Nkula A Rehabilitation Project, Malawi
Fast Track Rehabilitation
Challenges and Opportunities of Rehabilitations with Timely Limited Funding

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Introduction

Hydropower refurbishment projects show a general trend for exceedance of the planned project completion time. Various factors as too optimistic assumptions, wrong expectations from stakeholders, unknown and unforeseeable conditions of existing structures, long decision-making processes during different project stages are often resulting in delays and time overruns or - in worst case - to significant interruptions as a consequence of disputes or arbitration. Such time overruns are on one hand frustrating for all involved parties and on the other hand creating additional costs resulting from longer execution times and lost revenues due to extended outages of the power plants. While many financing institutions, lenders or donors take the general risk of delays in refurbishment projects into consideration by allowing for prolongation of their granted funds, grants from the Millennium Challenge Cooperation (MCC), have a strict expiration date, without the possibility for any time extension.

The experience gained during the refurbishment and upgrade of the Nkula A HPP, part of the infrastructure development project of the Millennium Challenge Cooperation in Malawi, showed that such strictly time-limited funds create challenges but mainly served as a motivator and enlightened the opportunities for the execution of rehabilitation projects.

Since Malawi is ranked as one of the 10 poorest countries in the world[1], the expiry of the granted funds and the subsequent transfer of outstanding payment responsibilities to the Government of Malawi (GoM) was defined as a major risk by all stakeholders and therefore mitigation measures to ensure a timely completion of the project were elaborated and implemented during all project phases. This approach finally led to completing this rehabilitation project three days before the planned taking-over date and 2 months before the Compact End Date of the Millennium Challenge funding.

In the following, the main aspects which were identified being key for a successful and in time completion of the project under the given financing constraints are summarized.

1. Background

1.1 Millennium Challenge Corporation Compact for Malawi

In 2007, Malawi was evaluated as eligible for Compact Assistance by the Millennium Challenge Cooperation, a bilateral United States foreign aid agency. In September 2013, the Republic of Malawi, represented by Millennium Challenge Account - Malawi (MCA-M), the national utility Electricity Generation Company Malawi (EGENCO), the Electricity Supply Corporation of Malawi (ESCOM) and the Millennium Challenge Corporation (MCC) signed a 350 Mio. USD contract, which focused on investments in environmental and natural resource management and the energy sector, to increase individual and business incomes and reduce poverty by improving the availability, reliability and quality of the power supply, expanding access to power, thereby reducing the cost of doing business, and revitalizing Malawi’s power sector.[1]

Fichtner GmbH & Co. KG was engaged by MCA-M as Owner’s Engineer to direct and monitor the implementation of the projects of the environmental and natural resource management and infrastructure development programs. The latter mainly included the installation of new transmission lines and substations as well as the revitalization of the Nkula A hydropower station was one of the key elements of this compact.

The MCC compact was set up for an implementation time of 5 years. Resultingly, the compact and the allocated grant expired on 20th September 2018, on the Compact End Date (CED). The compact period of 5 years included all project phases, starting with a basic design, identification and definition of required rehabilitation / replacement measures and scope, preparation of the technical specifications and tender documents, international competitive tendering, contract award including the project implementation.

Contrary to many other financing models, grant or loan agreements, MCC Compacts and the related grants strictly expire at a pre-defined CED, without any possibility for time extension. Resulting from that, any contract- and all related payment- obligations still outstanding at the CED are transferred to the beneficiary government.

1.2 Malawi power sector and the role of the Nkula A rehabilitation and upgrade

Presently, the Malawian power system relies almost exclusively on the hydropower production capacities. The existing meaningful powerplants (Nkula A, Nkula B, Tedzani I, II, III and Kapichira), with the overall installed capacity of about 345 MW are all located at the Shire River, which originates from Malawi Lake. All those power plants along the Shire River were commissioned between 1966 (Nkula A) and 2013 (Kapichira Phase II).

