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Applying Waterfall-Agile Hybrid Methodology for Optimized Maintenance Activities in Geothermal Power Plants: A Case of Olkaria II Power Station, Kenya

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ABSTRACT

In Africa, the Kenya Electricity Generating Company (KenGen) is the leading geothermal power generator. KenGen owns and operates five conventional geothermal power plants and twenty-one wellhead units. The oldest operational geothermal plant is the Olkaria II Power Station, which has an installed capacity of 105 MW from three generating units, each rated at 35 MW. In May 2023, Olkaria II Unit 1 was shut down for 30 days to undertake planned contracted work on repairing the circulating water system pipework. The maintenance team took advantage of this outage to conduct a mini-overhaul. The overall objective was to inspect the unit and perform remedial work to restore its output from 29 MW to its rated capacity of 35 MW. During the inspection, it was noted that one turbine blade had fractured. Due to the complexity of the task at hand, a comprehensive project repair methodology needed to be adopted to ensure the unit was brought back within the contractor's 30-day timeline. Therefore, a hybrid methodology combining Waterfall and Agile approaches was employed. This involved comprehensive planning and scheduling, optimal resource allocation, and proactive maintenance and communication. Since this unique task had not been undertaken at this power plant before, this paper proposes detailing the activities involved in the turbine reblading process. It also demonstrates how the hybrid methodology approach transformed a potential crisis into an opportunity for capacity building and cost savings.

1 INTRODUCTION

Kenya Electricity Generating Company (KenGen) is the leading geothermal power generator in Kenya. KenGen owns and operates five conventional geothermal power plants and twenty-one wellhead units. The oldest operational geothermal plant is the Olkaria II Power Station, which has an installed capacity of 105 MW from three generating units, each rated at 35 MW. Two units were commissioned in 2003, and the third in 2010. The contracted capacity with Kenya Power, the system operator, is 101 MW, while 4 MW serves parasitic loads. Since commissioning, the plant equipment has undergone periodic maintenance to ensure continuous operations, extend its useful life, and streamline its performance and availability. While implementing these maintenance activities at the Olkaria II Power Station, various project management methodologies are deployed based on the project requirements and characteristics. This ensures that desired schedules and requirements are met at optimal costs, within a planned timeline, and to the desired quality. One such methodology is the hybrid approach that combines Waterfall and Agile methods.

1.1 Background

In May 2023, Olkaria II Unit 1 was shut down for 30 days to undertake planned contracted work on repairing the circulating water system pipework. The maintenance team took advantage of this outage to conduct a mini-overhaul. The overall objective was to inspect the unit and perform remedial work to restore its output from 29 MW to its rated capacity of 35 MW. As part of the inspection, the turbine rotor was lifted on Tuesday, 23rd May 2023. Upon inspection, it was noted that one stage three (3) blade had fractured at its root intersection with the rotor disc and broken off, causing minor secondary dents in subsequent stages. A comprehensive repair methodology had to be adopted to ensure the unit was returned within the contractor's 30-day timeline.

2 PROJECT MANAGEMENT IN MAINTENANCE

Project management in maintenance is the structured application of relevant principles, tools, and techniques to plan, execute, and control maintenance activities, thereby ensuring that maintenance work is completed efficiently, safely, and within budget while minimizing downtime and maximizing asset reliability. Ideally, a major overhaul in the Olkaria power stations takes approximately 45 days. However, the timeline available was 30 days, as provided by the contractor repairing the circulating water pipework. To complete the turbine repairs within a shorter timeline, we needed to combine elements of various project management methodologies without compromising cost, quality, or safety.

2.1 Project management methodology adopted

The project employed a hybrid project management approach, strategically integrating the structured, phase-driven elements of the Waterfall methodology with the adaptive, iterative principles of Agile. Key aspects of the Waterfall method in the project included detailed upfront planning, a 30-day deadline, and strict adherence to safety protocols, engineering standards, and regulatory checks. Elements aligned with the Agile method were prototyping and testing (trial fits of new blades before complete installation), cross-functional collaboration between teams, and daily stand-up meetings that kept the team aligned on progress and roadblocks.

