Rehabilitation and completion works at Bumbuna Falls HEP:

a case history of interrupted and continued implementation activities

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Introduction

Rehabilitation and completion works of the Bumbuna Falls HEP in Sierra Leone required the solution of uncommon technical problems in planning and execution due to the peculiar starting conditions of the Plant and to the complexity of the works that were required. In the context of rehabilitation works in the hydropower sector, relevant experience was gained from activities such as: a) the complete rehabilitation of the deteriorated asphalt concrete face of the dam; b) the repair of damaged tunnel linings; c) the rehabilitation of the right bank gate control structure and equipment; d) the rehabilitation of main and auxiliary mechanical and electrical equipment, damaged during a relatively long period of abandonment and e) the development of monitoring systems and safety programs specifically tailored to the needs and characteristics of the Project.

The Paper presents an overall description of these rehabilitation and completion works; specific aspects of the rehabilitation of civil structures and main equipment with emphasis on assessments, criteria, specifications and construction methods; procedures for monitoring and dam safety control; and conclusions drawn from the Bumbuna case.

1. Background

The Bumbuna Falls Hydroelectric Project (Phase 1) is the first stage development of the hydropower potential of Seli River in Sierra Leone. It is the first major hydropower development in the country's history and is the main reliable option to reduce the country's fuel importation dependency. The hydropower plant is located on the Seli River, some 200 km northeast of the capital city Freetown (see Figure 1). Main Project components are a hydroelectric generation scheme at Bumbuna Falls with a first phase installed capacity of 50 MW and a 161 kV transmission line, 200 km long, connecting the power station to Freetown.

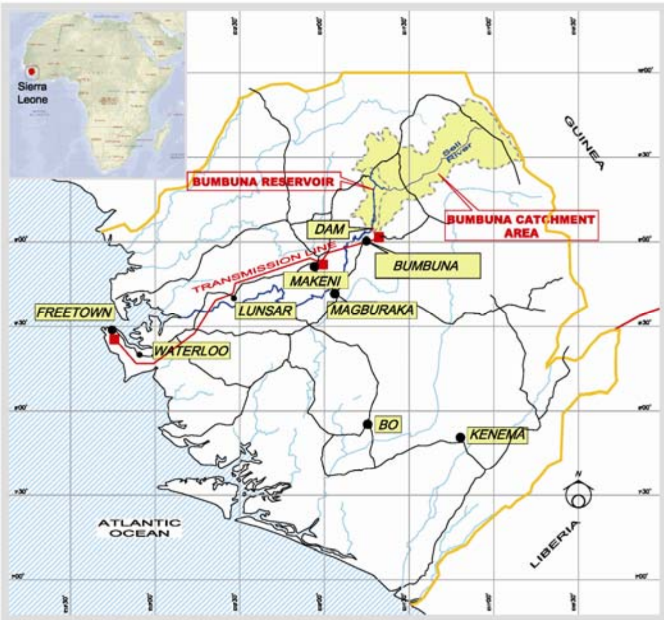

Figure 1-Location of the Bumbuna Falls Project area.

The Bumbuna Scheme was identified as a favourable hydroelectric development source in 1970. In 1980, a feasibility study by the World Bank, predicted a potential energy production of about ten times the requirement of the central part of Sierra Leone and staged implementation of the project was recommended. In November 1983, a further economic review resulted in the decision to investigate the possibility of a scaled down version of the Bumbuna Plant (Phase 1 of the Project) and to carry out further feasibility studies. The results reported in July 1984 demonstrated that substantial savings would be achieved by modifications of the previous layout and that Project phasing would not compromise later stage full-scale development of the generation potential of the Bumbuna site.

Main implementation activities of the Project, including the construction of civil works and procurement of electrical and mechanical equipment, started in the early nineties and reached an estimated 80% degree of completion in May 1997, when they were interrupted by the Civil War in the Country.

In March 2004, after an interruption of 7 years, construction activities were retaken starting with an assessment of the state of the civil works and equipment as well as the reinstatement of site, camp and plant facilities. Among other questions involved, the assessment included the detailed consideration of safety and reliability aspects of the executed civil works and the state of equipment at the Bumbuna site.
The generally positive result of this assessment resulted in the decision taken by the Government of Sierra Leone, the Owner, to proceed with Project rehabilitation and completion, the main object of this Paper.

