EFFECTIVE TURBINE PLANT OUTAGE EXECUTION

Pieter Krige

[1] ProGen Principal engineer 18/21 Railside place Dinsdale Hamilton New Zealand. pieter@progen.co.nz

Andrew Nish

[2] Mercury Turbine specialist. Andrew.nish@mercury.co.nz

Keywords: Turbine, outage, maintenance.

ABSTRACT

The results of a systematic approach to several extraordinary turbine maintenance outages that were executed over one year by ProGen as the service provider will be discussed. All of these outages were conducted successfully within the time and budget parameters set. There were no commissioning or operational issues encountered upon return to service. All of the outages were planned to a tight schedule based on optimizing historical performances. Although emergent work was discovered during most of the projects the work was able to be managed within the allowed time frame and within the planned budget.

The paper will discuss the challenges faced and successes achieved with the execution of these outages. It will focus on the principles followed to ensure the outcomes achieved.

The principles discussed will be:

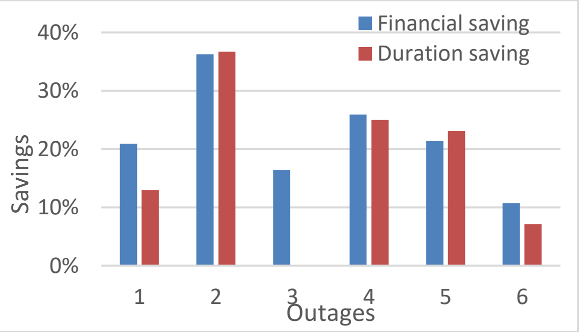
1. Partnership relationship between the supplier and the owner/operator
2. Planning for the outage using historic and forecasted findings
3. Plant life cycle managing and forecast
4. Preparation for execution done to the correct level
5. Decision making during the complete process leading up to the outage
6. Execution of the outage
7. Technical communication and decision making during the outage
8. Reporting on the completed outage
9. Post outage actions and planning for future outages

1. BACKGROUND

1.1 Planned vs Actual

All the outages executed during the period of one year were done in less or equal time planned but all were completed within the budget. The following graph summarizes the time and cost savings

Figure 1: Savings realized in terms of time and costs for 6 outages executed



From the graph it can be seen that all outages resulted in lower cost than budgeted. All outages apart from #3 were executed in less time than planned while none of the outages were delivered late. Noteworthy is outages 1, 3 and 6 where the cost saving was higher than the duration saving, this was due to effective execution that performed better than planned. The cost shown above only included execution labor costs.

The reduction in outage time can result in significant production gains and financial savings as well as additional earnings due to additional available production time. In some cases arguments can be made that the reduction in time and therefore the additional production time can offset a great portion of the cost to execute the outage.

1.2 Saving and Plant reliability

The first reaction normally on savings on outage duration and cost is that it was due to poor planning or a plan with too much fat and an excessive budget. The second argument is that the gains were at the expense of quality and will result in reduced plant reliability into the future.

All the plans were based on previous best achievements and in many cases these plans were already reduced for the optimizations included during the preparation phase.

All the units returned to service without any system or operational problems and all are still running without any symptoms that are relate to quality during the outages

1.3 Plant integrity

During all the outages, improved quality plans and documentation were used that resulted in much better records and decision-making tools and better quality.

Long standing problems were solved during some outages. These include problems such as cylinder half joint leaks, cylinder distortion, pipework strain, gland system under performance, oil and steam leaks.

Some of these problems were outside of the scope of the outage but were addressed when the symptoms were identified in the machines.

During the outages data was captured to be used outside the outage for the life plan of each machine to ensure that the machine integrity will be improved for the future and preparation for future outages can be done more accurately.

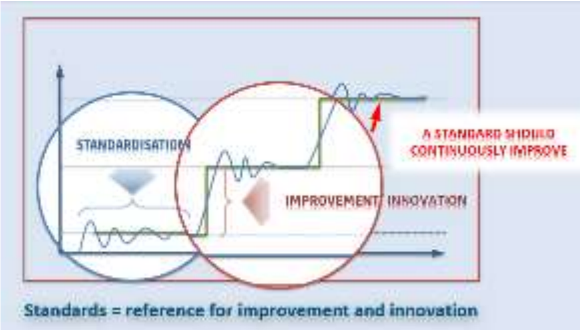
1.4 How it was done

It is not the intention of this presentation to re-write the text books on the methodology for the various aspects of the execution of projects but to point out the benefits of close relationship between the supplier and the owner as well as the importance to focus on the practical aspects and to have the correct skills available and aligned goals for all the phases of any project life cycle.