2.2 Maintenance project planning

Maintenance project planning involves identifying and determining the resources required to undertake a project in advance. This ensures that projects are implemented smoothly with limited time, personnel, and financial resources, with minimal effort.

After confirming the availability of complete spare sets, extensive discussions were held to determine the best course of action to restore the damaged turbine stages. A cross-functional team was established to brainstorm viable options for restoring the Unit within the given timelines.

The brainstorming session listed four options in order of priority, from best to least preferred, as shown in Table 1 below.

Table 1. Selected options and their characteristics

#	Option Description	Characteristics of Options
1	Re-blading using internal capacity	Cost saving by eliminating Third-Party contracted services, minimizing outage period and consequential revenue losses. Capacity building enhancement for KenGen staff following exposure to previous contracted re-blading exercises. Potential growth of new revenue stream for KenGen.
2	Remote/Online support from Original Equipment Manufacturer (OEM) or other firms with re-blading capacity	Depended on the responsiveness and willingness of these firms to adopt this approach. Onsite participation of the OEM would not be readily available due to long mobilization timelines.
3	Direct Procurement from a prequalified local machining firm that has previously carried out re-blading works at Olkaria	Longer delivery period compared to both re-blading using internal capacity and remote/online support from OEM or other firms with re-blading capacity.
4	Restricted tendering of the entire scope of works to prequalified machining firms	From experience, this approach involved long procurement timelines that would result in major revenue leakages.

2.3 Team selection and development of the restoration roadmap

In 2019, Olkaria II Power Station faced a similar challenge in Unit 2, and an external contractor was engaged to do the repairs. However, following the same restoration route would have resulted in longer delivery lead times due to the lengthy procurement process. The waterfall method was adopted for the development of the restoration roadmap, in which a cross-functional team of Engineers and Technicians was selected to develop a roadmap for reblading using internal capacities, with guidance from available maintenance manuals and general experience. The project was considered complex because no similar activity had been carried out internally, and strict timelines for restoring the Unit to maximum output were in place.

3 EXECUTION

The execution phase commenced on 26th May 2023. All requisite tools and materials were mobilized from other power stations to maximize wrench time in readiness for the reblading exercise. The summarized schedule adopted is shown in Table 2 below.

Table 2. Summarized reblading schedule

#	Activity	Target Start Date	Target Completion Date
1.	Determination of required spares and tooling	26/05/2023	26/05/2023
2.	Removal of Stage 3 rotating blades	26/05/2023	29/05/2023
3.	Cleaning of Turbine rotor and new blades	30/05/2023	31/05/2023
4.	Inspection and testing of Turbine rotor and diaphragms (Non-Destructive Tests – Visual, Magnetic Particle Inspection and Ultrasonic)	1/06/2023	5/06/2023
5.	Static balancing	1/06/2023	2/06/2023
6.	Machining of locking pins (Set Pins and Stage Key)	30/05/2023	1/06/2023
7.	Assembly of new blades onto the Turbine rotor disc	6/06/2023	9/06/2023
8.	Turbine assembly	10/06/2023	14/06/2023
9.	Commissioning	15/06/2023	15/06/2023

3.1 Team selection and development of the restoration roadmap

The turbine blade removal process was complex and intricate. The team brainstormed and researched the admissible approach to adopt. Having no prior experience ensured that the removal process was conducted with the utmost care, where the stopping blade was identified due to the straight shroud profile. All the blades, bar the stopper blade, were extracted, as shown in Figure 1 below. A specialized jig was fabricated to remove the last stopper blade.

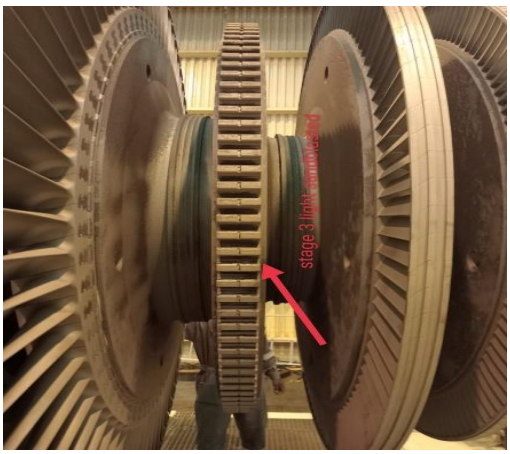


Figure 1. Turbine rotor without 3rd stage blades

3.2 Cleaning the turbine rotor and new blades

Cleaning machine parts is a crucial aspect of maintaining steam turbines. It involves removing contaminants such as oils, greases, polishing compounds, dust, and dirt, and is essential to ensuring the functionality and aesthetic appeal of machine components. The turbine rotor was cleaned by sandblasting. Sandblasting involves blasting turbines with grit to remove scale and deposits. This procedure was carried out in a fully contained environment to prevent contamination of the surrounding area. The third-stage grooves were blown with compressed air and wiped with a dry cloth to remove any remaining sand particles from sandblasting, preparing for blade installation. The spare blades numbered 1 to 122 were cleaned of their protective coating using diesel, abrasive pads, cotton rags, and scrapers, as shown in Figure 2.



Figure 2. Cleaning spare blades and sandblasting the rotor disc

3.3 Inspection and testing of turbine rotor diaphragms

The integrity of the affected components on the turbine rotor was ascertained through Non-Destructive Testing (NDT). These tests included Visual Inspection (VI), Magnetic Testing (MT), and Ultrasonic Testing (UT). These tests were conducted to prevent catastrophic, costly breakdowns, such as blade failures, that could result in revenue loss, penalties, consequential repair costs, or the ultimate replacement of damaged turbine components. The MT and UT services were contracted to external bidders through a restricted tendering method to machining firms that had participated in or provided such services in similar re-blading works at Olkaria. This was also buttressed by a recommendation from the Original Equipment Manufacturer (OEM) to conduct NDT on turbine components during overhaul to prevent catastrophic, costly failures. Furthermore, this was a complex task and had to be completed within the given timelines.

3.4 Balancing

Static balancing involves resolving primary forces into a single plane and adding a correction mass in that plane only. On the other hand, dynamic balancing uses sensitive electronic equipment to detect the centrifugal force or couple produced by rotation. It adjusts the system's weight to align the effective mass center with the axis of rotation. For this project, the team performed static balancing, measuring the weights of the individual blades with high precision to 0.0001 kg. Dynamic balancing was outsourced to an experienced service provider.

3.5 Machining of locking pins

Blade locking pins were not available at the stores. Therefore, 6 meters of 6mm diameter Stainless Steel (SS) rods were procured and machined at the Plant's Workshop. The purpose of the pins is to lock the blades and prevent them from disintegrating at the high rotor speeds.

3.6 Turbine blade assembly

The final blade assembly utilized specialized tools and a jig. Feeler gauge measurements were taken for the clearances on the slanted edges between each blade. Nickel-based anti-corrosion paste was applied to the roots of the new blades before insertion. The blade assembly process is illustrated in Figure 3.

