headrace pipeline has to be replaced with new bigger pipeline

b. Other option is to go for two pipelines, viz-a-viz, repairing existing line and installing an additional line.

c. For upgrading the installed capacity, the entire project requires to be reconstructed except dam and head works; i.e., all the components like headrace pipeline, penstock system, power house, turbine-generator equipment and all associated switchgear, control, metering and protection including transformer. The transmission line can be retained. Cost estimates for this option has to be prepared after site visit by Civil contractor and obtaining budgetary offer for electro mechanical and electrical equipment.

d. Economic analysis can be done after finalising cost estimates and obtaining details about available tariff and other financial parameters like rate of interest, cost of finance, etc.