A Dam Safety Review Panel (DSRP) appointed by the World Bank, has carried out two meetings at site on 2004 and 2007 in order to evaluate the quality and safety of works prior to and after rehabilitation. The DSRP concluded that the works comply with safety and operation reliability criteria and gave recommendations on the monitoring and safety programs to be implemented for the first Reservoir impoundment operation.

2. Project characteristics

In its final design the main component structures of the Bumbuna Falls power station (see Figure 2) are:

Main Dam- asphalt concrete faced rock fill dam across the Seli River. The dam has a volume of 2.5 million m^3, maximum height of 88 m and crest length of 440 m. The asphalt concrete facing membrane covers an area of 51.000 m^2 and is composed by three layers: a) upper, consisting of a 9 cm thick impervious membrane; b) intermediate, consisting of an 8 cm thick regulating layer; and c) lower, a bedding layer with a minimum thickness of 8 cm.

Figure. 2-Aerial view of the Project Site.

The Reservoir created by impoundment has a surface area of 18 km^2 at max. operation level and a volume of about 420 hm^3.It is Y-shaped, with a 30 km long main branch and two secondary upstream branches 7 km and 11 km long. The main branch width varies between 200 m and 1000 m.

Left Bank Structures- include a diversion tunnel combined with a vertical non-gated shaft spillway and terminal flip bucket. The tunnel bypasses the dam on the left bank, is 620 m long and has a diameter of 9 m. The left tunnel, used as diversion facility during the construction period, will also be used to spill frequent floods during the operation period. It has design capacity of 1500 m^3/s.

Right Bank Structures- include a diversion tunnel combined with an intake tower structure, a vertical ungated shaft spillway, a gate controlled outlet structure and off-takes for the turbine discharge. The dimensions of the right tunnel are similar to those of the left one. This tunnel also has been used as diversion facility during phases of the construction period. It will serve as an auxiliary spillway for flood discharges above 1000 m^3/s. During the plant operation period, this tunnel is used as headrace waterway connecting the intake structure to the powerhouse.

The tunnel intake arrangement consists of a hexagonal shaped tower structure, 93 m high that includes six inlet sluices protected by trash racks, a drop mouth entrance and a vertical shaft. A 7.5 m diameter cylindrical gate is installed in the tower in order to allow the closure of the inlet and permit the tunnel emptying for inspection purpose.

At the downstream end of the tunnel, a 7.4 m x 7.0 m radial gate is provided in order to enable the operation as Power tunnel. This gate will normally be closed during plant operation and will be automatically opened, when necessary, to release exceptional flood discharges. During such rare events, powerhouse operation has to be interrupted.

Powerhouse- semi-outdoor powerhouse located on a platform downstream of the dam, adjacent to the right tunnel. It houses two 25 MW capacity vertical-axis units, consisting of Francis turbines coupled with 3-phase synchronous generators. Rated speed is 333.3 rpm. The Powerhouse arrangement also includes assembly and auxiliary services areas, a control building and an auxiliary generator building. A 115 ton capacity gantry crane is provided for equipment assembly and maintenance purpose. .

Bumbuna Substation- located adjacent to the powerhouse with two step-up transformers; connected to the transmission line to Freetown.

Transmission Line–a single circuit, 161 kV line, interlinking the Substations in Bumbuna and Freetown The line is 200 km long, equipped with 400 mm^2 ACSR conductors. The Line includes a special provision to supply electricity to Makeni, a major city along the transmission route at 42 km distance from Bumbuna.

Freetown Substation - located near the existing Kingtom thermal power station to facilitate the connection of the hydroelectric supply from Bumbuna to the existing distribution network in Freetown. The substation is equipped with 2 three-winding step-down transformers rated at 161/15/34.5 kV.

3. State of main project components at the end of the interruption period

3.1 Introduction

The Engineer and the Contractor have jointly carried out assessment activities, including field inspections, tests and detailed inventories in order to assess the prevailing state of civil works and equipment after 7 years of interruption of implementation activities. These assessment activities, reported at the beginning of 2005, characterized the extent of damages and enabled the preparation of cost estimates, construction and procurement schedules and specifications for the rehabilitation and completion works. Main relevant aspects of the assessment are presented in the sequence.

