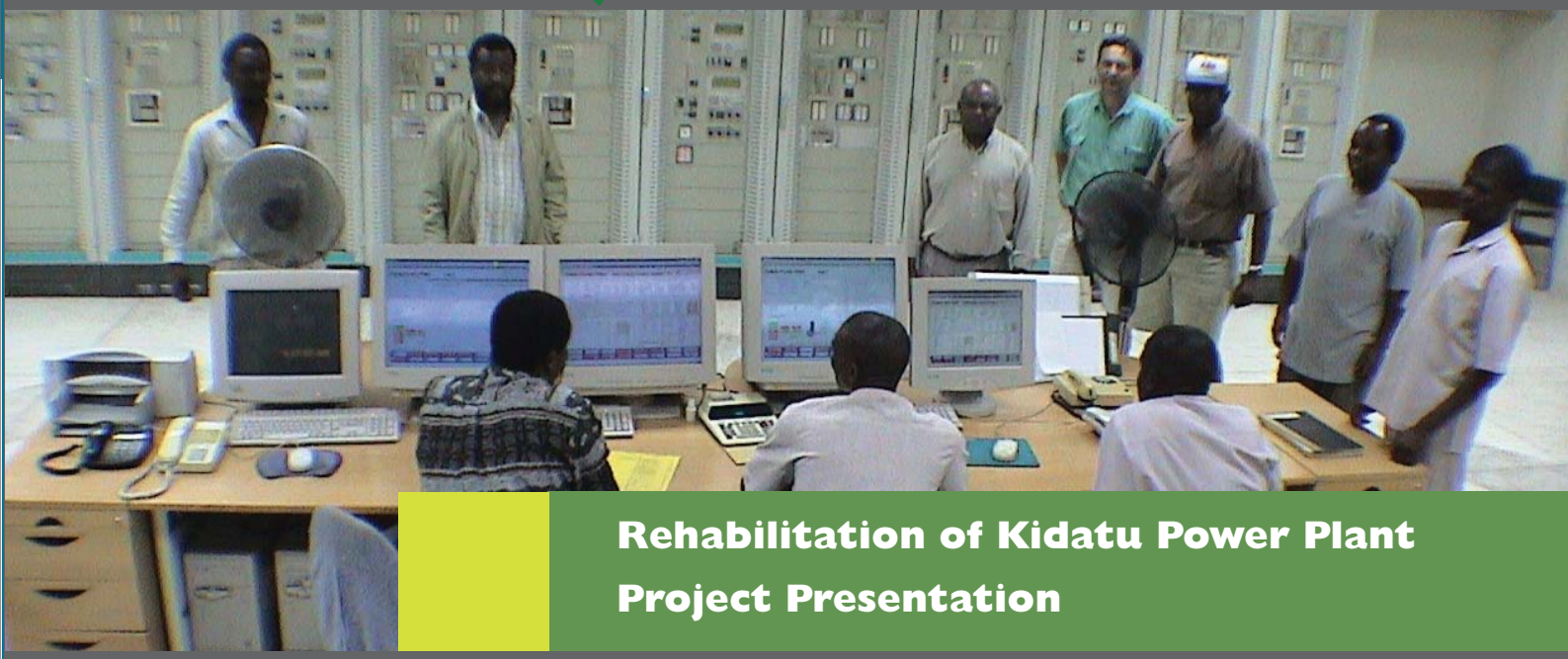
TANESCO



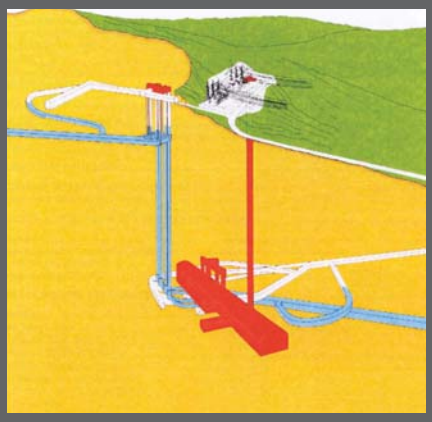
Rehabilitation of Kidatu Power Plant
Project Presentation

Norconsult

The 200 MW Kidatu power plant is located on the Great Ruaha River in the region of Morogoro in central Tanzania about 280 km west of Dar es Salaam.