2. PARTNERSHIP RELATIONSHIP BETWEEN THE SUPPLIER AND THE OWNER/OPERATOR

It is important to foster and maintain sound relationships. The purpose of having an established partnership with a supplier is so that one can create standardization. Without standardization there is no improvement possible. Once standards are in place then there is a reference for improvement.

Figure 2 The importance of innovation



This partnership allows for constant communication on plant performances so that they are constantly engaged and are always aware of the operating and performance of all the geothermal generating plant.

A solid partnership allows for implementation of best practices and the alignment of objectives. It allows and caters for the opportunity of building up a strong skills base and the development of competent resources which sets up for success.

All personnel to be used on all projects are mutually agreed to ensure both parties are satisfied with the skill package. A target of 80% of the repeatability of the resources must be met. Through this process we have built up exceptionally good hand-picked teams.

Budgets are based on estimates with invoicing done on real expenditure and actual consumption.

Overheads are kept to the minimum. All support services such as safety, quality control, rigging, crane driving, logistics etc. is handled within the team.

The lead for all aspects of the outage is kept to a small dedicated experience and qualified group, specialists are only used when required.

3. PLANNING FOR THE OUTAGE USING HISTORIC AND PREDICTED INFORMATION

Anyone operating in the maintenance of steam turbines in the geothermal environment will know that surprises are to be expected. The number of geothermal variables and their interaction associated with the critical parameters are significantly more difficult to predict than the steam turbine maintenance in the more controllable environment of fossil fired thermal plants.

It is therefore not uncommon to open a geothermal machine to find a surprise package of erosion, corrosion, geothermal deposits and distortion. Such discoveries often have a significant impact on the best planning and preparation carried out for any maintenance project in this environment.

3.1 Plant operational and turbovisory data

It is vital to ensure that the preparation includes the condition assessment of the machine well in advance of any outage. Severe damage mechanisms such as erosion and deposits may have some symptoms detectable by plant operational and turbovisory data and therefore the data must be carefully reviewed on a continual basis.

For such a review to be effective critical skills are required as the information sought could be well disguised and hidden in the bulk of information.

3.2 Plant physical condition assessment and trends

Evaluating historic reports in conjunction with another to form trends of the life cycle and failure mechanisms for each component is paramount. For this reason, the quality of records and reports are vital. A project executed without the completion of an ITP with accurate ITR's and also without a detailed report with findings and forecasted developments and proposals becomes a void in the life of the plant that can have a severe impact on future projects.

The quality and accuracy of the information is as vital as the relevance of the information captured. It must be understood why information is captured to ensure that the correct information package is available to be used to the purpose intended.

3.3 Scope of work during the outage

When all the information has been evaluated, the scope of work for the planned outage can be developed with calculated predictions. The scope must be compiled such that the goal of the project outcome is supported. At this point it is important to distinguish between the requirements to meet the goals of the project and the extra's. It is often tempting to return a machine back to the as new condition, spending time and money instead of harvesting the residual life left in the components, deferring major expense and suffering extended outage durations.

There is always a consideration to be made of time versus expenditure. It is often much easier to replace components rather than expending a measured amount of time, effort and cost on assessment and refurbishment.

When the condition assessment of a machine is complete, then it becomes possible to accurately determine the impact of the various options for each component in terms of replacement, repair, refurbishment or rotable strategies.

3.4 Planning

The plan for a project must be as realistic as possible without any allowance for unlikely contingencies. Probabilities and likelihood of expected contingencies need to be weighted before addition to the plan. Should such contingencies exist, all effort must be made to quantify the variables accurately.

When a potential scenario exists that cannot be accurately planned for, it may be necessary to compile a separate plan with that scenario as a plan B. This will prevent the focus on the possibility distorting the rest of the plan.

A plan should always contain all known activities with the correct logic links, necessary resources, measured durations and an accurate critical path. To allow for poor performance in a plan is inviting that performance to the project.

