Transmission & Bearing Corp.

Technical Notes by Dr. Mel

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Improved Competitiveness for Conventional Coal & Gas-fired Power Plants

A Justification for Re-evaluating Maintenance and Upgrade Policies.

For Many 1960-1970 Vintage Plants, Efficiencies can be Improved up to 15% (or more) and Operating Ranges can be Widened.

With the new administration in Washington, we have already seen a difference in the regulatory philosophy being exhibited. A new attitude has appeared which strives to greatly reduce regulations on electricity generators and at the same time protect the environment in a more reasonable manner.

Under the prior regulatory regime, the regulations were so onerous that many conventional coal-fired and gas-fired generating stations were either (a) planned for permanent shut-down because the regulations were making them unprofitable, (b) the regulations would force installation of very expensive emission controls, or (c) the stations would run with minimal maintenance until they were no longer operable, and then close.

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With the new attitude

in Washington, this is the opportune time to re-evaluate all maintenance and upgrade policies ... to improve efficiency, performance, availability, and reliability.

Many Generation Stations are Excellent Candidates for Upgrades with Substantial Efficiency and Performance Upgrades:

Candidate Plants: Prior to the 1980s, utilities enjoyed a constantly growing demand for electricity. Most generating stations of the era were designed as base-load power generators operating at or near max generation. Equipment was selected for quick delivery and not necessarily sized to optimize the efficiency of the generating unit. With the range of options available today, efficiency and performance optimizations for these older plants can be achieved.

Today the question before us is this: Are these older plants valuable or are we better off just shutting them down? Consider this: As each new solar or wind project comes on line, the need for stand-by power increases. The renewable source generators provide intermittent power. Stand-by generating stations are required in periods of reduced solar and wind generation. **Due to the need to have back-up power plants and to pay for the capital to build new plants, the levelized cost of solar and wind is very high—3-5 times the cost of electricity from existing coal fired powered plants.** However, these older plants have been PAID FOR. Only the upgrades have to be paid for, making these plants highly desirable.

Existing generating stations that can turn down to low generation and then can come up to full power in a short period of time can help to alleviate the problems caused by intermittent sources. Due to the nature of the steam cycle, sub-critical steam plants that are retrofitted with known upgrade technologies are better suited to run down to10% of maximum capacity. Such plants can provide this much-needed stand-by capacity, and with lower heat rates, they can compete with other generating stations.

Effective Upgrades to Achieve Substantial Efficiency, Availability, Reliability, and Operability Improvements of Rotating Machinery:

The major technologies that can be implemented for the turbine-generators and the associated auxiliary rotating equipment that can significantly improve the efficiency, availability, reliability and operability of power plants are these:

1. Retrofitting 3-D steam path technology can often improve efficiency by 6-10%.
2. Optimizing the size of high power Boiler Feed Pumps, Induced Draft Fans and Forced Draft Fans, as well as introducing Variable Speed Fluid Drives where possible can improve the efficiency from 2% to 4% for each function.

For conventional coal-fired and natural gas-fired large steam turbine-generator units, a good starting point is this:

1. Select expected operational functionality, depending in part on boiler design:
    - To operate on constant throttle pressure over the entire load range, using partial arc control valve methodology, or
    - To operate on "Sliding Pressure" over all or a portion of the load range.
    - Determine desired minimum stable generation as a percentage of full load rating.
2. Implement an upgraded steam path using available 3-D steam flow design techniques and control valve operation to achieve the operation method selected above. HP, IP, and LP turbine sections are all candidates for upgrades by the major turbine manufacturers. TRI Align-A-Pad® tilting pad bearings have been designed to suit the particular characteristics of upgraded turbine and nozzle block designs, permitting even greater improvements in MW generation and efficiency than can be achieved with standard OEM bearings. With the resulting redesigned new rotor and bearing system, greater availability, reliability, and operability can be expected. Improved reliability leads to fewer starts and stops and reduces associated costs.
3. Optimize sizing and powering of large auxiliary equipment, primarily boiler feed pumps and fans:

Most BFPs and Fans are NOT optimized to support the existing turbine steam path, and more importantly at this time, they are NOT optimized for any upgraded turbine steam path. Furthermore, it is very UNLIKELY that they are designed for operating over a wide operating generation range including stable operation at a new minimum of approximately 10% of maximum generation. Such low generation conditions that are stable can be and have been achieved using Variable Speed Fluid Drives to power BFPs and Fans.

Regarding BFPs, the impellers and stationary parts can be redesigned and manufactured to optimize stable feed water flow conditions and power consumption for the revised turbine operating conditions.