The availability, reliability and quality of Malawi's electrical power supply has been a clear and constant obstacle to economic growth due to frequent black-out or lack of accessibility.[2] Due to the strong dependency of the power supply on the Shire River cascade and resultingly on the outflows of the Malawi Lake, the availability of the related hydropower stations has a key role in almost all private and industrial sectors in Malawi. While the construction of Kapichira Phase II was concluded in 2013, all other plants are in operation for already decades.

Fig. 1. Left: Nkula reservoir; Right: Nkula A hydropower station before rehabilitation

Nkula A is the first stage in the Shire River cascade and was the first hydropower plant built in Malawi. The three vertical Francis turbines and generators at Nkula A as well as most of the mechanical and electrical auxiliary equipment had never been refurbished since commissioning. Consequently, the plant's availability and technical condition had significantly decreased and had reached a critical level before the major refurbishment was initiated. Due to the overall power shortage in Malawi, especially during peaking-hours, even the loss or unavailability of Nkula A with its original capacity of 24 MW, equivalent to approximately 7% of the country's total installed capacity, was considered as an unacceptable and major risk for the Malawian power sector. For the overall goal to increase the capacity, efficiency, and stability of the national electricity grid the revitalization of the Nkula A hydropower plant became one of the key projects of the MCC infrastructure development project.

With the increasing power demand in Malawi over the years, the different stages of the Shire River cascade were constructed. As part of this development, adjacent to Nkula A, the power station Nkula B, with a capacity of 100 MW, was constructed and finally commissioned in 1996. While Nkula A was originally designed as a run-off river plant without any storage capacity, Nkula B was designed as a storage plant, including the construction a new dam, creating a head pond with a capacity of approximately 1,940,000 m^3 (Fig. 1). The Nkula A intake, located next to the new dam, was now connected to the new reservoir. Consequently, the impounding of this daily head pond raised the head water level of Nkula A HPP by more than 7 metres.

All equipment and structures for Nkula B were designed according to the new head water level at the reservoir. However, the investments on Nkula A HPP were limited to minor, incomplete modification works on the intake structure. The concept for the modifications of the intake of Nkula A did only foresee the extension of the supporting piers and the guide rails for the installation of the intake stop logs, however no lateral walls to the structure. Due to the absence of such lateral walls, extending the original intake structure, it was not possible any more to dewater the waterways of Nkula A without draining the complete reservoir, since Nkula B has been built. Inspections of the waterways or repair works at Nkula A were therefore only possible while the reservoir was empty and consequently while Nkula B was out of operation.

Due to its importance of Nkula B for the countries power supply (30% of the total installed capacity), any outage of Nkula B always had significant impact on Malawi's grid stability and was therefore avoided. Maintenance and inspections on both power plants, but especially on the smaller Nkula A, were therefore reduced to a minimum.

Fig. 2. Left: Nkula A intake structure before rehabilitation; Right: Nkula A intake structure after modification works

1.3 Scope and focus of the rehabilitation and upgrade works at Nkula A

The revitalization project for the Nkula A hydropower plant included the refurbishment of the electro-mechanical equipment and hydraulic steel structures, replacement and upgrading of the electromechanical balance of plant equipment as well as the reconstruction of the existing 66kV switchyard.

In addition to the rehabilitation works in the plant itself, one of the key aspects and main goals of the rehabilitation of Nkula A was the needed modification of the intake structure in such a way to allow for isolation of the Nkula A waterways without draining the reservoir and affecting the operation of Nkula B.

When Nkula B was built, the generating equipment of Nkula A was not modified to benefit from the increased head potential. Furthermore, due to a mismatch in the original design, the turbine output, with a design capacity of approximately 10.2 MW was always limited by the maximum generator output, with a design capacity of approximately 8 MW.

By upgrading the turbine design to the new, higher available head (after Nkula B was built) and at the same time rectification of the mismatch between the design capacities of the turbine and the generator it was possible to increase the plant's design capacity by 50% from 24 MW to approximately 36 MW.

