POWERCHINA'S PRACTICES FOR HYDROPOWER IN AFRICA

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1. INTRODUCTION

POWERCHINA, as one of the world's largest power and energy generation designer-constructor, it is incumbent upon POWERCHINA to focus upon utilization of appropriate design and construction measures during project implementation to optimize the design, ensure construction quality, shorten the construction duration to the extent possible and to minimize construction costs while paying attention to protect the environment, undertake and fulfill social responsibilities, facilitate capacity building through long-term technology transfer including indigenous African personnel training of the host countries.

2. DESIGN

Design is the premise and foundation of hydropower project construction for ensuring project quality, ensuring progress, environmental protection and cost savings. Hydropower stations in different countries and locations have different characteristics and it is necessary to choose the appropriate design and features based on the project's topography, geology, hydrology, material acquisition and cost.

POWERCHINA's focus is to meet or exceed the Contract and Employer specified requirements - expectations including environmental and social responsibilities. The project design is determined-developed with design processes and procedures which are compliant with Chinese and generally accepted international practices. The plan includes the following considerations:

- Design compliance with Chinese and generally accepted international practices,
- Adoption of relevant codes and standards,
- Adherence to formal design processes and procedures,
- Identification and formalization of project funding,

Development of the Project Basic Design followed by detailed design criteria, calculations, mathematical and actual reduced and full-scale models particularly for hydraulic operational performance, mass concrete structure-spillway structural and thermal design performance.

- High-quality of work performance,
- High-standard Quality Assurance and Quality Control (QA/QC) procedures,
- Design that best ensures Project "scheduled completion implementation".
- Competitive Contract Price,

The Project Feasibility Study(FS) of technical – economic – environmental parameters is subject to Governmental regulatory and Employer acceptance. The FS effectively represents "near-to-final" design, construction planning and scheduling. Typically, the FS better ensures design and construction with latest, approved for construction, Project requirements.

The "starting activities" are primarily those of consultation, review and updating of the Project Feasibility Study, i.e., technical and economic/financial requirements, and the ESIA, i.e., Environment and Social Impact Assessment.This work will include identification of supplemental subsurface-geotechnical-geological, hydraulic and other investigations as may be required for preparation of the Basic and Final Designs including updating/refining of the design and construction planning schedule and estimated costs. The FS typically represents the basis for preparing and issuing of tender project documentation.

Where appropriate, and with the acceptance of the Project Employer, "state-of-the-art" design and construction techniques are adopted with the focus upon maximum utilization of PowerChina'sglobally experienced construction management and personnel, modern construction equipment, and maximize the use of available indigenous resources.

By the nature of hydropower development, to avoid political and public criticism, the development must strictly adhere to not only technical and economic conditions, but also environmental and social requirements to ensure compliance with, and support of, the regulatory authorities Contract, Employer, and environmental, ecological - social requirements.

Once the hydropower project is commissioned, long-term operation and maintenance will commence. At this stage, the transfer of design, construction, project information and data including operation and maintenance manuals, formalization of operational process and procedural techniques will be required and therefore these must be prepared for timely.

Design optimization of hydropower potential includes: thedetermination of the proposed installed power and generation capacities, confirmation of spillway design floods after a comprehensive analysis of the latest hydrological information and data, finalization of project design, layouts and arrangements. The design must take into consideration the influence upon the project of upstream and downstream transmission-transmission systems including parameters and characteristics thereof as well as topography, transportation infrastructure, land-usage, land utilization, residents, social infrastructure etcetera. Numerous multi-disciplinary professionals and experts are involved in the design process including those of the Governmental and Regulatory Authorities and Employer. The project's influence and impact upon communities, businesses, etcetera must be assessed before confirmation of Project final design characteristics and parameters.

For generation transmission and distribution, the design must ensure Project compliance with the regulatory authorities, specified current and future load demand, transmission and distribution, reservoir, and river technical and environmental management.

Some POWERCHINA case studies are provided herein.

