

Z-R Consulting's Outage Support Philosophy

Z-R Consulting has frequently been called for assistance following plant outages where all work was performed to “industry standards” by all initially involved parties, including shop repairs, balancing, and realignment and reinstallation, but where the unit still could not operate upon restart (or could only operate on the edge of allowable margins). Z-R Consulting has found that “industry standards” contain assumptions on expected rotor condition and rotordynamics behavior, and are only fully acceptable when dealing with rotors measuring within the initial OEM runout tolerances or guidelines from ISO 1940.

However, in many “special cases” (which are quite common in the rotor service industry), unexpected operational excursions or simply many years of rotor operation have created rotor bows, eccentricities or coupling defects outside of ISO 1940 tolerances. In these cases, “standard industry practices” are often insufficient and do not fully address rotordynamics behavior caused by such defects. Upon unit restart, this can result in lost days or weeks of power production for field balancing (which is not true balancing) or adjustments to patch up the problem, which often leads to larger problems in the future.

Through many years of experience in dealing with such “special cases”, Z-R Consulting has developed a full turbine-generator outage approach that is guaranteed to identify and fully remedy all rotor flaws, such that a smooth post-outage restart without needing field balancing can be guaranteed if all recommendations are properly followed. Z-R Consulting's approach is designed to fit readily within a standard outage plan, and only adds minimal time and expense to acquire all required data for our proper analysis, but is guaranteed to save the plant substantial costs for future repairs or downtime in the long run.

In light of this, the following overview of Z-R Consulting's technical approach for full outage support and rotor oversight is offered:

I. Prior to outage:

The plant should confer with Z-R Consulting prior to finalizing a general outage workscope, since Z-R Consulting's workscope and procedures must be blended into the general plant outage plan and workscope. In summary, Z-R Consulting's procedures to incorporate into the workscope include:

- Record vibration data during unit shutdown for rotordynamic behavior and condition assessment
- Physical rotor evaluation from as-received shop data, including full runouts of rotor body and couplings/faces with sufficient measuring locations
- Finite element modeling of the rotor (if needed)

- Identifying required shop machining corrections (if needed)
- Verifying shop repair/machining results through final full runout evaluation
- Shop rotor balancing using our proprietary balancing method on a high or low speed balancing machine
- Applying our alignment recommendations during reinstallation (if needed), and verifying coupling alignment data at reinstallation
- Recording unit vibration at startup to verify unit condition

II. On-site at the plant, at start of outage:

- A. Z-R Consulting should verify that the unit scheduled for outage has required functional vibration monitoring instrumentation for proper diagnostics and evaluation. “Required instrumentation” means two proximity probes per bearing, with at least one seismic sensor per bearing. If lacking necessary instrumentation, Z-R Consulting should instrument the machine with temporary sensors. This instrumentation is required to generate Bode plots, polar plots, shaft orbits, shaft centerline plots and other means of analysis for Z-R Consulting to evaluate and identify faults in all components of the rotor train, as well as verify bearing alignment. The findings here are used in part to determine and guide and/or supplement necessary shop procedures.
- B. At a convenient time for the plant, prior to or at the beginning of the scheduled outage, Z-R Consulting should be present on-site to record full vibration readings for a unit shutdown, from unloading, to roll down, to full stop. From this data, Z-R Consulting will point to any abnormalities of the turbine-generator in its present state, including bearing alignment and condition of couplings. In case only a partial outage is planned (when not all rotors or bearings are going to be removed for repair), Z-R Consulting will point out any concerns regarding the components not currently scheduled for work and will point out the need for potential compromises during the unit restart, either for what should be done to optimize the unit within imposed limitations, or for what the best-case expectations should be upon restart. Depending on findings, any critical alterations to the planned workscope would also be identified and discussed.

Additionally, prior to any disassembly, oil bore readings identifying the initial shaft and bearings’ position should be taken as a reference and provided to Z-R Consulting.

- C. Concurrently or prior to the outage and as necessary, Z-R Consulting will construct a finite element model of the rotor being serviced (and/or whole rotor train) to verify critical speeds and resonant frequencies (lateral and torsional), assess operating procedures (startup, shutdown, holding speeds, etc.), optimize alignment and catenary curve, as well as model/modify bearing properties if relevant. This analysis is especially important if an LP turbine has experienced any breaking of lashing wires or breaking of L-0 blades.

III. Shop work:

- A. Z-R Consulting's participation in shop work would be with minimum interference in established shop procedures, except in areas directly affecting rotordynamics (TIR measurement and evaluation, required machining corrections, often of couplings or journals, and balancing method if/when required). Z-R Consulting's participation and methods will not interfere with any established, proper procedure of the shop (but may interfere with and prevent "shortcuts"). However, it is crucial that the service shop be fully aware of Z-R Consulting's requirements prior to the outage and commencing work, to anticipate appropriate scheduling and allocation of shop resources. If there are any questions or issues, Z-R Consulting will visit with the shop ahead of time to clarify requirements and explain the approach and purpose, and assist the shop with determining appropriate scheduling to accommodate the required procedures.
- B. Z-R Consulting should be present or kept informed for rotor incoming total indicator runout (TIR) measurements, to ensure sufficient data points are taken for couplings, faces, journals, and the rotor body. Immediately after acquiring incoming TIR measurements, Z-R Consulting will perform an eccentricities evaluation of the whole rotor (couplings, journal and body) from a rotordynamics point of view. The evaluation results will indicate what *must* be machined, what should be machined, what can be balanced and in what method. Z-R Consulting will evaluate and determine based on the rotor condition if the rotor has a sufficient number of balancing planes to be correctly balanced. Recommended shop work will be optimized to maximize rotor reliability and to minimize cost. (Z-R Consulting does not perform any metallurgical assessment of rotors.)
- C. Z-R Consulting can provide guidance for machining corrections as needed (including the need and/or suitability for adding balancing planes to accommodate our balancing method, if required based on rotor condition – any residually bowed rotor *must* be balanced in at least 3 balancing planes). Following rotor machining/repairs, Z-R Consulting will verify the success of repairs through another full TIR evaluation of the rotor body, journals, and couplings/faces. Criteria for determination and acceptance of the rotor condition (of body and couplings) will be ISO 1940 or GE standards.
- D. Z-R Consulting should be present to witness rotor balancing by a service shop. If the rotors are fully within ISO 1940 tolerances, the shop can acceptably use the standard industry approach, and Z-R Consulting will supervise, but need not actively guide the process. However, in the case of rotors with bows or body eccentricities exceeding 0.002", the rotor must be balanced from the start using Z-R Consulting's 2N+1 balancing method (where the first rotor critical must be balanced in three balancing planes simultaneously).

IV. Reinstallation and startup on-site at the plant:

- A. During physical rotor reinstallation and bearing alignment, Z-R Consulting need not be present on-site for the physical installation work. However, prior to coupling the rotors, 16-point adjacent-coupling face readings (feeler gauge measurements), as well as rim readings (dial indicator), should be sent to Z-R Consulting for evaluation and comments.
- B. Z-R Consulting should be present on site during unit restart to acquire vibration data to verify that vibration levels and any other relevant parameters are acceptable for unit operation. If any issues or concerns arise, Z-R Consulting will provide immediate analysis and recommendations for any action if needed.

V. Other Services:

A. Root Cause Analysis:

If a unit is experiencing turbine-generator operational problems (often seen as “vibration”), the root cause is not necessarily found in the turbine or generator alone, but can also be from other areas such as bearing design or positioning, overall rotor train alignment, other unit subsystems such as the lube-oil system or control system, or from plant operation practices, or many other sources. For any unit experiencing problems, Z-R Consulting can provide root cause analysis of the problem, and will guarantee determination of the specific root cause(s), and will provide specific solution(s) to resolve the problem.

B. In-Shop Vendor Collaboration:

Z-R Consulting is available to meet with new shop vendors to synchronize Z-R Consulting’s unique requirements and the shop’s standard procedures, in any crucial area where a difference is noted (most likely in TIR measurements and rotor balancing). Typically, in most other areas standard industry practices are suitable, and Z-R Consulting will verify that the shop’s approach adheres to those standards. For shop vendors unfamiliar with some of our methods, Z-R Consulting will discuss the approach and instruct the shop on the required procedures, assure understanding and agreement of time and labor requirements, and verify the capacity of the shop to properly perform all required work.

Subsequent verification of machining work or repairs can also be performed remotely upon receiving properly taken rotor measurement data, saving costs for travel and on-site time.

It could be noted that one shop in particular that Z-R Consulting frequently consults with fully understands, accepts and follows our rotor oversight approach – this is the Toshiba rotor service facility in West Allis, Wi.

C. On-Site Field Advisement:

Z-R Consulting will provide any advisement on-site as needed, as a representative would likely already be on site for shutdown or startup monitoring when relevant site work is taking place. If proper site data is taken (oil bore readings, coupling feeler gauge and rim dial indicator readings during installation), Z-R Consulting can provide further analysis and guidance remotely as well.

As with all our past and present customers, Z-R Consulting will actively represent the interest of the plant in dealing with repair vendors, OEMs, and other service groups and personnel, and will present our findings and provide expertise as needed at meetings, as well as in project reports.