3.2 Asphalt concrete dam facing

At the time of the interruption, the first two layers had been completed, while the placing of the upper impervious layer was still in progress and an area of 6800 m2 had yet to be completed. Placing of the sealing coat had not commenced yet. During the period of interruption, the dam face remained directly exposed to weather conditions and thermal stresses without the sealing coat protection and the temperature mitigation effect of the impoundment

Visual inspection showed the occurrence of fissures, cracks and ripples in extensive areas of the upstream face corresponding to about 35 % of the total surface.
A detailed survey was carried out in order to classify areas affected by different types of ageing phenomena, as follows:

- Cracks – Large and deep cracks crossing the entire impervious layer, or penetrate deeper than half of the layer thickness were detected over an area of about 1000 m^2. Repair works were considered necessary to restore the functionality of the lining in these areas
- Fissures - Fissures penetrating less than 2 cm into the layer were detected over an area of about 15000 m^2. Repair works were also deemed necessary to assure the long term performance of the lining in these areas
- Superficial Fissures – Patterns of surface fissures were present over almost the entire dam facing. In these areas the treatment could be restricted to the application of the sealing coat.

Figure 3-Impervious facing at the end of the interruption period

Laboratory tests were carried out on cores drilled in the impervious facing in order to verify material properties after exposure to ageing action. Test results showed a slight deviation of the mix used with respect to the optimum design studied at the time of construction. In particular, the filler content resulted about 2% higher whereas the bitumen content was low but within the accepted limits. Bitumen characteristics were found to comply with the limits of standards and a medium to low adhesion behaviour between bitumen and aggregates was shown by the adhesion tests.

On the basis of results of the site inspections and the laboratory tests, the following causes for the impervious membrane quality decay were identified:

- ageing phenomena of surface-level bitumen (oxidation, hardening, loss of adhesion) due to long term exposure to air and sunshine without a sealing coat protection,
- high temperatures reached by the lining due to direct exposure to sun radiation without the mitigation effect of an impoundment.

It is also likely that, in the areas where major fissures were observed, the quality of the impervious layer was inferior to that of other parts of the lining due to different placing and compaction conditions or other reasons related to the mix characteristics (performance of anti-stripping agent, filler-bitumen ratio, etc) causing the acceleration of the ageing phenomena and the occurrence of deeper fissures.

3.3 Right and Left Tunnels

The extended use of the right and left tunnels for diversion purpose (1992 – 2004) has resulted in similar erosion phenomena in the concrete lining of both tunnels. The main types of erosion occurrences observed during site inspections can be classified as follows:

- Deep erosion - The occurrence of intense erosion effects in the invert zone was observed in both tunnels. Affected areas, extending over the entire tunnel length and a 2 to 4 m wide strip in the invert zone, are indicative of erosion mainly caused by sediments transported by the flow during the diversion period. The maximum erosion depths observed in different sections ranged from 2 to 12 cm. In some locations, steel meshes and reinforcement bars were exposed and damaged. The occurrence of deep holes with depth ranging from 10 to 25 cm was observed near the steel lined sections and in locations where steel reinforcements were destroyed.

Figure 4-Erosion along tunnels invert zones

- Superficial erosion - Areas characterized by shallow erosion occurrences had not been subjected to any perceivable geometric change but, due to the uncovering of aggregates, presented an increased roughness ranging from 2-3 mm to 7-8 mm Furthermore, leakage paths were detected in several zones, especially in the areas corresponding to the construction joints.

3.4 Control Gates and Steel Lining

Most of the steel components and gates were installed before the interruption of activities and had not been removed since their installation. Other non-installed metallic materials, hydraulic and mechanical components supplied to the site were stored under severe exposure conditions and remained unattended during the period of interruption.

In particular, the Right tunnel steel linings were in place, with the exception of the intake elbow. The installation of the cylindrical intake gate had almost been completed, whereas trash racks and rakes still needed to be installed. The radial gate had been installed, waiting for the installation of the emergency operating system. The steel lining of the left spillway had only been partially installed and embedded.

Following the results of the assessment activities, it was concluded that the hydraulic equipment such as rams, pumps and valves, were not in bad condition and could be maintained and refurbished at site, whereas the majority of the electric motors, mechanical gear boxes and lifting mechanisms needed to be replaced as the adverse weather conditions of recent years of exposure had resulted in accelerated deterioration. The majority of the hydraulic components seals and PLC device batteries had also to be replaced. The electronic control systems of the radial control gate and the cylindrical intake gate control had to be replaced in order to ensure their proper functioning.

3.5 Electro-Mechanical Equipment

At the time of the interruption, only the two draft tubes and the 115/15 tons gantry crane had been installed. The major part of the Electro-mechanical equipment and materials were supplied and stored at site, during the period of interruption of works, under highly inadequate conditions and were moved without proper control. Parts of the supplied materials were missing or had been severely damaged. The packaging of auxiliaries and accessories was often found broken, the wooden crates and aluminium foils eaten by rodents or damaged by adverse weather conditions.

The main parts of the generator supply (4 half stators, two rotors, two upper brackets) were poorly stored in a grain storehouse at the Freetown Harbour and the bulk of the parts were stored in the Contractor's Warehouses at the job site.

The 2 step-up transformers for the Bumbuna substation were found in the substation yard, without nitrogen gas or oil. The 2 spiral casings of the turbines were also found in an open space near the Power House. Also one turbine runner and the Generator shafts were stored outdoors in boxes under very poor conditions.

3.6 Transmission Line

Transmission line construction had almost been completed at the time of the interruption of works. The majority of the equipment had been destroyed during the interruption period. Structures, such as steel towers, bolts, nuts, and electrical equipment, ASCR conductors, insulators and supports, were accessible to local population. In some cases, materials such as aluminium, porcelain and steel were re-used for other purposes.
Consequently, a large number of towers needed rehabilitation works or had to be replaced. Furthermore, a large quantity of conductors also had to be replaced (about 450 km) together with insulators, plates and dumpers, as these had either been stolen or severely damaged.

4. Rehabilitation and completion activities

4.1 General scope

Rehabilitation and completion of civil engineering structures and electro-mechanical equipment/installations required the following specific activities:

- **Civil works-** repair of the dam asphalt concrete facing; repair and surface treatment of concrete and steel structures; repair of tunnel linings; slope stabilization works; completion of concrete and metallic structures notably in the powerhouse area; and miscellaneous complementary works.
  These construction activities are the general responsibility of the Main Contractor, Salini Costruttori, Italy, with the support of specialized sub-contractors.
- **Electro and Hydro mechanical equipment-** inspections; rehabilitation of equipments including gates, hydro-generators, transformers, hoisting equipment, auxiliary equipment; rehabilitation of installations; additional procurements of equipment and assembly activities.
  These activities are under the general responsibility of the Main Contractor and included participation of the original Suppliers complemented by other specialized Manufacturers.
- **HV Transmission Line and access road-** rehabilitation of the access road; erection of collapsed towers; replacement of missing or damaged steel elements and other components; and rehabilitation of the step-down substations at Freetown and Makeni. These activities are under the general responsibility of the Contractor, SAE Power Lines, Italy.

Important aspects of the completed rehabilitation and completion activities are reported below.

4.2 Schedule

The rehabilitation of civil works, equipment and installations implemented before the interruption of construction activities, as well as the completion of civil construction and equipment assembly, started in August 2005 and are presently reaching completion.

Figure 5-Rehabilitation and completion works in the Powerhouse and Substation area

These activities aim at the Impoundment of the Reservoir starting in December 2007 and completed in June 2008.

Due to financial constraints, mobilization for the rehabilitation and completion of the H.V. Transmission Line activities only started in July 2007 and their completion is planned for June 2008. Plant operation is expected to start in July 2008.

4.3 Asphalt concrete facing

The impervious facing was completely rehabilitated by a sequence of operations that included:

Figure 6–Rehabilitation works of the asphalt concrete facing

- Milling the face surface to a depth of 3 cm, except in the zones where the upper layer had not been completed before interruption. The minimum thickness of 3 cm was considered a suitable average value based on samples cored in the areas where the effects of the ageing phenomena were more noticeable.
- Rehabilitation works along the cut-off wall by replacing damaged copper foils and removal of vegetation (e.g. roots).
- Cleaning of the entire milled surface from debris, oil patches; drying and application of an emulsion (tack coat) by spraying, in order to ensure an effective bond between the old and the new impervious layer.
- Execution of a 300 m² area trial facing and testing
- Placement of the impervious lining in the areas that had not been executed before the interruption of works.
- Placing of a 6 cm thick impervious layer over the entire face area and protection by a seal coating to prevent against ageing effects

4.4 Right and left tunnels

Repair works carried out in the tunnels had the objective to restore design geometry and finishing of the areas subjected to erosion. Rehabilitation works methodology was defined following the detailed investigation in both tunnels and tailored to meet the specific state of the concrete lining. Construction made use of pre-packaged high performance mortars.

Repair works for the different types of erosion included:

Deep erosion (surfaces with irregularities greater than 4 cm) – deep erosion occurred mainly in the invert zones. The following technical guidelines were adopted for the treatment of such occurrences:

- Minimum 5 cm deep cut- out and removal of the concrete by scarification down to 2 cm below the pre-existing reinforcements.
- Cleaning of base surfaces requiring an overlay by high pressure water jets to enhance bonding
- Brushing of reinforcements to eliminate adhered concrete, rust and oxidations.
- Where the existing reinforcements were eradicated, the bars have been replaced
- Use of a mix consisting of sand, cement and synthetic resin emulsion as bonding agent

- Control of potential shrinkages by use of very low w/c ratio repair concrete. Use of welded wire mesh in order to reduce shrinkage potential

Superficial erosion (surfaces with irregularities between 5 mm and 4 cm) – surface erosion occurred mainly along the sidewalls. Repairs were carried out based on:

- Cleaning of eroded surfaces using water jets at operating pressures of 200 bars, in order to remove eventual loose material and eliminate oil and grease as well as organic and inorganic deposits.
- Wetting the cleaned surfaces up to complete saturation, one day prior to mortar application; removal of excess water by compressed air jet a few hours before the application
- Use of a pre-packaged fibre reinforced and shrinkage free mortar, applied to the prepared surface by a flat trowel. The high strength (40 MPa) characteristics of the mortar, along with the proper preparation of the surface were considered necessary to secure the required bonding and resistance of repaired parts.

Figure 7-Tunnel rehabilitation works

Finishing- all surfaces repaired using the procedure described above were finished using a pre-packaged two-components cement mortar; application using a flat trowel to a maximum thickness of 3-4 mm

The application of this mortar coating was needed to assure a hydraulically smooth surface of the repaired concrete lining, as well as a high resistance to the exposure to water and air due to the high content of synthetic resins.

4.5 Hydraulic steel structures

Rehabilitation of the hydraulic steel structures mainly concentrated on the structures already erected or installed in the right tunnel, namely the cylindrical gate, the steel lining and the radial gate. Minor repairs were needed for other material stored at site.

Cylindrical gate: Although in good condition, the hydraulic cylinder was carefully serviced and minor repairs carried out on the by-pass valve. Steel linkages and steel elements were all sandblasted and repainted. The PLC was controlled in detail and the majority of the batteries, cables and wirings were replaced.

Steel lining: Rehabilitation activities, including the preparation of surfaces and the application of paint have been performed in accordance with the general technical specification as follows

- Surface were sandblasted according to SIS 055900 grade 2 ½
- A zinc-rich primer with epoxy resin base has been applied as undercoat with minimum dry film thickness of 0.04mm
- A coal tar epoxy paint was used with dry film thickness not less than 0.28 mm.
- The steel lining was carefully inspected and the areas that either did not meet the requirements stated by the Technical Specification or showed oxidation occurrences were sandblasted and repainted.