4. PLANT LIFE CYCLE MANAGING AND FORECAST

Generating Plant cannot be run to failure and needs to be operated and maintained in accordance with Pressure Equipment Cranes Passenger Ropeways (PECPR) regulations. Ensuring that long term reliability and performance is achieved and maintained by operating within manufacturers' specifications.

The life cycle plan of a turbine generator must be seen as a living plan and must be flexible to adapt to the actual condition and operational requirements of the machine. Operational and maintenance practices must target the highest practicable levels of availability and reliability.

A single incident that occurs during operation or a finding during an outage or a new production requirement can result in significant change in the machine life cycle plan.

A life cycle plan can only be of value if all the life consuming aspects are carefully considered.

One of the most important criteria for the management of a life cycle plan is accurate condition assessment that is achieved with proper non-destructive evaluation, condition monitoring plant data evaluation, operational data and production requirements in order to:

- Reduce the likelihood of undetected failure mechanisms causing unplanned outages.
- Provide early detection of defects, allowing sufficient lead time for planning of repair, refurbishment or replacement.
- Assist in scope development for outages.

5. PREPARATION FOR EXECUTION DONE TO THE CORRECT LEVEL.

Preparation for a project is often neglected as it is not seen as productive time, but an hour spent on preparation can save days in execution. It is therefore vital to evaluate the bottlenecks and constraints critically to ensure that actions are taken to remove these delays during the execution.

The omission for example of the certification of a calibrated tool could result in major delays and even re-work.

Preparation is the time when the thinking caps must be on and innovative thinking can reap major benefits. An aspect like the floor plan during the execution can result in extended crane time and duplication of component movement. When the plan is properly compiled the execution, benefit is sometimes remarkable.

An example: During one outage the limited floor space and crane capacity had to be dealt with. An option used before was to ship the top casing to another nearby site where additional crane and floor space is available. This worked in the past but resulted in key skills travelling up and down and caused a disconnection between the teams at the two sites where interaction is important to achieve the required quality.

A truck was used as a mobile working platform and the top casing was fixed on the truck and all work done to the casing was done while positioned on the truck.

When crane work was required the truck pulled into the loading bay and when the loading bay was required for other activities, the truck was moved out. This resulted in major savings in time and massive increase in the quality. All resources required for the execution must be considered during the preparation. During the preparation the plan must be challenged to the finest detail to ensure that all aspects are prepared for at the correct time and level.

The following picture is an example of how not to use floor space available in a turbine outage project. The floor around the machine is occupied with office container, tee rooms, access containers and tool containers. It indicates that he planning and preparation was not done well and there were too many people at site, with extensive crane travel times and crane movement that would impact on productivity by preventing work while a load position incorrect travels over a work front..

Figure 3: how not to use available floor space

Preparation is also the time to prepare the quality documentation, and the system must be reviewed and approved for execution.

Other aspects related to the project execution not part of the plan is equally important during the preparation, items like safety manuals, training, accommodation, travelling etc. can have a major impact on the project if not prepared properly.

6. DECISION MAKING DURING THE COMPLETE PROCESS LEADING UP TO THE OUTAGE

Decision making is one of the most common sources of stress between customer and service provider as any decision taken can be very easily seen as negative when it presents challenging consequences. For a partnership to have agreement during the decision-making process it is vital that the goal is shared and that all decisions impacting the other party is taken with the consultation with the other party.

This is a simple argument but it becomes complicated when those parties do not have the same goals and will never have due to the difference business focus. Therefore, such a partnership must be very clear in terms of the responsibility of each entity and communication must be top priority.

The different constraints of each entity play a major role in the decisions taken. For example, the production requirements of the plant versus the capacity of the service provider.

It is therefore very important that the partners are clear to each other and that mutual respect for each other's constraints is vital.

Such a relationship takes time to form and the stability of the individuals involved is important as any changes can lead to setbacks in the development of the relationship.

For these outages the engagement continued from the completion of the previous outage on each machine until the execution of the outages referred to in this paper. Only one of the machines was a first-time outage but the team members stayed the same.

In the period leading up to an outage the reports from previous outages forms the basis of any discussions on any topic. As the scope of work changes between outages on a machine, certain topics has to use information from outages prior to the latest.

It is vital that any decision made during the life of any project is that the decision makers are qualified for the job. Turbines and the technology involved can be very easily underestimated and this could lead to major problems later in the life of the plant.