The construction of Kidatu power scheme was started in the early seventies with the commissioning of the two first units at 50 MW each in 1975. The last two 50 MW units were commissioned in 1980, making a total installation of 200 MW.

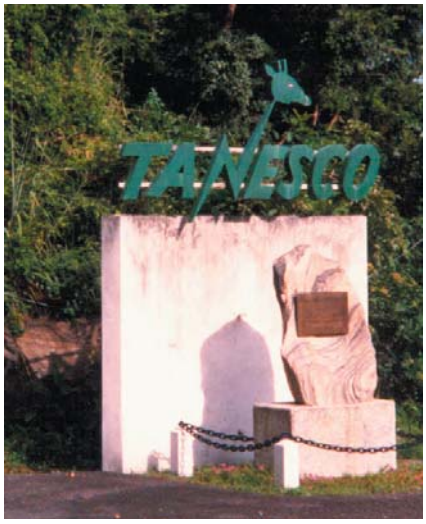
Since its initial inauguration in 1975, Kidatu power plant has played a very important role in Tanzania's electric power supply. When the first phase of the Kidatu rehabilitation project started in 1991, Kidatu's installation represented more than 50% of the installed capacity in Tanzania. Today, Tanzania has a total installation of about 800 MW, of which Kidatu generates about 50% of the total energy consumption in Tanzania.



KIDATU KEY DATA

- Catchment area	80 000 km²
- River run-off (mean value)	191 m3/s
- Discharge capacity	140 m3/s
- Turbine capacity	4x52,5 MW
- Generator capacity	4x60 MVA
- Annual generation	1,2 TWh
- Annual asset creation	11 billion SEK
	(at average consumer sales tariff)

Machine hall before and after rehabilitation



Tailrace into Great Ruaha river

Rehabilitation of Kidatu Power Plant

A successful rehabilitation of Kidatu power plant has increased the annual production with approximately 5.5 GWh. State of the art technology was successfully introduced with a fully integrated efficiency optimisation program, which is unique in the hydropower world.

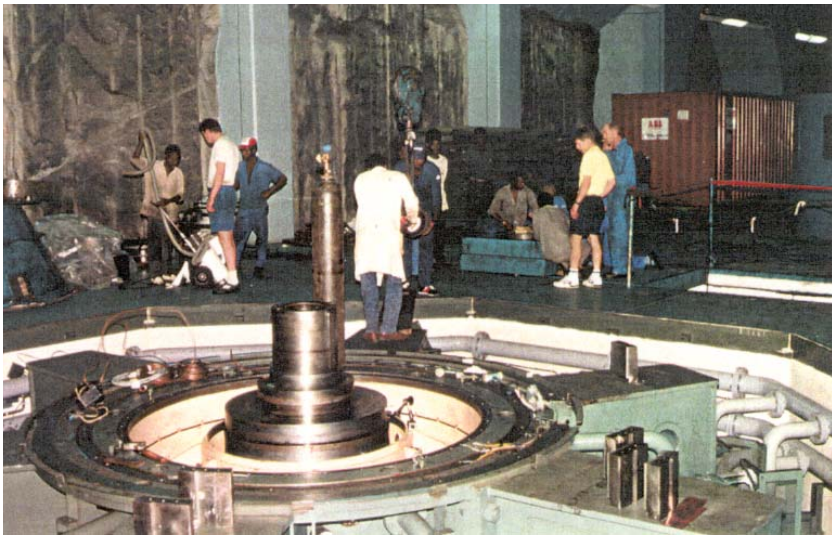
Kidatu is an underground power station with four vertical Francis units of 50 MW each and designed for a total discharge of about 140 m^3 per second. The power plant utilises a maximum head of 175 m between the intake and the tailrace. The intake reservoir has a live storage of 125 million m^3 contained by a 40 m high earth and rockfill dam with a crest length of 350 m. Three spillway sector gates have a total capacity of 6,000 m^3/s. The headrace tunnel is unlined with a length of 9.6 km. The tailrace tunnel has a length of 1.0 km.

A vertical steel-lined penstock feeds each of the Francis stainless steel turbines. Litostroy Lubjana made the two first units while Voith made the two last units designed for about 35 m^3/second each. Rade Koncar in Zagreb,- Yugoslavia manufactured the generators. Each unit has a total rotating mass of about 180 tonnes, rotating at a speed of 375 revolutions per minute

Power from the generators is fed to the single-phase transformers located in the powerhouse cavern via 10.5 kV polyethylene insulated cables. From the main 220 kV transformers the power is led through an 85_m vertical cable shaft to the pothead yard via 220 kV oil immersed power cables. There are four 220 kV overhead lines connecting to the 220 kV switchyard.

Although not very old after only twenty years of operation, Kidatu had already reached a stage where rehabilitation became necessary in order to maintain a reliable power supply to Tanzania. The severe damage of generator 1 in 1990 triggered the Urgent Repairs Project - Phase 1.

New excitation system



Generator under rehabilitation

THE URGENT REPAIRS PROJECT-PHASE I

Phase I, known as the urgent repairs project, was started in 1991 with the main objective to carry out urgent repairs of the damaged generating unit 1. The project included a complete repair of generator 1 and replacement of the rotating exciters with a static excitation system.

Phase I was successfully completed within a year's period in December 1993 at a total 1993 cost of SEK 25 million.

New pipline insulation

Cavitation on the runner

REHABILITATION OF KIDATU POWER PLANT - PHASE II

The rehabilitation of the Kidatu was continued with Phase II in 1995 when Norconsult was awarded a contract for consulting services.

The feasibility study dated March 1996 recommended that TANESCO perform a number of actions to increase the overall power supply reliability in Tanzania. Sida decided to assist with financial support to the implementation of the most important parts through the rehabilitation of the Kidatu power plant - phase II project. Tender documents were prepared, and the following contracts were signed on 10 June 1998:

1. Rehabilitation of the mechanical works: Kvaerner Energy AS (now GE Hydro)
2. Rehabilitation of the electrical works ABB Kraft AS (now Alstom Power)
3. Delivery and installation of control and protection equipment.: Siemens AS (now Voith Siemens)
4. Improvements of the Maintenance Management System (MMS): Norconsult AS
5. Consultancy Services: Norconsult AS

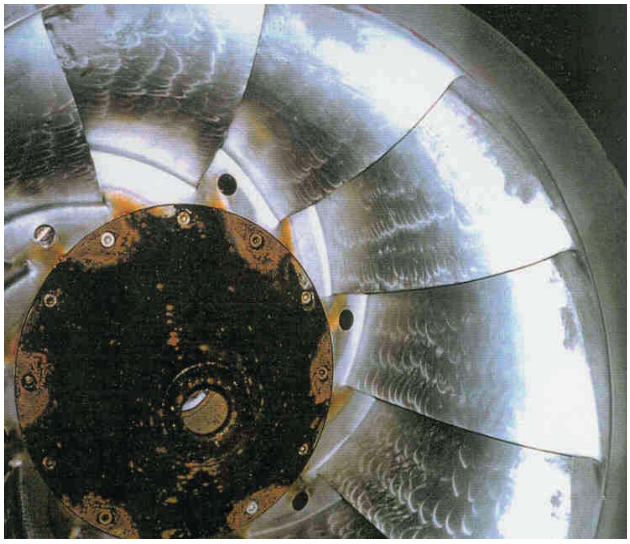
The Project

The rehabilitation of the Kidatu power plant, phase II project, has a total budget of about SEK 103 million (about Euro 10 million) jointly funded by Sida and NORAD with Sida as the lead donor. The project was contracted with turnkey deliveries. The duration of the rehabilitation activities was considerably extended till about four years in order to accommodate for related operational interference and other unforeseen difficulties.

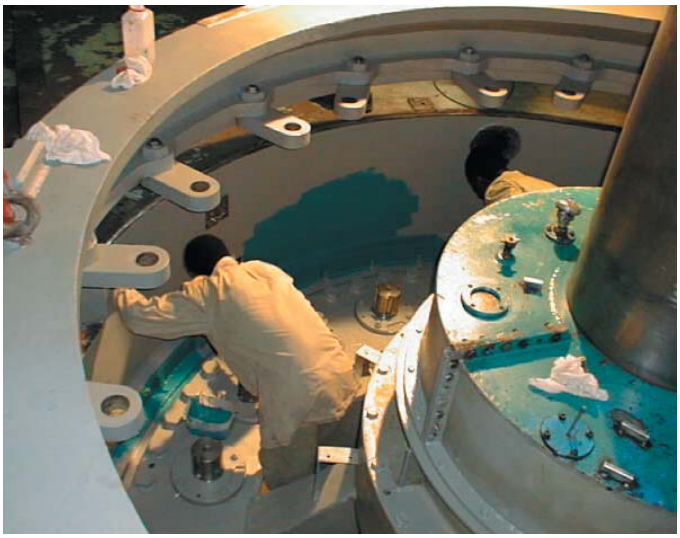
The rehabilitation project was performed with only one unit out of operation at a time due to generation constraints in the Tanzanian grid.

The Contractors provided experienced supervisors with responsibility for guiding and instructing the skilled and unskilled manpower helpers provided by TANESCO. This arrangement was carried out in order to minimise project costs and to improve the on the job training.

Sandblasting exhaust arrangement



Francis runner



Rehabilitation of turbine 2

MECHANICAL WORKS

Vertical Turning Lathe (VTL)

The cavitation of the runners 1 and 2 were severe, and considerable repair works were foreseen. In order to improve the quality of the repair works, it was decided to install a vertical turning lathe (VTL) machining mill to ensure a proper machining of the large rotating parts.

The VTL was located on the machine hall floor enabling the use of the over-head crane to move heavy parts into the VTL and back without further need of mobile cranes etc.

Surface Treatment

The feasibility study had revealed an urgent need to recondition the steel lined waterways and pressure shafts as these were in a poor condition. Further, corrosion could lead to a complete collapse of the steel lining. Consequently, it was necessary to recondition these parts with a new protective layer of paint.

All the steel lined waterways (mainly the 185-meter high vertical shafts) were sandblasted and painted. The total painted areas amounted to approximately 8,000 m^2. In order to protect the powerhouse from exposure to quarts sand and dust, a huge ventilation system was arranged to make an under pressure inside the cavern, thus sucking the dust and sand particles out through the pothead yard.

Turbine Rehabilitation

Almost all the blades of the turbine runners 1 and 2 had severe cavitation both on the inlet and suction side. Some of these damages were as large as 300 by 100 mm and almost 20 mm deep. When grinding, some of the cavities proved to be almost through the blade. Consequently, it became difficult to repair with a good and lasting result.

The runners were grinded and weld-repaired at the Kidatu, and new facing plates were fitted.

New Turbine Governors

New turbine governors have been installed for units 1 and 2 while the turbine governors for units 3 and 4 will be replaced during year 2003.

Pipeline Insulation for Cooling Water Pipes

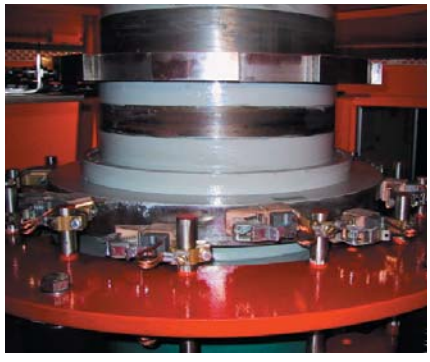
The insulation of the cooling water pipes was heavily damaged and created huge condensation problems inside the powerhouse. The increased air humidity made water drip almost all over the plant, causing considerable contamination.

In order to implement a new computerised control and protection system, there was a need to improve the working environment. New insulation materials made of armaflex were purchased and installed by TANESCO labour force. The result was extremely positive, and the condensation and dripping problem is now almost gone.

GENERATOR WORKS

A main problem at Kidatu was the capacity limitation of the generators due to heating problems in the bearings, reducing the available capacity to approximately 175 MW of continuous load.

Moreover, the bearings had severe oil leakages and some were leaking up to two litres of oil per day. The slip-ring housing was ventilated from the generator pit, and as a result carbon dust from the excitation system was mixed with oil from the bearings and carried around inside the generator pit. The combination of carbon dust



New slipring brushes

and oil vapour encapsulated by high voltage windings is a dangerous mix. This probably caused the flashover and damage in 1990. There were also problems related to other topics that needed consideration.

As recommended in the feasibility study, it was agreed to modify the bearings to avoid overheating and oil leakages by introducing additional sealings. It was also agreed to modify the ventilation of the slip-ring housing with a different and new arrangement, which meant a complete reconstruction of the slip-ring housings.

During the modifications the rotor was removed and completely cleaned for oil and carbon dust. Since the rotor and stator were completely soaked with oil, it was dripping oil onto the machine hall floor for several weeks after having been taken out of operation.

The water in Great Ruaha river contains a large amount of particles like humus, slam, dirt, sediments etc. As a comparison, the ferro content is about 1,000 times the average of European rivers. All these particles will gradually contribute to clogging of the cooling system like water pipes and coolers. When opening some of the coolers, some of the pipes were found to be completely clogged, causing overheating of the bearings.

Clogged air coolers

Sandblasted air coolers

Air coolers repaired with PP5

Clogged cooling water pipes

CONTROL AND PROTECTION SYSTEM

The original control and protection equipment from 1975 was still in operation after 25 years in service. However, there were several severe defects and it was difficult to acquire necessary spare parts. Some of the electromechanical protection relays were mal-functioning and represented an operational risk for a reliable power supply to Tanzania. Moreover, due to several extensions, modifications and replacements the documentation was no longer reliable and made it difficult to perform corrective maintenance works when needed.

Computerised Control and Protection System

Consequently, it was concluded to carry out a complete replacement of the conventional technology based control and protection system to an almost 100% computerised system.

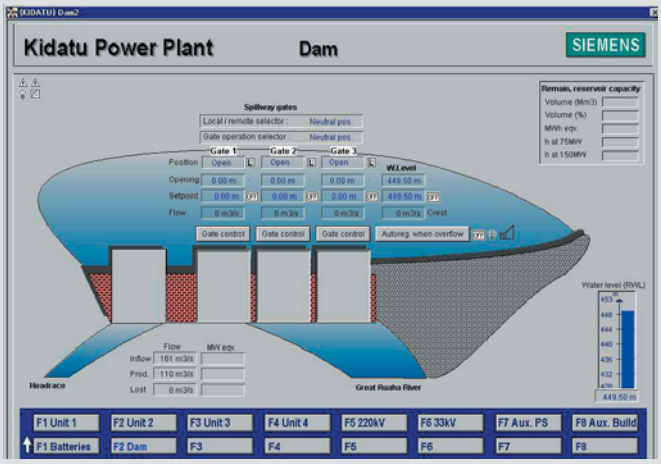
The general computer knowledge at Kidatu was minimal, and considerable training was needed to ensure a safe and reliable operation of the plant.

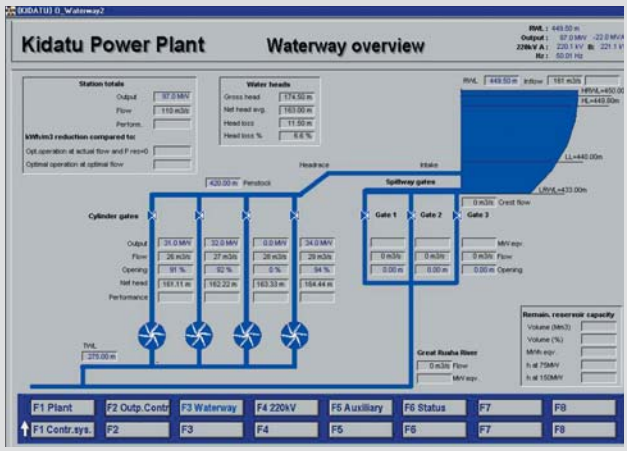
Since Kidatu is crucial in the Tanzanian grid, it was emphasised that it should be possible to operate the generating units even if a unit controller was out of operation. This facility included a portion of conventional technology that is located inside the relay panels. The new control and protection system covers now all the four generating units inside the machine hall including the generating feeders at the 220 kV switchyard building.

Water Monitoring System

With a large number of dynamic factors influencing the total efficiency factor, it is very difficult for operators to select an optimum machine setting manually.

A computerised optimisation module was therefore developed and installed. The software picks up a large number of parameters from the process that forms the basis to calculate the optimum individual





Runaid screen pictures

unit setting to meet the instant demand requirements from the grid. The software is constructed with mathematical modules that instantaneously calculate and update the settings towards an autonomous alternating power demand.

The optimisation system is fully integrated with the central and unit computers and governs the unit setting as a fully automised system. There is also a manual mode option. When using this mode the software presents instantly the difference between the optimum and the manual setting. The average manual operation setting seems to deviate from the optimum setting in a range between 1% and 3%.

A 2% efficiency increase represents an additional production of about 24 GWh. The increased power sales to consumers will therefore amount to about Euro 2 million on an annual basis with the current consumer sales tariff.

MAINTENANCE MANAGEMENT SYSTEM

The Kidatu had a manual maintenance system that was implemented in 1975. Unfortunately, the system had not been updated with necessary adoptions during later extensions and replacement of equipment.

General aging of the plant through deterioration of equipment and components requires improved maintenance by the years to maintain the required reliability. Availability of spare parts and other resources could also have been better. However, this has been difficult to evaluate since the manual system did not have any experience records.

The computerised maintenance management system (MMS) JobTech was installed to improve the maintenance in general. In addition, a substantial effort was done to upgrade the various maintenance routines. A large number of new routines were introduces, both for old equipment and in particular, for new equipment.

ENVIRONMENTAL IMPROVEMENTS

The working environment for the operation and maintenance staff at the Kidatu was rather lousy with an average ambient temperature in the cavern up to 35°C with parts of the plant being extremely noisy, dirty and scarcely illuminated.

As a final touch-up, the whole power plant was agreed to be painted in lighter colours.

From a working environment point of view, the conditions at the Kidatu is now drastically improved. The following items may be mentioned in this respect:

- Reduced cavern temperature with about 8°C
- Oil leakages almost eliminated
- Spread of carbon dust eliminated
- Higher illumination through repainting with light colours and improved lighting
- Introduction of modern technology with less operational disturbances

With these improvements, the Kidatu does again appear clean and beautiful and should contribute considerably to an improved working environment, which is again expected to encourage and motivate the staff to improve their work.

Turbine corridor in painting process

Project Benefit

There are several factors that contribute to an improved total economy for the Kidatu and Tanzania. Below we are just focusing on the major factors:

1. **The available power generation capacity was increased from 175 MW to 210 MW, which represents an additional generation capacity of 35 MW. This additional generation capacity is deeply needed both for peaking power and as base-load during the rainy seasons. Since commissioning, the rehabilitated units have been operated continuously on almost full load at 50 MW, representing an additional annual production of about 150 GWh. In monetary terms this energy may be sold to consumers for about Euro 14 million, making it unnecessary to purchase power from IPTL at about Euro 11 million annually.**
2. **Through improved efficiency, an average total efficiency increase of 2% will represent an additional production of about 24 GWh. The increased power sales to consumers will therefore amount to about Euro 2.1 million on an annual basis with the current consumer sales tariff.**
3. **Through implementation of a new control and protection system, reduced outages of the plant will increase production by an estimated Euro 0.1 million per year.**

Based on the environmental, reliability and other benefit achievements, we may conclude that the project has been very successful, fulfilling all the required development objectives. It should be noted that the rehabilitation costs have been fully repaid with less than one year in full operation after rehabilitation of three units.

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