2. Risks and mitigation measures related to time limited funding

2.1 General

A project's success is mainly measured in terms of completing the project within the constraints of fulfilment of performance and functional requirements, quality, cost and time. While of course for the Nkula A rehabilitation project all those key factors were important, the focus for the Employer (MCA-M) and beneficiary (EGENCO) was completing the project before the CED on 20th September 2018, to effectively and efficiently make use of the availability of the time limited grant from MCC, in order to reach the goals defined in the Compact.

From the experiences gained during execution of rehabilitation projects of hydropower plants of similar age, condition and complexity, all stakeholders were sufficiently aware of the types of challenges they would face in their attempt to complete the rehabilitation of the entire powerplant and related civil structures including design, tender and implementation stage within the fixed period of 5 years.

Since Malawi is ranked as one of the 10 poorest countries in the world[1], the potential risk of not completing the rehabilitation project in time, before expiry of the granted funds and consequently running the risk of requiring to transfer outstanding payment responsibilities to the Government of Malawi was defined as a major risk for the Employer and beneficiary.

2.2 Organizational measures and project set-up

Besides indispensable factors as well-established communication channels, transparency, experienced parties, and open relationship between all stakeholders, regular design coordination meetings were one of the key factors for reaching fast consents and decisions with regards to accepting possible technical solutions to encountered challenges. Such design coordination meetings were held at least on a quarter yearly basis after project start. To allow the participation of all stakeholders, including the Employer and beneficiary, such meetings were always held in Malawi and parties from abroad (Contractor, Engineer and Independent Engineer) committed and managed to always assign the necessary key personnel, enabling detailed technical discussion and reaching common decisions, right there at the meetings. These meetings were also used to pro-actively start discussions about newly identified risks which could be affecting the project's implementation and to develop mitigation measures in close coordination, involving the client at an early phase.

In many rehabilitation projects, substantial delays or even project interruptions are caused by disputes or arbitration. In rehabilitation projects based on a Design-Built approach ("FIDIC Yellow Book"), such disputes are often the results of contractor's claims for compensation for unforeseeable conditions. While this clause in general leaves room for interpretation of the reasonably foreseeable extent of works, discussions on this topic often escalate due to different assumptions and expectation from both sides. It must be considered essential to ensure the clients' and lenders' / donors' awareness that rehabilitation projects which are based on lump-sum contracts and are using FIDIC Yellow Book as General Conditions of Contract do in general not eliminate the risk for additional works and related costs, as clients, lenders / donors tend to assume. This risk can of course be reduced by thorough and detailed investigations as well as by providing comprehensive data and information to bidders before contract award. But experiences show that pre-bid information, especially for rehabilitation projects, which involve a considerable amount of civil works are either not available or not to the extent or details that would be necessary to avoid justified claims from contractor for unforeseeable conditions. It is therefore considered crucial to identify and thoroughly evaluate areas providing potential for unforeseeable works during an early stage of the project and to bring those to the attention of the client and donors. Only by comparing the possibly arising additional costs with the costs and time for additional investigations, a cost- and time efficient approach can be defined which is beneficial for the client.

Due to the imposed overall short and challenging project execution time and the existing restrictions for shutting down and dewatering the plant, thorough and detailed inspections of Nkula A's equipment and structures during the design phase of the project were not possible. Namely, the inaccessible intake and transition structure, the embedded parts of the turbine, the draft tube slab and the three surface penstocks were identified as areas with high risk for potential of requiring unforeseen works. The significance of the outcome of non-destructive tests, especially on civil structures, was considered limited under the given limitations of the project time frame and without the possibility of shutting down and dewatering the two plants. It was therefore decided in agreement with the client to accept the level of uncertainty and to foresee contingencies in sufficient amount for those risks. By this approach, it was assured that those contingencies could be made available on short notice and without much administrative efforts, such that they did not hinder or even hold up the decision making and progress of the works.