The level of acceptable risk must be agreed between the parties and all aspects of a risk decision must be clearly understood before decisions are made.

For example, it is very easy to replace any and all components that has wear or affected by an active failure mechanism. It is a lot more complicated to use components for as long as possible until the component use has resulted in the maximum return without putting the plant availability and reliability at an unacceptable risk.

The strategy in place for outage execution is that regular meetings are held with clear actions and targets.

Example of where innovative thinking caused major improvement were:

- Deficiencies in previously used Quality systems lead to the revise of the system. The results were clear from the onset and lead to major benefits like improved accuracy and reduction in rework and therefore major improvement in productivity.
- A jig designed and built before an outage was used to machine seal components independently based on data capture in the outage. The seals were turned around in record time and the clearance associated problems solved.
- The specific distortion of a casing was causing major set-up and clearance problems during the outage. A strategy was proposed to bolt the casing to the foundation before the half joint was separated. This resulted in a surprising success and saved significant time during the clearance checking and re-build of the cylinder.

7. EXECUTION OF AN OUTAGE

The execution of the outage is the coming together of all the planning and preparation and is a time to do as the negotiation and options evaluation should have been done. The executing team should know exactly what to expect and what to do from the word go to the point of site clearance on an individual level.

The better the team knows each other and the role of each individual in the team the better.

For the outages covered the team stayed more or less the same. The lead from the customer and ProGen was the same for all the outages, more than 80% of each outage team members was also part of previous outages.

For any turbine generator outage, a major component of successful execution is to have the correct motivated skills available for the execution. No form of planning and preparation can replace well trained and experienced trade staff. Execution is all about getting the job done and done right. The team mentioned above is a very carefully selected team and the compilation comes over a long period with each individual selected for a certain skill set and personality.

Any new member is carefully selected and in the first encounter placed together with known members that can guide and keep an eye on the novice.

Such a team however must be led by the correct technical lead, to ensure focus is in the correct direction. The engineer must understand the machine design and function of each component clearly as well as the failure mechanisms that are involved. This is essential for the successful execution as well as the gathering of the correct relevant information.

The first outage of the 6 was also the initiation of a new level quality system from ProGen with upgraded ITP and ITR's. The results that came with this was remarkable. Decisions were made on accurate data and the results verified. The system is real time and no time is lost in the process.

The level of trade skill and technique required for the proper service of Turbine generators are in many cases underestimated. Visually these machines appear simple, but there is a lot more to it than meets commonly considered. Due to the proper understanding we ensure that the methodology employed is to the highest standard. There are often very subtle failure mechanisms introduced into turbine generator due to lack of understanding, that can severely affect the machine capacity, availability and reliability. One such is phenomenon magnetism.

Figure 4: A magnet base drill used on a rotor disc

The picture above shows the use of a magnet base drill to drill balance holes on a rotor disc. This is a picture taken on a plant in NZ. To the layman this looks like a well-resourced tradesman drilling holes accurately. To the turbine specialist this is a disaster in the making as the residual magnetism left in the rotor may lead to current generation that will cause bearing or seal failure or worse.

Logistical aspects of the outage were well prepared and the execution team can focus on execution. Spares and consumables are at hand, ready and prepared, no time is lost with trivial distractions.

Large logistical components like mobile cranes and rotor transport was well planned and executed, with not impact on outage time.

In many cases the level of preparation lead to significant gains. For example:

- A planned re-blade of a rotor was prepared so well that the actual re-blade was done in shorter time than even the OEM had done before.
- A rotor shipping, balancing and returning exercise was done with a duration much shorter than planned as all the preparation caused all the activities to fall in place.

8. TECHNICAL COMMUNICATION AND DECISION MAKING DURING AND OUTAGE

One of the vital components is communication between the execution partners and for these projects the real time communication and decision making was very effective.