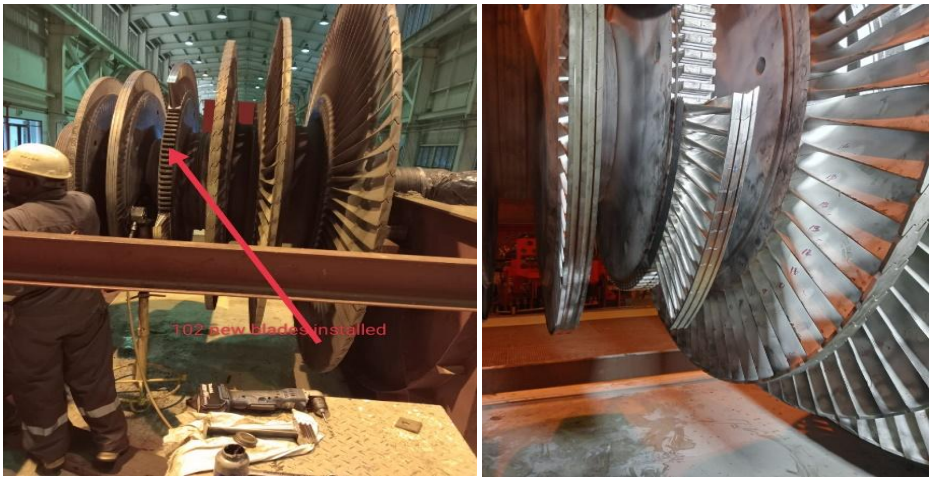


Figure 3. Turbine blade assembly process

3.7 Commissioning

The final blade assembly utilized specialized tools and a jig. Feeler gauge measurements were taken for the clearances on the slanted edges between each blade. Nickel-based anti-corrosion paste was applied to the roots of the new blades before insertion. The blade assembly process is illustrated in Figure 3.

4 LESSONS FOR THE POWER GENERATION SECTOR

The Olkaria II experience underscores several critical lessons for the broader power generation industry. First, hybrid project management methodologies—combining Waterfall's structured planning with Agile's adaptability—are highly effective in managing complex maintenance projects under stringent timelines. Traditional Waterfall approaches alone often lack the flexibility to accommodate unexpected technical challenges, such as the fractured turbine blade discovered mid-project. Conversely, pure Agile methods may struggle with the regulatory and safety constraints inherent in power plant operations. The hybrid approach enabled detailed upfront planning while allowing iterative adjustments through daily stand-ups and rapid decision-making.

Second, the case highlights the strategic value of internal capacity building. By leveraging in-house expertise rather than outsourcing repairs, KenGen avoided procurement delays and significantly reduced costs. This approach also facilitated knowledge transfer, equipping technical teams with hands-on experience in turbine reblading—a capability that will reduce future reliance on external contractors.

Third, proactive resource mobilization and cross-functional collaboration proved indispensable. The ability to pool tools and materials from other stations and assemble a multidisciplinary team ensured that the project maintained momentum despite its complexity. Finally, the emphasis on continuous communication—through daily progress reviews and transparent reporting—helped mitigate risks and maintain alignment across stakeholders. For the power generation sector, these lessons advocate for institutionalizing hybrid methodologies, investing in workforce development, and fostering agile communication frameworks to enhance resilience and operational efficiency.

5 CONCLUSIONS AND RECOMMENDATIONS

The successful restoration of Olkaria II Unit 1 within the contractor's 30-day window demonstrates that hybrid project management methodologies can transform high-risk maintenance projects into opportunities for operational excellence. The Waterfall-Agile integration provided the structure necessary for compliance and safety while enabling flexibility to address unforeseen technical challenges. This approach not only ensured timely completion but also delivered cost savings and strengthened internal technical capacity.

Based on these outcomes, several recommendations emerge for the power generation sector. First, utilities should formalize hybrid project management frameworks tailored to maintenance activities, incorporating clear guidelines for when and how to blend Waterfall and Agile principles. Second, organizations should invest in structured training programs to equip engineers and technicians with both technical and project management skills, ensuring they are ready for complex interventions. Third, proactive resource planning—including the creation of centralized inventories and rapid mobilization protocols—should be prioritized to minimize

downtime during critical outages. Fourth, companies should establish robust communication channels, such as daily progress reviews and digital dashboards, to enhance transparency and accelerate decision-making.

Finally, it is recommended that utilities develop a repository of case studies, such as Olkaria II, to serve as a reference for future projects. This repository should capture technical procedures, risk mitigation strategies, and lessons learned to promote continuous improvement across the industry. By institutionalizing these practices, power generation companies can achieve greater reliability, cost efficiency, and resilience in an increasingly dynamic energy landscape.

Acknowledgements

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