Radial Gate: Repair works of the radial gate included:

- Hydraulic power unit- complete checking of the oil-driven power system and replacement of oil filters, gaskets, valves and manometers; flushing and cleaning of the circuits and tanks; replacement of hydraulic power unit components such as pressure gauges, hoses and valves, that were not operational

- Gaskets and gate mantle- due to the exposure to sun radiation and heat, rubber sealings had to be replaced to ascertain water tightness of the radial gate. Steel surfaces, such as counterweight, bolts, nuts and gate mantle were sandblasted and painted. Steel ropes for the counterweight operation were replaced and new regulation adjustments were carried out.
- Tendons and trunnion beam- before final tensioning of the 300 t capacity cables, each of the 24 component tendons was rehabilitated by cleaning and greasing; the 30 mm thick elastic bearing of the beam as well as the guide sleeve neoprene washers of the tendons were subjected to endoscope screening and refurbished with sealing silicone rubber to avoid the entrance of the mortar during casting. The tensioning process was carried out under full control by monitoring the applied pressure on the trunnion using 24 load cells installed between the bearing plate and each tendon nut.
- Gate monitoring. Additional strain gauges have been installed at critical points of the gate body, arms and trunnion beam in order to improve stress monitoring. An accelerometer and several temperature sensors have also been installed and wired to a processor unit control board.

Rehabilitation activities have been completed; all the tests required for final approval have shown that the hydraulic steel structures comply with set design and operation criteria.

4.6 Electro Mechanical Equipment

Prior to the execution of assembly and installation activities the electrical and mechanical equipments to be located in the Powerhouse and the Substation were the object of rehabilitation works including:

- Draft tubes and manifolds- sandblasting and repainting of the two draft tubes, the upper cone and some parts of the manifolds. Painting work was carried out at site in accordance with the established technical specifications and control of the minimum paint thickness of 370 micron
- Turbine Shafts and bearings- the two turbine shafts were sent for proper revamping by a well-qualified manufacturer workshop in order to remedy damages caused by corrosion, pitting and deep scratches. The revamping process has also been performed on guide bearing, thrust bearing pads and Babbitt metal for both the generators and the turbines since they were affected by chemical corrosion and pitting. Straightness and run out controls for the guide bearing pad contact surface have also been performed and certified. The quality of the rehabilitation process as well as the correctness of the installation and erection procedures carried out at site allowed to obtain satisfactory results during checks and tests performed after the generator – turbine shafts coupling and alignment
- Stator halves- moisture and contaminants were removed by cleaning and heating. Refurbishment of a number of coils was carried out by the generator Manufacturer.
- Rotor poles- several rotor poles have been found badly rusted and displayed a very low insulation capacity; 8 poles were sent to the manufacturer's workshop for rehabilitation while the remaining ones have been properly maintained at site using heating. The tests performed after the erection of the Unit 1 rotor were found to be satisfactory

Figure 8-Assembly of generator rotor and stator after rehabilitation

- The excitation system, single-phase transformers and hydraulic panels-were found to be in a bad mechanical and electrical condition and therefore have been refurbished by the Manufacturers
- LV service installation- most of the LV distribution panels have been sent to the Manufacturers for complete rewiring and proper maintenance

- DCS Control System- electronics of the DCS system panels as well as the original software manager have been updated by the Manufacturer. This included the implementation of new functions and carrying out new control and commissioning steps for both hardware and software. All the original hardware supplies for the stations located in the control room and for the local operation were upgraded.
- Step-up Transformers- the electromechanical parts that were found broken, such as relays, winding thermal image, thermometers, local electrical panel and piping have been replaced. Rehabilitation by means of proper oil conditioning and treatment apparatus has been carried out at site to recover the insulation properties of the coils
- Substation equipment- only few steel structures needed to be replaced. Control cabinet and interconnection cubicles have been refurbished partly at site and partly at the Manufacturer's workshop
- LV cables: about 5000 m of LV cable were lost and replaced. Wooden cable reels found in bad condition have been replaced by new ones at the site.
- Turbine inlet valves- external surfaces of the valves and servomotors have been repainted; some missing components have been replaced; solenoid valves for oil pressure system, electrical junction boxes, manometers, flexible pipes have been refurbished at site. Worn seals and gaskets have been replaced
- Gantry Crane- replacement of stolen or damaged motors as well as refurbishment of all others parts has been carried out at site.

One of the most critical activities for the successful rehabilitation of the Plant was the detailed inventory of the supplies carried out by cross checking all packing lists with the materials present at site. The scope of this activity was to determine all missing materials- either lost or stolen- for availability at the time of equipment assembly. The long time needed to arrange transport to site could cause severe delays due to the lack of small equipment parts at the time of their installation.