During execution, no time is programmed for decision making and any findings therefore have to be discussed and a mutually agreed decision made without impact on the execution process or timetable. Examples

- During the inspection of the turbine it was found the gland steam system suffered from a design deficiency. A re-design was proposed, executed and commissioned within the outage within 10 days. Following the outage, this system functions as required.
- Upon opening a turbine, it was found that the rotor had suffered severe damage due to erosion of deposit built up in a critical area. A stress analyses and risk assessment was done in the time it took to clean and NDE the rotor. The rotor was re-installed for a 2-year period to allow the procurement of a new rotor.
- A turbine casing was leaking during operation for many years, following strip down an evaluation was done and actions implemented such as scraping of the half joint and changes to the bolting procedure. This resulted in the long-term leak resolved. An FEA done following the outage confirmed that the decisions taken during the outage were correct.
- Upon opening a turbine, it was found that the prepared plan to fix a known clearance problem was based on inaccurate historic information. The plan was changed and another method devised and implemented and the problem was resolved.
- Upon opening of a turbine cylinder symptoms of inadequate bolt clamping force was identified. Although the bolts passed NDE done in the prescribed way, the engineer suggested additional NDE. All the bolts in the specific area were found cracked, some virtually through the bolt.

The lessons we learned included:

- The decision-making group should be as small as possible
- The decision makers should know what they are dealing with
- There is no time for politics and other time-consuming games
- Nice to have's must be avoided
- The easy way is not necessarily the right way

9. REPORTING ON COMPLETED OUTAGES

In many companies, and for many individuals, outage reports are considered an unnecessary expenditure. That can be true if the report does not represent the value of the cost to compile the report.

When a report contains accurate facts regarding the condition of the machine, the findings during the outage and valuable information for future outage planning and optimization, then it is unlikely that the repot cost can be considered too high.

For a report to be relevant and accurate, it should be completed and available as soon as possible following and outage to ensure that the memory of the outage is captured in full.

For the 6 outages discussed in this document, all the reports were delivered within 3 weeks following the outage. All reports content is captured as it happens on a daily basis following the outage it is merely organized and tidied up.

The report content is considered so valuable that during outages, hard copies of the past outages reports are at hand. This is a major benefit for quality assurance and optimization.

The typical additional expense for a report is one weeks Labour for one individual.

Major components of outage reports are:

- Health and safety considerations
- Execution of the scope
- The completed IP and ITR's
- Findings and what were done to resolve it
- NDE
- Future recommendations of all aspects of the outage
- Pictures

In the lifecycle management of high value capital machinery, outage reports are considered a key element for accurate information. Without such reports, the decision maker is in a much weaker position and therefore will not be able to optimally manage the plant availability and reliability. During outages the team will be faced with surprise findings that may result in outage delays and risk-based decisions that may result in loss of plant reliability and availability.

10. POST OUTAGE ACTIONS AND PLANNING FOR THE NEXT

Post Outage the Outage service report is compiled by ProGen and submitted within 2 weeks post outage. This report addresses the work that was carried out during the outage in great detail. Provides health, safety and environmental feedback and the last section of the report contains recommendations.

These recommendations normally arrange from a whole host of issues that were identified during the outage that were not deemed critical enough to address during the outage or due to time or spare constraints were deferred. The recommendations also focus on lessons learnt and how to improve on the next outage.

These recommendations are then compiled into an action plan to ensure that they are addressed and actioned in order to ensure that they are correctly planned for and addressed at the next opportunity. This also allows for budgets to be updated to secure the required future spares or special tooling that will be needed.

In conjunction with the ProGen service report a separate post shut report is compiled by the Owner's turbine specialist that captures the shut performance from the owner's point of view. It also addresses what refurbishment work needs to be carried out on the spares that were replaced during the outage to get them serviceable for the next outage and to ensure that they are viable spares should they be needed in case of a breakdown.

The asset strategies are then updated to reflect the work that was carried out during the outage as well as updating the asset score of each component and plans are then adjusted and updated accordingly.

A post shut review meeting is held with the entire outage team where the whole outage is focused on. This allows for external factors to the turbine to be addressed and lessons learnt are discussed and documented to ensure that the outage bar keeps getting raised and that the outages go from strength to strength.

A post shut meeting is then held between the Owner and ProGen to discuss what went well and what did not. Detailed discussions are held on how the standards can be improved to ensure continuous improvement.

These are all incorporated into the planning for future outages as well as how the lessons learnt can be applied across the immediate upcoming shuts.

As part of the future planning the risks are also discussed and agreed to. Future plans are then updated, and innovative ways are documented to reduce or eliminate the risks.

In all the planning leading up to future shuts including the scope of work development for each upcoming outage, ProGen is always involved in all the meetings and deliberations and this process aligns the thinking and results in a very sound outage plan with consequential good outage outcomes.

ACKNOWLEDGEMENT: