

DEVELOPMENT of the LUFUBU RIVER BASIN HYDROPOWER CASCADE PROJECT

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Abstract

The paper describes the development of the Lufubu Hydropower Cascade Project in Zambia, comprising of three plants in cascade totalling 326 MW (Phase 2). The project is being promoted by the Lufubu Power Company (LPC) a private Zambian company which, with the support of consulting engineers Studio Pietrangeli (SP) and transaction advisors Fieldstone South Africa, is developing the design, environmental and social impact assessments (ESIA), obtaining concessions and licences, and negotiating with other interested parties (off-takers, EPC contractors, operation and maintenance contractors, etc.). Moreover, LPC is currently in negotiations with the Zambian government for the Implementation Agreement (IA) and with national electricity utility, ZESCO, for the Power Purchase Agreement (PPA).

This paper focuses on the most relevant aspects:

- the investigations carried out to develop the conceptual scheme and the feasibility design;
- the main technical features of the plants and the transmission lines, as well as the network system in which the project is inserted;
- key elements of the ESIA;
- approbation process being followed with the Zambian government and the financing structures.

1 - Introduction

The Lufubu River, running through the Northern Province of Zambia is the largest tributary of Lake Tanganyika, originating at 1500 m a.s.l. and winding its way through the Nsumbu National Park before flowing into southern Lake Tanganyika at approx. 800 m a.s.l.

Northern Province is a predominantly rural province, with agriculture being fundamental for the population's livelihood. The province has lagged behind in terms of development due to poor and inadequate growth-enhancing infrastructure and access to social services that have posed a challenge for development.

This slow growth has unfortunately led investors to favour the richer and more developed southern areas of Zambia. In fact, most of the power generating plants (existing and planned) are in the south of the country meaning that substantial energy to be transferred over long distances to the centre and north where more than 70% of the entire load demand is found.

The installed capacity of power generation facilities in Zambia, as of December 2014, was about 2400 MW. Hydropower plants cover more than 94% of the total installed capacity. ZESCO owns the majority of the plants totalling about 2200 MW, followed by Copperbelt Energy Corporation (CEC) with 80 MW emergency power gas turbine (standby), and Independent Power Producers (IPPs) with about 110 MW.

In 2013 the founder of the first IPP in Zambia, the Lunsemfwa Hydro Power Company (LHPC), with ancestral ties to this part of the country where the project is located, came up with the idea of exploring the possibility of exploiting the Lufubu River for hydropower.

The Lufubu Cascade project was thus born thanks to the vision of a successful entrepreneur whose dream is to promote the development of his native land, and an engineering company whose driving philosophy is to come up with rapid, technically sound and economic solutions.

2 – Fast Track Approach

2.1 Introduction

There was absolutely no official topography or geological coverage of the envisaged project area, not to mention studies on the exploitation of the Lufubu River. In order to develop, in the shortest time possible, a conceptual design based on solid, albeit preliminary, investigations, SP's first stage of data acquisition included:

- Topography: SRTM (Shuttle Radar Topographical Mission) database; SATELLITE stereoscopic imagery; DRONE stereoscopic images; ground survey with DGPS (Differential Global Positioning System).
- Geology: surface geology; SASW (Spectral Analysis of Surface Waves) survey; geophysical survey.

These investigations were carried out directly by SP's experts using in-house instrumentation to acquire reliable data on which to base a reliable conceptual scheme and subsequent feasibility study. The Fast-Track Approach attracts financing since the quicker a project is implemented, the sooner it starts operation and the earlier the investors have a return on their investment. It means not only saving money, but often revenues from early generation.

2.2 Mapping

The topographic data was acquired using three different methodologies. The data was often complementary and when plentiful was used to verify reciprocal reliability. The techniques applied were:

- PLEIADES. Photogrammetric restitution of images acquired by the PLEIADES satellite system;
- DRONE. Photogrammetric restitution of drone-originated images;
- DGPS.

The satellite survey focused on the Lufubu River covering an area approximately 4 km wide and 100 km long for a total extension of 370 km². The drone survey focused on the main works for each plant (dam, waterways and powerhouse). An overall area of about 67 km² was surveyed with a total number of 7403 pictures taken during 81 flights.

All the topographic activities were completed in 4 weeks during which time SP's experts acquired the drone images, Ground Control Points (GCPs) for both drone and satellite images and performed real-time restitution of the contour lines.