In general, most of the key stakeholders in rehabilitation projects have an interest to complete the works in time. While operators and owners want to bring their plants back to commercial operation to minimize loss of revenues, Contractor’s are mainly motivated by economic aspects, often affected by contractually defined clauses for delay damages or penalties. However, such clauses do not apply in case of time extensions which have to be granted because of unforeseeable conditions. None regard of any granted time extension, for the rehabilitation of Nkula A, the contractor was aware that the grant will expire on 20th September 2018 and that the contract will then be transferred to the Government of Malawi. The transfer from an internationally funded project, with guaranteed funding, to a project owned by the Government of Malawi after the Compact End Date was considered as a substantial risk by the Contractor and provided additional and severe motivation to complete the project in time even under occurrence of additional works. Consequently, the contractor was willing to mobilize additional workforce without additional costs, to accept and share technical risks and provided flexibility regarding changes and compromises. The common motivation of all stakeholders was identified as the main key factor for finalization of the project in time.

2.3 Technical measures in design and implementation

While the risk and potential unforeseen conditions of inaccessible civil structures and hydraulic steel structures were accepted and planned for to be covered by contingencies, the scope of works related to electro-mechanical equipment had to be defined in a way to minimize the risk for unforeseen condition and additional works especially during a late stage of the project.

Due to the age of the hydropower plant, non-availability of spare parts, overall condition as well as the possibility of considerable capacity upgrade of approximately 50%, the electrical equipment needed a total replacement. This included the replacement of all generator parts, the electrical auxiliary systems and the 66kV outdoor switchyard equipment. It was decided to install new generators with pre-assembled global vacuum impregnation stators, which only need minor assembly works at site and therefore allowed for an extremely short erection and implementation time without substantial risks. For the same reason, and the general space constraints in the switchyard area, 66kV hybrid switchgears were installed to replace the original air-insulated switchgears.

Fig. 3. Left: Lowering of the pre-assembled vacuum impregnation generator stator; Right: 66kV hybrid switchgears

As usual in rehabilitation projects, the possibility for reusing and refurbishment of existing mechanical equipment was also under discussion for Nkula A. Due to the unavailability of information about the present condition respectively doubtful condition of the existing equipment, it was however decided to replace the respective parts by new equipment. By clear definitions of the interfaces to remaining elements, the E+M contractor was in the position to deliver equipment to site for installation which was fully designed, manufactured, pre-assembled and tested in his facilities. For the three vertical Francis turbines, only the embedded parts, namely the draft tube liner, the spiral casing and the stay ring were kept for refurbishment. All other parts, incl. turbine head cover, bottom ring, turbine shaft, runner, guide bearing, draft tube cone, etc. were subject to replacement. To avoid time consuming and costly in situ machining of the stay ring for connecting the new head cover and bottom ring, it was agreed to use stainless steel insert rings back-filled with a resin casting instead. Furthermore, since this solution does not require any material removal, it has no impact on the strength of the existing structure and does not require specific machining tools (Fig. 5). All the mechanical auxiliary systems were replaced.

All hydraulic steel structures, including gates, stop logs, trash rack screens and cleaning machine, powerhouse crane and lifting equipment, were replaced. Also, the penstock butterfly valves DN2000 were completely dismantled and replaced including all auxiliary systems and the up- and downstream connection pipes.

Fig. 4. Left: Lowering of new turbine and shaft; Right: new penstock butterfly valve and upstream pipe

Fig. 5. Left: Sketch of modification of stay ring by insert ring and resin casting; Right: Method under implementation

The approach to replace most of the existing electro-mechanical equipment was mainly selected due to time constraints and in order to reduce the risk of delays caused by redesigning, manufacturing and transportation. The cost implication of replacement of the electro-mechanical equipment compared to rehabilitation of the equipment was evaluated to be marginal. The unavailability of manufacturing / repair facilities and workshops capable of refurbishing parts of the mechanical equipment in Malawi, would have caused considerable transportation costs and time impact with the remaining risk of inapplicability of the equipment.

As for many refurbishment projects, also for Nkula A reliable information and documentation of the existing civil structures were very limited and many times not accessible at all for investigations. Therefore, wherever possible, designs for civil work modifications were developed under the aspect of fast implementation time but also with focus on greatest possible independence from the existing structures. For example, this was applied for the design of the strengthening solution which was to be implemented to allow for dewatering of the intake structure and transition tunnel of Nkula A under the increased head water pressure. The modification of the transition tunnel between the intake tower and the concrete lined headrace tunnel is illustrated in Fig. 6.

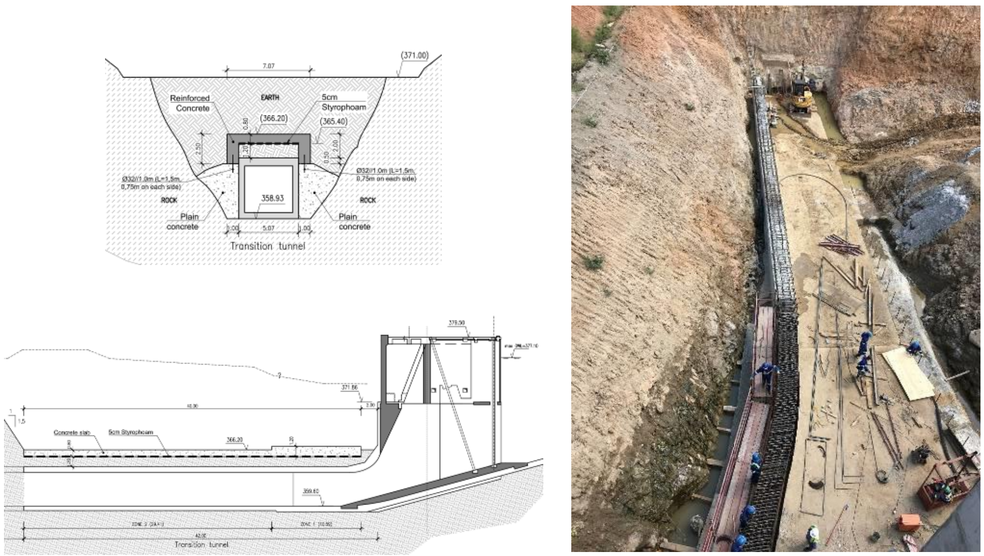

Fig. 6. Modification of transition tunnel at intake of Nkula A by means of a protection slab

By installing a reinforced protection slab above the transition tunnel, supported by plain concrete on both sides of tunnel, all occurring external loads were securely transferred to the surrounding rock. A 5 cm Styrofoam sheet was placed below the protection slab to ensure that no loads, resulting from possible deflection of the slab under the pressure of sediments settling above the transition tunnel, are transferred to the original tunnel top. This design allowed for proper planning and timing, deployment of the required materials and assignment of enough labour without knowledge of the exact condition and construction details of the existing transition tunnel. Starting investigations, design and further planning only after excavation of the area would have caused unrecoverable delays at a very late phase of the project.

3. Conclusions

The strict time limited availability of funding for the rehabilitation of Nkula A and the subsequently needed transfer from an internationally funded project with guaranteed funding to a project owned by the Government of Malawi after expiry of the funds, in case that the rehabilitation project would not be completed in time, was considered as a substantial risk. However, this potential risk and the therefrom resulting pressure created at the same time a common goal and motivation to complete the project in time for all stakeholder.

The awareness of the related challenges, transparent relationships, the high willingness of all stakeholders as well as the application of design approaches which enabled fast decision making and implementation as well as smallest possible interference with and dependency on existing structures and equipment were key factors for a successful project completion. By the selected set-up and measures taken, the total rehabilitation and upgrade project could be implemented within 16 months after site mobilization. All works, including trial runs, were finalized 3 days before the planned completion date, 2 months before the Compact End Date of the Millennium Challenge funding and within budget.

References

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