In order to ensure proper conservation measures for the rehabilitated equipment until their final installation, temporary stores were made available utilizing existing site installations such as warehouse, cement store and dynamite store.

5. Monitoring and safety programs

An important aspect of the rehabilitation and completion works for Bumbuna Falls HEP is the implementation of monitoring programs and plans aimed at the safety of the dam, its appurtenant structures and the downstream area. Provisions related to such safety aspects were tailored to meet the very special requirements of the Project. The main components are outlined in the sequence.

Dam Monitoring Program: During the period of construction (1992-93), dam instrumentation mainly consisting of piezometers, settlement gages and inclinometers were installed in 3 monitored cross sections. Measurements corresponding to the prevailing river diversion phase scenarios were collected until the interruption of site activities in 1997.

After the resumption of works, a detailed assessment was carried out in order to evaluate the state and conditions of the dam instrumentation. The assessment showed that some important instruments such as piezometers in the dam body were no longer operational. Other instruments such as upstream face inclinometers and settling gages required rehabilitation. Due to the importance of monitoring water pressures and seepage in order to verify the behaviour of the dam after its rehabilitation, a plan was established for the best use of recoverable instruments and addition of boreholes down to the foundations for water level measurements in the central and abutment zones of the dam.

Dam monitoring is essential for the first Reservoir filling. Detailed monitoring procedures and safety checks were designed taking into account the possible contingencies of the first filling operation as well as the subsequent operation period. These are based on a systematic collection and analysis of measurements and other observations triggering required actions in the cases of emergency, alert and normality.

First Impoundment Plan: In order to minimize potential safety risks, a filling operation in 3 to 4 successive phases is forecasted. Within safe limits, these phases can be adjusted to the monitored dam behaviour, taking into account the inflow hydrology during the filling period, the operation of the right bank tunnel and the operation of closure and plugging of the left bank tunnel. The aims of the phased filling operation are to limit the maximum rate of water level rise to 1 m/day and to assure time availability for the observation of dam behaviour at the end of each phase.

The main purpose of the Impoundment Plan is to coordinate all involved inspection, monitoring, construction and operation activities in a safe and reliable manner. It defines the responsibilities and actions to be taken by the Owner, the Engineer and the Contractor in the different possible situations and contingencies.

Emergency Preparedness Plan: Planning studies related to the safety of the Bumbuna Dam and the downstream river valley included airborne laser surveys of potentially areas at risk, dam break analysis and the preparation of the corresponding inundation maps. Such studies were conducted following international engineering practices and conservative PMP-PMF assumptions.

The Emergency Preparedness Plan defines measures to be taken and responsibilities in handling emergencies. During the operation period, overall responsibility for this Plan will be a task of the Plant Operator, still to be defined. During the preceding period, which includes the end of construction and reservoir impoundment operation, responsibility for safety matters will be borne by a Dam Safety Committee consisting of representatives of the Owner, the Engineer and the Contractor. Actions are currently being taken by the Government of Sierra Leone to implement the recommendations of this Plan.

6. Conclusions

At present, the rehabilitation and completion works of the Bumbuna Falls Power Plant have essentially been concluded. Rehabilitation works of the Transmission System are in progress. A next step is the reservoir impoundment, commissioning and start of Project operation.

Diversified civil construction and equipment related activities were needed for the purpose of rehabilitation and completion. The results that were achieved comply with updated design criteria and international standards of safety and quality.

Key strategic factors for the development of these activities were: the detailed initial assessment of the state of civil works and equipments at site; the extensive verification/review of safety matters and project features; the selection of appropriate working procedures, techniques and materials for the rehabilitation work; and the active participation of qualified technical personnel and workmanship in the sensitive areas of involvement.

Acknowledgement

The Authors wish to acknowledge the valuable support and the contributions received from representatives of the Bumbuna Project Implementation Unit, the World Bank, the Contractor Salini Costruttori and the Dam Safety Review Panel members. They also wish to express their appreciation for the contributions provided by A.Caporaso, F.Birindelli and S.Galantino, members of the Bumbuna design team, during the preparation of this paper.

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