2.1 Rock-Fill Concrete, Self-Compacting Concrete of Zongo-II Hydropower Project in Democratic Republic of the Congo (DRC)

The DRC is rich in hydropower potential but deficient of actual hydropower generation capacity. The ZongoII hydropower station is located in the Lower Congo Province. The dam length is195m, maximum dam height is 22.8m, and the installed capacity is 150MW. The length of the diversion tunnel is 2544m. Construction implementation commenced in 2015. The project was financed by the Export-Import Bank of China.

Although good/sound quality of rock is available in sufficient quantities within proximity to the site for the production of quality concrete construction aggregate, cement supplies are limited and must usually be imported. To optimize and expedite construction, including control of dam concrete placement (and monitoring compliance with maximum concrete curing temperatures), the following measures are typically undertaken: optimization of dam type selection, dam and conventional structural design, optimization of concrete mix constituents, introduction of innovative construction methodologies, for design of the rock-fill concrete dam.

The Zongo II design is the first application of a rock-fill concrete dam in Africa.

Due to cement and admixtureshortages, the mixing ratio of self-compacting concrete was studied and eventually adopted. Through innovative, theoretical and practical research, the concrete mix ratio of reduced admixture concrete, fine aggregate concrete was ultimately determined with a maximum aggregate size of 12.5mm. The concrete mix was found to have good/sound engineering and placement characteristics and performance, including anti-segregation, thereby better ensuring the self-compacting effect of the concrete.

Through laboratory and production tests, comparative studies were carried out on the grain size and optimal thickness and dimensions of concrete placements. For required compaction, an aggregate size of 20-50cm and a placement layer thickness of 60cm was adopted.

To meet the requirements of temperature control, and to ensure construction quality and improving construction efficiency, the following measures were adopted; support forms used stone-block formwork delivered using dump trucks and handling with backhoes,gantry crane for stone-laying and fine aggregate concrete placing, concrete curing using water sprinkling of placed works, continuous placement of rock-fill and concrete materials.

2.2 The Application of "Goose-shaped Plates"for the Powerhouse Roof of the Imboulou Hydropower Station in the Republic of Congo

The principle function of the Imboulou Hydropower Station is to be the cornerstone of peak regulation, transmission frequency modulation. The power station has a total installed capacity of 120MW with an annual generation capability of 685 million kWh.The length of the powerhouse including the erection bay is 128.4m.

The powerhouse and erection bay adopts a goose-shape plate roof structure.The goose-shaped plate is a concrete structure comprised of beam and plate elements developed based on "V-shaped" slab designed to support relatively large external roof loads.The plate functions as a spatial framework with excellent performance properties, and with characteristics of small volume, short construction period, and relatively lower cost compared with other concrete roof structures.

The advantages of this structure are:

(1) At the commencement of the Imboulouproject, the powerhouse roof was designed as metal surface cladding with a steel support structure. The roof are 167t steel frame and 295m3 concrete. By using goose-shape plates, the total quantity of concrete is 279m3 and the steel reinforcing bars is 43t.

(2) According to the initial project schedule, the construction duration for the roof with an integral steel support structure was 218 days. With the goose-shaped plates, the construction period was reduced by nearly 7 months.

2.3 The Application of Rectangular Gallery in Souapiti HydropowerProject in Guinea

The Souapiti Hydropower Project is located within the midstream of the KonkouréRiver in Guinea. The reservoir'stotal capacity is 7.489 billion cubic meters. The powerhouse installed capacity is 450MW.The dam is designed as an RCC gravity-type structure with a length of 1164m and a maximum height of 120m.

Within the RCC gravity dam, a three-level grouting gallery with regular transverse ventilation galleries is provided thereby dividing RCC placement into multiple areas. The gallery is rectangular shaped with prefabricated concrete slabs.

3. CONSTRUCTION

The main POWERCHINA construction management processes and procedures include, but are not necessarily limited, to:

Compliance with Contract, Employer and ESIA (Environmental Social StudiesImpact Assessment) specified conditions and requirements,

Scheduled construction planning and scheduling in compliance with the Contract,

Utilization of latest construction methodologies, processes and procedures with particular attention to construction techniques, and selection of construction equipment,

EPC Contractor focus upon for QA and HSE,

EPC Contractor is generally required, as appears to be the current global trend, to be fully responsible for all conditions foreseen/unforeseen, anticipated/non-anticipated et ceterawhich can adversely influence the Contract Price,

Local market construction resources: skilled/unskilled labor, availability of project materials and construction equipment,

Innovation and utilization of latest proven international and generally accepted construction technologies, methodologies and practices,

Compliance with international codes and standards, and if used, Chinese codes and standards which can be demonstrated to be effectively equivalent,

Capabilities for providing/arranging project funding and/or buyer's credit,

3.1 Construction Methodologyof Busuanga Hydropower Station in the Democratic Republic of Congo

The Busuanga Hydropower Projectis on the Lualaba River in the southern area of the Democratic Republic of Congo, adopts a double curvature arch dam,which is the highest thin arch dam in Africa. The maximum height of the dam is 141.5m. The dam body is of RCC construction with a total RCC quantity in the order of 420,000 m^3.The total installed capacity of the power station is 240MW.

The project's river closure scheme takes full advantage of the site's natural topographical conditions within arelatively narrow, steep-sidedgorge section. The closure section is between the dam site and the intake of the diversion tunnel. According to the hydrological characteristics of the low runoff of the Lualaba River in August, the directional blasting for, and filling of, the cofferdam was adopted for river closure.

The is of RCC construction with parabolic hyperbolic arch curvature. The curvature of the dam body along the vertical and horizontal directions changes continuously which requires the formworkto be capable of movement/adjustment within a predetermined tolerance for vertical and horizontal orientation. This arrangement achieves the requiredscheduled, relativelyquick and efficient relocation/adjustment turnover of the formwork. The formwork sections are 2.7m long and 1.8m high whichare capable of folding instead of bending, A joint plate allows for 30mm horizontal adjustment tolerance to address the designs "V" and "inverted V" shaped openings. The formwork design ensures the achievement of the specified alignment tolerances.

This project adopts a computerized-digital system to support construction. This system permits a variety of activities including project management, internet access. The system was found to ensure betterand improve the quality of concrete construction while improving management efficiency.

The optimum RCC mix considers natural riverbed and from quarried granite for concrete/RCC construction aggregate. Laboratory and field testing determines the minimum cement content, concrete transport slump loss in the high-temperature area, cement hydration speed and rate of heat release, the effect of internal placement plus hydration and ambient temperature during concrete setting and curing. With this system, a centralized overview of data is available for the whole dam during construction period. The system allows for the real-time collection, input and manual analysis of dam internal temperature distributions.

3.2 Embankment Methodologyof Uganda Isimba Dam

The Isimba Hydropower Station Projectin Uganda is a run-of-river hydropower project located in southern Uganda. The dam length is 1625m. The total installed capacity is 183.2MW capable of an average annual generation of 1.039 billion kWh. The project arrangements include concrete gravity dam, clay core rockfill dam, spillway andpowerhouse. The project was financed by the Export-Import Bank of China.

The site of the IsimbaProject has special geological conditions that require meticulous attention. The clay is generally interwoven with gravel and volcanic rock crust. The available clay material layer has an uneven thickness which leads to excavation difficulties including relatively high surface stripping ratios. The design incorporates anti-seepage earth material with a hard-shell mixture as a core wall of the embankment dam.

The methodology for embankment construction filling is to place sand first and soil later. For the fine filter material, a pre-made paving machine is used for the filling-levelingprocess. The methodology accelerates the embankment filling progress while reducing cost.

3.3 Construction of RCC in Ghana Bui Hydropower Station

The Bui Hydropower Project is located at the intersection of northern Ghana and Côte d'Ivoire, on the Black Volta Riverwith 150 km upstream of the Volta Reservoir. Bui is the second-largest hydropower station in Ghana.

The Bui project is an RCC dam with a length of 492.5m and a maximum dam height of 114m. The Project's total installed capacity is 404MW. The project was financed by the Export-Import Bank of China, of which 45% was preferential buyer's loan, 45% was export buyer's credit, and 10% was funded by the owner. It was the largest loan project provided by the Chinese government in Ghana at that time.

During the RCC construction, POWERCHINAused technologies for conveyance and placement of RCC in sloped lift-layers.

Concrete was delivered directly to the construction placing area through pipes. The placement layers were compacted continually without interruption. The quality inspection during and after the construction showsthat the construction quality of Bui isgood. The connection of the RCC layers is good, and the seepage through the dam bodyis far less than the specification.

Ultra-long-distance belt conveyorto transport concrete from the batching plant to the point of placement. During the period from January 2012 to May 2012, a total of 58,275m3 of RCC was transported and placed without segregation.

3.4 Zungeru Hydropower Project, Nigeria

The project is located in Niger State in central Nigeria, 150 kilometers awayfrom Abuja, the country's capital. The installed capacity is 700MW. It includes barrage dam, water inlet, dam body spillway and stilling pond, dam-toe powerhouse and tailrace. The dam is designed with RCC gravity dam in the middle and core wall rockfill dam on both banks, with a total length of about 2400m.

The cost of the rockfill dams is lower than that of RCC gravity dam. Tractebel, the Employer's consultant, maximized utilization of the rockfill dam section while minimizing the length of the RCC section. The final design is for a 1090 length of RCC dam section with a maximum dam height of 90m.The left bank rockfill dam is 325m longwhile the right bank is 1000m long.

The dam is of RCC gravity. The rockfill embankments have an asphaltic concrete core. The maximum height of the joint between the asphaltic core and the RCC dam is 78m. This height was unprecedented at the time of the design-construction.

3.5 Integration of Design and Construction

POWERCHINAownsseven (7) hydropower design institutes allowing POWERCHINA to organize in-house design teams and consistently develop optimalsolutions for design and construction.

4. PRINCIPLES OF ENVIRONMENT PROTECTION

Sharing the same objectives of theworld's Sustainable Development Goals (SDGs), POWERCHINA has taken various and continual measures to extensively protect the environment and ensure achievement of sustainable development goals.

4.1 Main environmental protection measures for Guinea's KalétaHydroelectric Project in The Republic of Guinea

(1) The project was heavily dependent upon local resources. The original bifurcation, confluence, waterfalls and river vegetation were preserved so that the land surface areafor the Project could be reduced significantly by 180,000 m^2.

(2) During the construction period, a self-contained mini-hydropowerstation was provided thereby reducing reliance upon diesel generation. Mini-hydro generation totaled some 21 million kWh replacing relatively expensive and polluting diesel generation.

(3) Unnecessary deforestation was strictly controlled in conjunction with a reforestation rate of 92%. When accompanying the President of Guinea on a site visit, the Organization for the Development of the Sénégal River gave high praise for the environmental protection works.

4.2 Reduction of Production and Emission of Pollutants in of the Bui Hydropower Station Project in Ghana

The project adopts dry production screening and desilting process which results in zero wastewater dischargewith sand and gravel. All dust produced in the system is collected and treated.

The system was equipped with dust collection to reduce cement and fly ash dust air pollution. The cooling water of the cooling system was recycled. Discharge wastewater wastreated through precipitation processes.

Water quality ofthe upstream reservoir, downstream and construction camps and living areas were monitored to ensure absolute minimization of any potential for water pollution accidents during the construction period.

For the borrow area,full considerations of local vegetation and selected plants were carried out. Borrow areas were reinstated upon project completion including quarry areas. Bare soil areas were covered completely with topsoil and green vegetation integrated with the surrounding environment.

4.3 Ecological Protection Work of Karuma Hydropower Project in Uganda

The normal water level of Karuma hydropower station wasdesigned as 1030.00m with the reservoir areaextending35km upstreamof the dam. The levels do not affect Nile River at the outlet of Kioga Lake. Stable river flows are ensured for power generation and during design floods.

The underground power complex minimized impacts on the environment. The powerhouse, along with generator sets, large transformers, GIS equipment, etceteraare located underground within a cavern of 80m below the ground surface. Two (2)tailwater water with each 8.5km in length, and various turbine-generator unit tunnels, are underground when within the surface limits of the national park thereby ensuring minimum impact on the animals and plants in the national park.

Fish ladders were built to facilitate fish migration upstream and downstream of the Project. Furthermore, a gate-control flow outlet was provided to ensure that a minimum ecological discharge of 100m3/s is maintained all time to support the diversity of aquatic life downstream of the project.

4.4 Active Communication with International Organizations

POWERCHINA actively cooperated with International Rivers, a Non-Governmental Organization(NGO) for related assessment activities focused upon environmental and social policies and also the practices of Chinese overseas hydropower constructors.

In 2015, International Rivers released the report of " Benchmarking the Policies and Practices of International Hydropower Companies STAGE 1: ENVIRONMENTAL AND SOCIAL POLICIES AND PRACTICES OF CHINESE OVERSEAS HYDROPOWER COMPANIES" through the International Hydropower Association(IHA) held in Beijing. In the evaluation of policy commitment and project practice, POWERCHINA ranks first among the seven state-owned hydropower enterprises in China

5. SOCIAL RESPONSIBILITY

Based upon the 17 sustainable development goals(SDGs) of the United Nations 2030 Agenda, POWERCHINAregards "Integration into Local Economic and Social Development" as an essential and strategic strategy.

POWERCHINA actively provides solutions to support local economic and social development.POWERCHINAalso established the Overseas Volunteer Association of in 2017which organizes voluntary participation of employees.

POWERCHINA also organizes global volunteer service activities on dates such as December 5, the United Nations International Volunteer Day including actively participating in localized services. This involvement integrates POWERCHINA into local public governance networks. Overseas volunteerspracticeglobal corporate social responsibilities.

Under the concept of "win-win cooperation", POWERCHINA promotes its overseas volunteer organizations to establish cooperative relations with international organizations, public welfare institutions and Chinese overseas organizations.

In Beijing, the association established relationship with the Beijing Volunteer Service Federation andjoined the "Belt and Road" volunteer service alliance supported by the project of "Strengthening China's Involvement in the Development of International Volunteer Service through South-South Cooperation and Belt and Road Initiative". This is supported by the United Nations Development Program (UNDP) and the volunteer organization (UNV) in China.

POWERCHINAhas launched three actions:

(1) "Technology for Life" aims to take advantage of technology and engineering, and support public welfare planning, popularization of science and technology, vocational education, rescue and relief, standard promotion and other service activities.

(2) "Green for Future" aims to solve the ecological problems brought by projects, and to realize the effective protection of the environment.

(3) "Love for World" aims to establish a better relationship with local communities and promote harmonious development through public welfare activities such as supporting for education, medical, public welfare organization service, community service, and maintenance for infrastructure.

Volunteers from the Soubre Hydropower Station Project Department of POWERCHINAactively helped local people build bridges and roads, expand waterworks. Volunteers have also been organized to care for orphans, needy and vulnerable children in local schools and institutions.

In 2017, Indonesia volunteers of POWERCHINA carried out the premature child-care action, in cooperation with the Indonesian Premature Association and the University of Indonesia. Hands-on support and donations of 50,000 dollars were made to the University of Indonesia for the research, development and manufacturing of the incubator for premature babies, which will benefit thousands of families.

6. CONCLUSION

In the process of the construction of African hydropower projects, POWERCHINAgives full play to the advantages in design and construction. Provides solutions to shorten the construction period and reduce the cost under the condition that the quality meets the requirements, so as to provide the upmost support for the owners. At the same time, according to the policy of company, POWERCHINA also does a good job in environmental protection, contribute community and sustainable development.