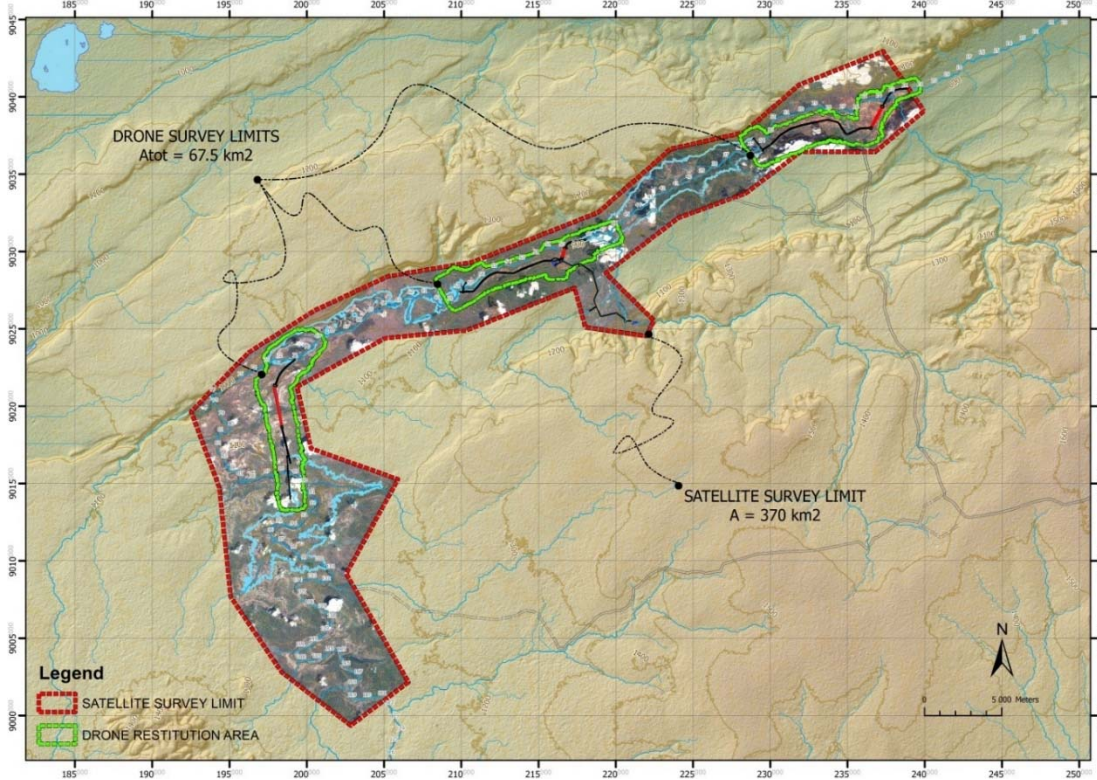


Fig. 1 – Survey Limit



Fig. 2 – Drone Survey

The accuracy of the satellite survey was 40 cm pixel for the imagery and 80 cm for the vertical accuracy. The accuracy of the drone survey is given in the following table showing the combination of flight elevation / Ground Sample Distance (GSD) / Digital Terrain Model (DTM) Accuracy adopted at the various works sections:

	Z_fly (m)	GSD (cm)	ACCURACY (cm)
Dam, PH, Tailrace/Outet	325	10	20
Canal and Penstock	490	15	30
detail over LU3 PH	100	3	6

2.3 Surface Geology, SASW and Geophysics

As mentioned, there was no reliable information on the project area so a geological survey was carried out together with the topographic mission. This survey was preceded by an in-depth photo-interpretation of satellite images (Landsat and Pleiades) and SRTM hillshade. Data processing (band combinations, surface attribute raster creation, slope, aspect and analysis of curvature maps of the geo-referenced stereoscopic blocks) enabled the main morpho-structural lineaments, morphological features and rock outcrops and fracturing to be identified at regional and dam site scale.

A vast surface survey of the project areas was performed and 11 seismic lines laid using SASW technology. This enabled the characteristics of the terrain to be investigated down to a depth of about 10 m.

At the end of the 4-week geological survey a geoseismic investigation campaign was prepared. This campaign also lasted approximately 4 weeks during which a total of 10,120 m along 60 seismic lines were investigated: 5200 m divided in 20 seismic lines at Lufubu 1; 2040 m in 18 seismic lines at Lufubu 2; 2880 m in 22 seismic lines at Lufubu 3.

Thanks to this Fast-Track Approach, all the data necessary for preparation of the conceptual scheme (first mission) and development of the feasibility study (second mission) was gathered in only 10 weeks.

3 – General Layout

3.1 The Scheme

The scheme of the cascade is comprised of three hydropower plants (LU1, LU2 and LU3) exploiting an overall head of approximately 330 m and an inflow volume of about 1.8 billion cubic metres (calculated at LU2), generating 1284 GWh/y.

A two-phase construction plan has been envisaged, characterized by the same annual energy production but with different Installed Power (IP). The three plants will have a plant factor of 0.9 (in Phase 1), but will be built in such a way as to allow for their future operation with a plant factor of 0.45 (in Phase 2). In fact, during construction all the civil works, in particular dam, head pond, power house and tailrace, will be built to allow for the expansion in Phase 2.

Upgrading of the headrace and electromechanical (EM) equipment and hydraulic steel structures (HSS) will be executed during Phase 2 when demand from the energy market favours the sale of peak and off-peak energy (as is already happening in many other countries). The installed power of the three plants will be:

HPP	Phase 1 MW	Phase 2 MW
LU 1	66	132
LU 2	43	86
LU 3	54	108
Cascade >	163	326

3.2 Main Civil Works

All three plants in the cascade will have a similar layout consisting in:

- dam;
- headrace canal, conveying flows from the reservoir to the head pond;
- head pond, from which the penstocks depart;
- 1 or 2 penstocks, depending on the phase (1 or 2);
- power house.

At both LU1 and LU2 plants Roller Compacted Concrete (RCC) dams have been envisaged, while at the LU3 plant a Concrete Faced Rockfill dam (CFRD) has been selected with a concrete central block hosting the overflow structure.

On the basis of the results of the geoseismic campaign, a self-supporting headrace canal has been chosen for all the plants. A rectangular box culvert of reinforced concrete has been foreseen, which will be concealed (filled over) after construction.

In Phase 1 all the plants will have a single penstock, which will be doubled in the future when the energy market changes. A surge shaft will be necessary along the penstocks at LU1 and LU3 plants to reduce the amplitude of pressure fluctuations.

The general layout is shown in Figure 3.

3.3 Main Electromechanical Works

In the first phase of the project the cascade will have an aggregate installed capacity of 163 MW, exploiting an overall head of approximately 320 m. In each powerhouse the main EM equipment will consist of inlet valves, vertical turbine and vertical synchronous generators.

The hydropower potential (head and discharge) at each site is suitable for vertical Francis turbines. Upstream of the turbines, at the spiral case inlet, the main inlet valves will shut off the flow to the turbine and stop the units in case the wicket gates fail to close.

The table below summarizes the main design features of the EM equipment and penstocks of the cascade:

MAIN EM EQUIPMENT DESIGN FEATURES	LU 1	LU 2	LU 3
<u>Turbine type</u>	Francis vertical	Francis vertical	Francis vertical
Installed Capacity (MW)	66	43	54
Average Gross Head (m)	146	83	92
Speed (rpm)	300	272.7	272.7
<u>Synchronous Generator</u>			
Rated Power (MVA)	76.5	50	62
Rated Speed (rpm)	300	272.7	272.7
Power Factor	0.85	0.85	0.85
Rated Voltage (kV)	11	11	11
<u>Main Inlet Valve</u>			
Type	Butterfly	Butterfly	Butterfly
Nominal Diameter (mm)	3000	3000	3000
<u>Penstock</u>			
Material	Steel	Steel	Steel
Internal Diameter (mm)	4200	4200	4500
Length (km)	2.6	0.6	2.1

3.4 Transmission System

The three plants will be connected by 132 kV overhead transmission lines (OHTL) and to a terminal substation at LU1 with a 330 kV OHTL for interconnection to the national grid at the 330 kV substation in Kasama. The scheme includes (see Fig. 4):

- two 132 kV OHTLs from LU3 to LU2, single-circuit, about 22 km long, rated 58 MVA each
- two 132 kV OHTLs from LU2 to LU1, single-circuit, about 20.5 km long, rated 110 MVA each
- one 132 kV OHTL from LU1 to Nsama, single-circuit, about 40 km long, rated 58 MVA
- one 330 kV OHTL from LU1 to Kasama, single-circuit, about 200 km long, rated 400 MVA

This scheme will enable the full power capacity of the cascade to be transferred to the national grid via a 330 kV OHTL as well as feeding the nearby Nsama district through the Nsama 132kV substation.

According to ZESCO, it is common practice to equip the 330 kV OHTLs with a twin bundle ACSR (Aluminum Conductor Steel Reinforced) "Bison" (Stot = 431.2mm², d = 27mm) in the Zambian grid, while the 132 kV lines will be equipped as follows:

- LU1 – LU2 with rated capacity of 210MVA, ACSR "Lynx" in twin bundle configuration (Stot=183 mm²)
- LU2 – LU3 with rated transmitted power of 116MVA with single ACSR "Lynx"
- LU1 – NSAMA equipped with ACSR single "Lynx"

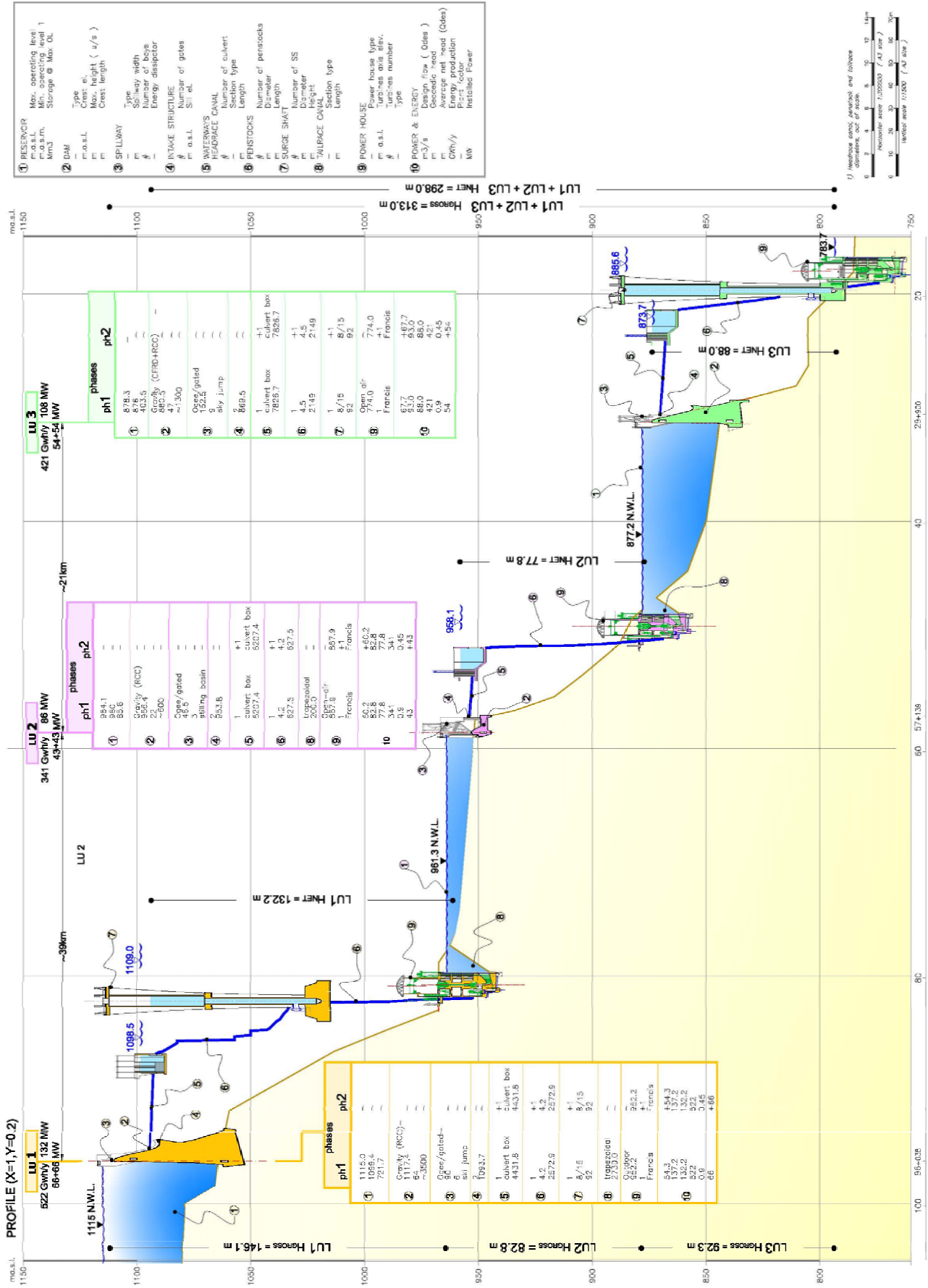


Fig. 3 – Lufubu cascade, General Layout

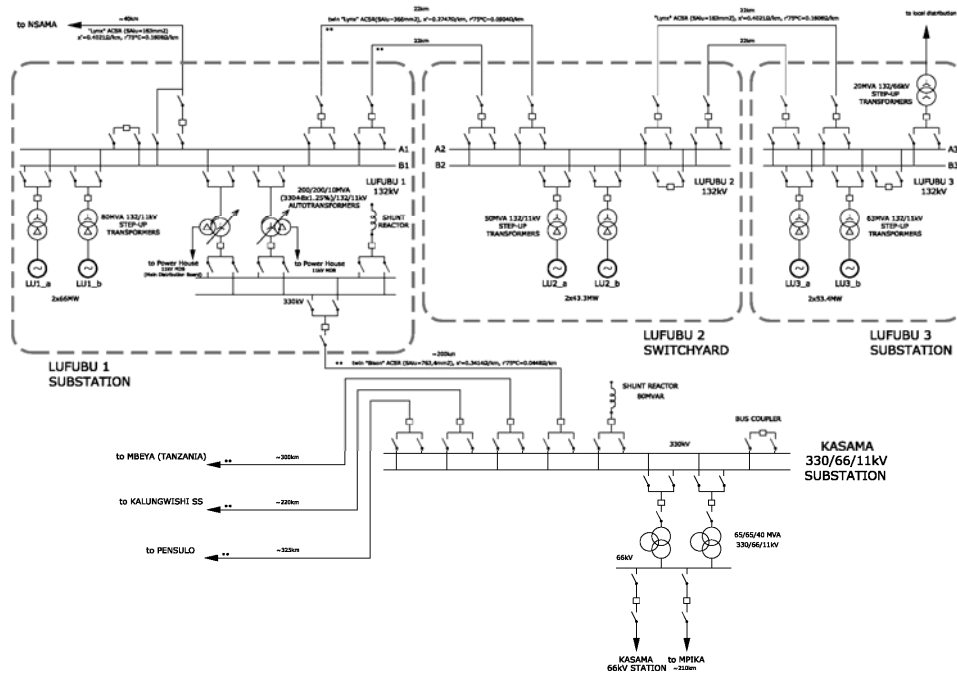


Fig. 4 - Lufubu Cascade electric system single line diagram

The LU1 substation will be interconnected to the 330 kV grid via two 330/132 kV autotransformers (ATRs). ZESCO is considering the implementation of an intermediate 330kV substation in Mporokoso some 65 km from LU1, where the lines departing from Kalungwishi and Lufubu schemes would be connected. However this would not substantially change the foreseen system since almost all the power flows from Lufubu would be dispatched to Kasama.

The expected average generation of the Lufubu Cascade represents a remarkable amount of energy available to dispatch to final users and cross-border exchanges. In this way, the Lufubu Cascade will play a key-role within a fully regionally coordinated generation-interconnection expansion plan, by responding to the national load growth rate and improving reliability and security of the transmission system in the north-eastern part of the country, presently affected by vast voltage drops and instability problems.

SP performed a power system analysis, based on the generation and transmission data available at the beginning of 2015, considering a load demand scenario as per target year 2030, to assess the capability of the future Zambian electric grid to receive the power from Lufubu in an electrically safe manner, at its fully developed stage (326 MW). In doing so, accurate network models were set up representing the Zambian power system, verifying the adequacy of the planned network infrastructures, identifying the need for improvements to ensure safe operation within the rules and requirements of the regional electric code.

In the target year 2030, Zambia's peak load demand is forecast to increase from today's 1800 MW up to 4300 MW and energy demand ~ 29000GWh/y. In this scenario, the Lufubu project will substantially contribute to cover the base load in Phase 1 (plant factor 0.9) and peak load in Phase 2 (plant factor 0.45), as well as reducing energy imports. Moreover, the vicinity of the project to the soon-to-be-constructed 330 kV Kasama – Mbeya corridor will provide a valuable, shortcut towards the Tanzanian boundary for power export purposes.

Lufubu Cascade will surely contribute to several ancillary services, as required by established international operation regulations of vast synchronous power pools such as SAPP, such as:

- a) voltage and reactive power control
- b) peaking load service
- c) primary frequency control
- d) secondary power-frequency control (by automatic remote control of some generating units) and tertiary power-frequency control (manual by operators)
- e) black-start capacity for system restoration after blackout event.

The results of the analysis confirm a steady-state reserve margin (against peak load) sufficient to allocate more than 600 MW for export purposes towards neighbouring countries, while the rating capacity of the interconnection lines is never approached in steady-state operation, as the voltage stability margin is reached rather earlier than this limit. The analysis is reasonably conservative, since it does not consider any contribution in voltage regulation by surrounding countries.

Voltage stability investigation finds acceptable operation up to ~350 MW of export to Tanzania, while the assessed total transfer capacity is somewhat close to 760 MW without any additional reactive compensation measure, and up to 1,090 MW by adopting plant factor correction. Short circuit levels at Lufubu High Voltage (HV) buses are rather low, and of no concern in breaking current selection of the circuit breakers, also considering the radial system typology of the interconnection up to Kasama station.

3.5 Zambian Power System

The Zambian electrical power system is operated under the aegis of the Southern African Power Pool (SAPP)/Southern African Development Community (SADC) as part of an interconnected power system, linking South Africa and Zimbabwe to the south via 330 kV lines, and the Democratic Republic of Congo (DRC) and Tanzania to the north and east at 220 kV and 66 kV voltage respectively. Fig. 5 shows the present grid including planned and committed transmission/generation projects as per year 2019 (source: ZESCO).

The Zambian electricity supply industry consists of three major market players namely ZESCO, CEC and the LHPC involved in generation, transmission, distribution and supply. System operation is coordinated by ZESCO's national control centre in conjunction with the various subsidiary control centres.

The mining sector and domestic consumers account for 82% of total electricity consumption. Zambia is also faced with the challenge of satisfying the demand of more than 80% of its population with renewable forms of energy. Presently, the system is operated with heavy load shedding schedules due to insufficient generating capability to cover the increasing load demand, as per the expected demand growth in the next few years between 150 to 200 MW per annum, with a severe and immediate shortfall in supply.

Therefore, both increasing the country's electricity generating capacity and reinforcing the transmission infrastructures are priorities.

With the aim of fulfilling the short and medium term energy needs, several projects are planned, mostly in the south (medium and large hydropower plants such as Itezhi Tezhi, Batoka, Kafue Gorge Lower as well as thermal plants such as Maamba), but also in the north. In fact, the Lufubu Cascade will fill a geographical gap, providing a substantial input of about 330 MW to the grid, i.e., about 15% of the present installed capacity.

As far as the transmission system is concerned the 330 kV system links the two major power stations of Kariba North Bank and Kafue Gorge. At the time of writing, the Extra High Voltage (EHV) system is composed of about 650 km of 220 kV lines and 3500 km of 330 kV lines (existing and under construction). The 132 kV and 88 kV network in operation is interconnected mostly at regional level.

The system includes generating stations whose total installed capacity is presently about 2400 MW (in 2015) and will likely reach about 7350 MW in 2030. The geographical location of primary energy resources of Zambia has brought about the construction of a significant number of plants in the south of the country, but 1100 MW of new projects (including Lufubu Cascade) are planned in the north of the country. Several of the largest newly planned power plants, some already under construction or commissioning, include:

- the hydropower cascades of Lufubu (330 MW), Kalungwishi (247 MW) Mambilina (334 MW) and Mombotuta (245 MW, partly shared with DRC) in the north
- Itezhi Tezhi (120 MW) and Kafue Gorge Lower (750 MW) HPPs in the centre
- Batoka North (1200 MW) HPP and the Maamba thermal plant (600 MW) in the extreme south.

Zambia is part of the SAPP, founded in 1995 and the first formal international and advanced power pool in Africa. Its primary aim is to provide reliable and economical electricity supply to the consumers of each of the SAPP members consistent with the reasonable utilisation of natural resources and the effect on the environment.

As far as the generation projects are concerned, the implementation of some priority projects in Zambia will greatly improve both the installed capacity and the available capacity, presently quite low due to maintenance and aging of the existing units. Thus making available in SAPP region both reserve capacity and available capacity for export purposes.

Considering benefits by HV interconnections and regional integration with Eastern and Central Africa Power Pools (EAPP and CAPP) and, together with the economic efficiency of an electrically integrated region and competitive tariffs markets promotion, ZESCO and SAPP are developing transmission projects recognized as priority projects. Savings of generation capacity may be achieved by interconnecting the power systems of neighbouring countries, given the possibility of sharing the maximum load demand (which would be likely less than the sum of the individual peak demands of each network), so that installed capacity may be tailored to inter-areas power transfer. This is particularly true in the case of Lufubu HPP Cascade, featured by a remarkable amount of dispatchable energy, where cheaper large size generating units could be desirable, whereas their economic use requires either a large system or interconnection.

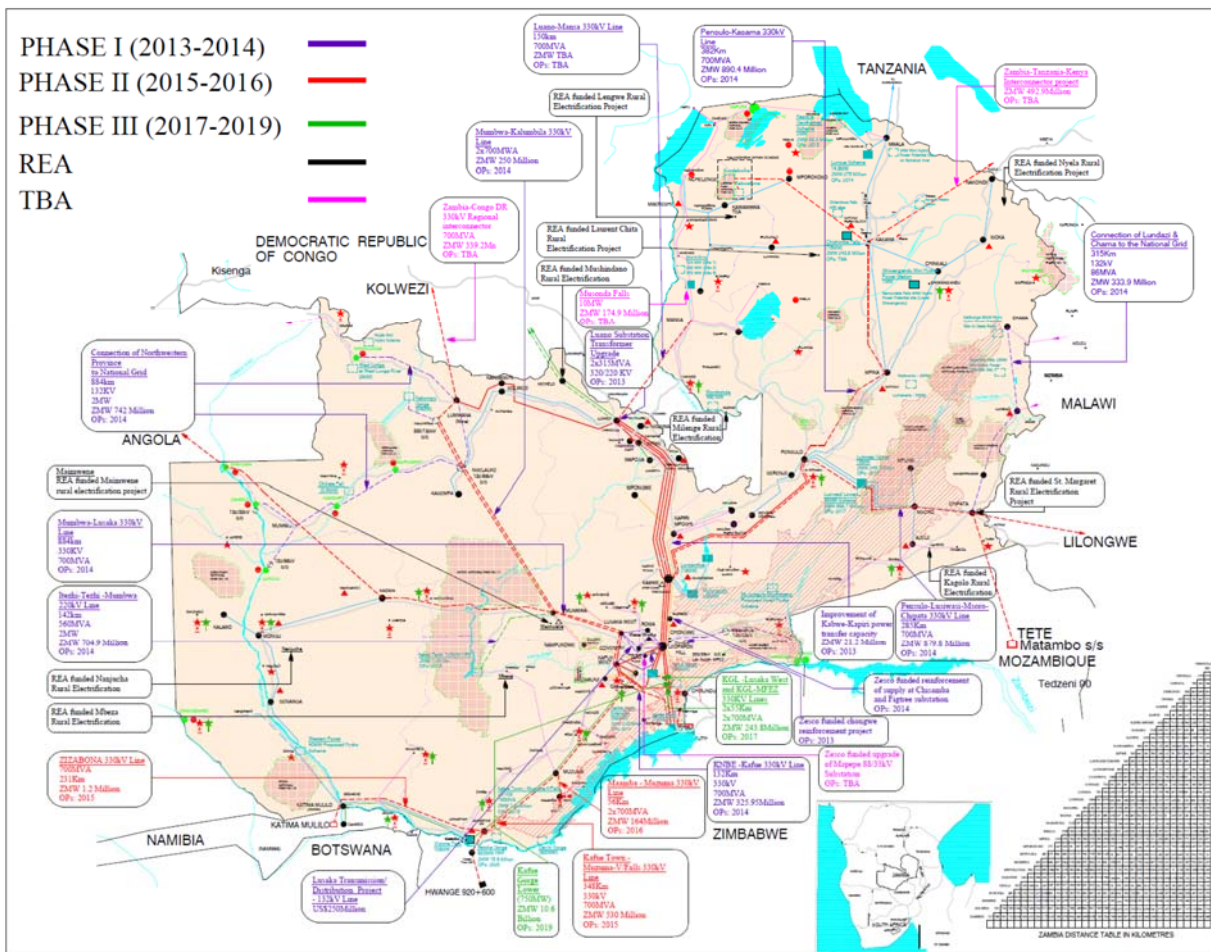


Fig. 5 - Zambian grid including planned and committed transmission/generation projects as per year 2019 (source: ZESCO)

4 – ESIA

4.1 Introduction

The Environmental and Social Impact Assessments for the Lufubu HPP and Transmission Lines were prepared in accordance with Zambian regulations, best international practices and the requirements of the project developer.

The key elements encountered for the ESIA are summarised in the following paragraphs.

4.2 Cascade

The reservoirs of all three plants will be located within the Nsumbu National Park so, legally, the inundated areas will still remain part of the Park, and therefore the change in land use will be practically negligible. Only two households will be involved in the resettlement.

The project site landscape will be temporarily compromised during the construction period, and the whole impacted area will be re-shaped in line with the previous habitat.

The impact of the construction phase will involve the terrestrial fauna, and a slow period of adaptation to the new environment far from the project area is expected. The new ecosystem created by the large amount of available water and fresh grass will encourage the fauna to return after the end of the works.

Fisheries may develop along the banks outside the Park boundary (LU3 reservoir). A standard planning scheme will be prepared by specialists, with particular attention to buffer and development areas that could arise at the back of the fishery. Tourism will definitely benefit from the cascade system and the creation of the impounded areas.

Generally, the impact on the whole area will be positive in light of the upgraded roads and the potential of having new tourist facilities in the area, boosting the development of leisure activities, such as boating and sailing sports, fishing, bird watching and photographic safaris. The water bodies will create other opportunities for wildlife, such as grazing lands for large herbivores during critical dry periods of the year.

The construction camp could be considered as the base for the development of eco-sustainable facilities in the first post-impounding phase. Part of the camp not used for dam management could be destined for the reception of tourists on the basis of tried and tested models in other parks and game areas.

About 9,600 Ha of the Nsumbu National Park will be inundated and most of the vegetation within the footprint will be cleared. The clearance operations in this area will have to be performed with the supervision of ZEMA (the Zambian Environmental Management Agency), ZAWA (the Zambia Wildlife Authority) and the National Forestry Department, and the surrounding areas will be restored only with indigenous vegetation.

Public transport from the northern rural areas to the more populated areas of Mporokoso and Kasama will be improved enhancing movement of the local people and those coming to do business in the area.

The regulation of the flow during heavy rain events will smooth the flood peaks, while during the dry season it will guarantee the constant presence of water in the river downstream of the dams.

The connections among original wildlife areas will be facilitated by suitable corridors in order to avoid reduction in biodiversity and to affect the ecosystem on a large scale.

4.3 Transmission Lines

A separate ESIA was required for the two transmission lines (OHTL) with corridor widths of 32 m for a length of about 80 km (132 kV) and 50 m for a length 200 km (330 kV) respectively.

Distances of about 23 km for the 132 kV OHTL corridor and 24 km for the 330 kV OHTL corridor will be cleared inside the Nsumbu National Park. Because of the particular features of the conservation area, the clearance operations will be performed under the supervision of ZEMA and ZAWA in conjunction with the National Forestry Department.

Electric and magnetic fields (EMF) are created from anything which produces, carries or is powered by electricity, and suitable corridors will be left free from any use by people living in the project area: 50 m wide for the 330 kV OHTL, and 32 m wide for the 132 kV OHTL. A census of the people living along the proposed transmission lines was carried out to identify the households to be resettled. The result was twenty two structures (20 within the 330 kV corridor and 2 within the 132 kV corridor), affecting 15 households for a total of 67 persons.

Cultivation under the transmission lines will be permitted. For now, the census has identified 25.96 Ha of land already cultivated (including recent cultivation).

The transmission line running south will require improved access roads during construction and this will benefit local communities. The future construction and improvement of the roads related to the project will bring a moderately positive impact mitigating the transport difficulties faced up to now.

The habitat within the construction corridor will be directly affected by removing plants, cutting down shrubs and felling trees. Access to pole sites by vehicles and equipment will cause more destruction of vegetation with subsequent soil erosion. Reforestation is foreseen in sensitive, erosion-prone areas.

A natural change in land use will occur because of the works. The characteristics of land affected by earth-moving machinery or occupied by project works will change and probably not support the current land use. People will be allowed to continue cultivating low profile crops along the transmission lines, and sensitive areas such as wetlands and riverbeds will be preserved.

Terrestrial fauna is expected to need a slow period of adaptation to the new environment more or less distant from the project area.

A significant impact will be due to the collision and electrocution of large birds with the transmission lines. For birds' safety, a length of 350 cm of the suspended insulators could provide enough distance between cross-arms and energized parts (required minimum is 60 cm).

5 – Approbation Process and Financing Structure

5.1 - Approbation Process

With a view to encouraging private development in the energy sector, the Government of Zambia has created a dedicated office called Office for Promoting Private Power Investment (OPPPPI).

Since there were no previously approved studies, the Lufubu project was subject to an initial “no objection” from the Government up to completion of the bankable feasibility study and governmental review and approval of the study report.

The approbative process for the Lufubu project was extraordinarily rapid and lasted little more than six months during which the government gave its approval of the design study and ZEMA approved the ESIA and RAP (Resettlement Action Plans) for the plants and transmission lines.

5.2– Financing Structure

As mentioned above, the LPC is a local Zambian developer that has secured the right to develop the hydropower project cascade along the Lufubu river. LPC is the primary party that initiated the project, the feasibility studies, ESIA, concessions and licences and negotiations with other project parties.

LPC is currently negotiating the IA with the Zambian government and the PPA with ZESCO assisted by the transaction advisor, Fieldstone South Africa. Fieldstone South Africa is also assisting LPC in selecting the most suitable project financing structure, optimising the capital structure and developing financial models.

The financing structure selected for Lufubu, which is shown in Fig.6, foresees that the project will be housed in a Special Purpose Vehicle (SPV) to be funded through a capital structure comprising 70% Senior Debt funding, 10% Mezzanine finance and 20% of Equity. The SPV will be a new legally distinct entity, established with the specific purpose of owning, constructing and operating the Lufubu hydropower cascade. The Senior Debt and Mezzanine debt will be provided by a variety of financial institutions. The Senior Debt will be the most substantial form of funding for the project.

Preliminary financial models developed by Fieldstone South Africa, assumes capital grace periods which will cover the construction period (48 months) and a long-term senior debt with tenor of 15 years.

LPC is currently discussing with various financing institutions for Senior Debt and Mezzanine Debt such as Development Finance Institutions, Multilateral International Institutions, Political Risk Insurance Providers, Commercial Banks and Export Credit Agencies.

LPC is also looking for a Strategic Equity provider with an offering that could support LPC’s desire to maximize its own shareholding.

As already mentioned above, Government support is expected to be in the form of an Implementation Agreement, which is currently under negotiation. The Government of Zambia will also support ZESCO by a Sovereign Guarantee for the obligations under the PPA. In the event that a PPA with ZESCO is not finalised, LPC will engage other customers, such as local mining companies and/or industries and/or export for a PPA.

The SPV will have complex challenges in coordinating all these entities. Usually, compared to other types of possible financing structures (hoist government financing, developer financing, resource-based infrastructure financing) the scheme selected for Lufubu project takes more time to reach operations and has higher up-front costs.

However, the current project finance structure was selected due to its own main strengths:

- Efficient allocation of project risks, placed on the parties willing and able to assume them. For example, investors who are interested in high risk may focus on the project pre-construction, while investors who are risk-averse may prefer to finance the Lufubu project in a later stage.
- No cash needed from Government of Zambia that can use its balance sheets for financing other services and programmes, such as national security, social programmes, and other infrastructure projects.
- High level due diligence, multiple parties involved in the financing will assure more comprehensive and deep due diligences, mainly due to the fact that multiple minds will be focused on project implementation.

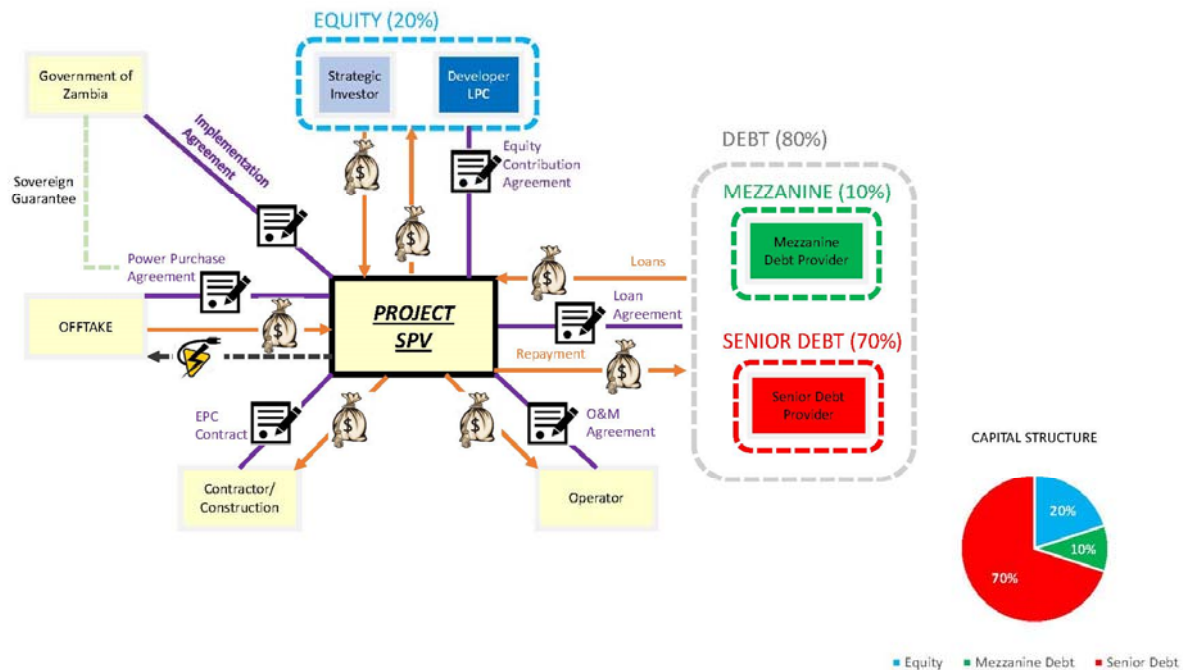


Fig. 6 – Project Finance Structure of Lufubu

6 – Conclusions

The scheme of Lufubu cascade with its 1284 GWh/y and 326 MW (Phase 2) represents one of the most important opportunities for development in the north of Zambia. The project, promoted and financed by a private company, has already received governmental approvals and is now at a negotiation stage for the Implementation Agreement with the Zambian government and Power Purchase Agreement with ZESCO, the national utility. The potential EPC contractors have already been prequalified and construction is expected to start in 2017.

The Authors

Antonio Brasca is a civil engineer and specialist in the design of large dams and hydropower plants with Studio Pietrangeli, Rome, Italy. His 20 years of professional experience include design and construction supervision of numerous dams and hydropower projects in Italy, Ethiopia, Zambia, Tanzania, Malawi, Sierra Leone and other African countries. Currently he is the chief designer and project manager of Lufubu HPPs hydropower cascade.

Stefano Galantino is an electrical engineer and specialist in hydropower developments with Studio Pietrangeli, Rome, Italy. His 13 years of professional experience include the design coordination and construction supervision of numerous hydropower Projects and HV transmission systems projects located in Italy, RDC/Rwanda/Burundi, Zambia, Zimbabwe, Sierra Leone, Ethiopia, and other African countries. He is presently the transmission system design coordinator for the Lufubu Project.

Fabio Vulpiani is a mechanical engineer and specialist in the design of hydropower plants, who joined Studio Pietrangeli, Rome, in 2011. His professional experience includes design coordination and construction supervision of the hydro-mechanical and electro-mechanical equipment in a number of large implementation hydropower projects located in Italy, RDC/Rwanda/Burundi, Zambia, Zimbabwe, Sierra Leone, Ethiopia, Jordan, Jamaica, Bosnia Herzegovina, Georgia, Tanzania and Malawi. His expertise also covers economic and financial studies for hydropower projects. He is presently the hydro-mechanical design coordinator for the Lufubu Project.

Aaron S. Nyirenda is an electrical engineer, who is presently Project Manager of the Lufubu Power Company. He covered the positions of Project Director of the Kariba North Bank Extension Project (2x180 MW) which was recently commissioned. Mr. Nyirenda has also been ZESCO's Project Manager for the rehabilitation of the major power generation plants, a Senior Manager for Generation and Transmission Development, a power station manager of the 900 MW Kafue Gorge Power station in Zambia. Mr. Nyirenda is a member of the Engineering Institution of Zambia (EIZ).