It is advantageous to drive the BFPs by Variable Speed Fluid Drives (VSFDs) that are in turn driven by either an induction motor or the end of the turbine-generator shaft. TRI designs these VSFDs and the associated auxiliary equipment to be able to operate anywhere in the head-capacity chart for the BFP that suits the turbine. It is interesting to note that a BFPs driven from a VSFD powered by the main turbine shaft is an extremely efficient method for powering boiler feed pumps, as compared to mechanical drive steam turbines because the steam stays in the main turbine which has much higher efficiency.

Regarding fans, fixed geometry fans, especially centrifugal fans, are simple devices and require relatively low maintenance as is necessary to achieve maximum availability and reliability. Fans can be designed or modified to suit the optimum air flow needs. The air flow controls can be modified to be primarily speed controlled and depend less on either outlet damper or inlet vane control. This is a critical point for improved efficiency over the entire load range, especially when low power for overnight operation is required.

Variable Speed Fluid Drives can be sized and manufactured to match the optimized fans, regarding fan speed range and absorbed power.

Electric Motors of sufficient power are used to drive the Variable Speed Fluid Drives. An advantage to the use of VSFDs is that the motors have only the input sections of the attached VSFDs to drive, and therefore, a 6000 hp, 600 rpm motor can rapidly accelerate to reach design speed in only a few seconds, perhaps 3 to 5 seconds. Much shorter than 45 to 60 seconds required to start when the motor is directly coupled to a heavy ID fan. This definitely minimizes the period of high inrush current, and therefore, minimizes the duty experienced by the motors. After reaching full speed, the VSFD is loaded.

Calculations for New Operating Conditions:

To determine the overall system efficiency improvements obtained by using the upgraded components described above, a computer program such as PEPSE can be used. PEPSE is a steady-state energy balance software program that calculates the performance of electric generating plants. It is supported by Curtiss-Wright.

While the efficiency improvements are dependent upon the circumstances for each generating unit, the clear consequence is that very substantial efficiency improvements can be made when all of the individual contributions are added up. This applies throughout the entire generation range as will be needed in the future, not just the maximum generation point typically used as the only evaluation point in the past.

TRI's History over the past 50 Years:

TRI has been in the business of solving rotor vibration, bearing damage issues, and other rotating machinery matters for over fifty years. This includes engineering analysis, design, manufacturing and installation of many retrofits and upgrades to improve operability and efficiency of power plants.

In this Evaluation Process, Please Consider What TRI can do for your Equipment:

- Babbitted Bearings: Fixed bore or tilting pad
- Basic replacement and repair. Most repairs are completed in a few days. Simple upgrades using a different bearing bore geometry are completed in the same time period as machining the original bore geometry. Our time schedule and pricing beats most OEMs. TRI bearings have proven to be the best for reliability and for resolving "problem" bearings. New fixed bore replacement bearings are manufactured in 4 to 6 weeks after receiving the steel forgings.

- New sophisticated tilting-pad bearing upgrades (TRI Align-A-Pad®) control difficult rotor

vibration and bearing damage issues. TRI can provide the engineering analysis of the equipment problems and can make these bearings in 4 to 8 weeks after receiving the specified steel.

- A very common use of TRI Align-A-Pad® Bearings is in HP or HP-IP Steam Turbines of all sizes. These bearings are capable of controlling rotor vibrations due to unbalance over the entire load range for partial-arc operation, or to eliminate sub-synchronous rotor vibrations, including eliminating "steam whirl" when the bearings are lightly loaded.
- "Lift oil" (jacking oil) mods to existing (or new) bearings reduce bearing wear, thereby reducing maintenance, and/or reducing turning gear motor amps.

Vibration Analysis and Diagnostics:

Today, there are many power plants and other companies that perform analyses and diagnostics of rotor vibration data taken from rotating machinery. TRI has been performing this service since 1971. This activity provides information that can be helpful in selecting what bearing designs would improve the vibration control or reduce bearing damage. Historically, based on this type of diagnostic activity, TRI expanded into the more complex business of making and installing bearings to resolve the identified problems. TRI continues to offer vibration analysis and diagnostic services today, as desired by power plant personnel.

Variable Speed Fluid Drives (Hydraulic Couplings) for Boiler Feed Pumps:

- Large Boiler Feed Pumps are driven by Variable Speed Fluid Drives, Variable Speed Steam Turbines, or by Variable Frequency Electrical/Electronic Motors.

- The most robust and reliable method, as well as the lowest cost alternative particularly when long term maintenance is considered, is the use of large variable speed fluid drives driven by the main steam turbine-generators or by induction motors. Many years ago, TRI developed upgraded designs for a major group of these Fluid Drives, that when incorporated, typically permit 10 to 12 years of operation between inspections.

Variable Speed (Mechanical Drive) steam turbines typically require maintenance on the valves and turbine steam path every 2 to 6 years, which affects availability and reliability and maintenance cost.

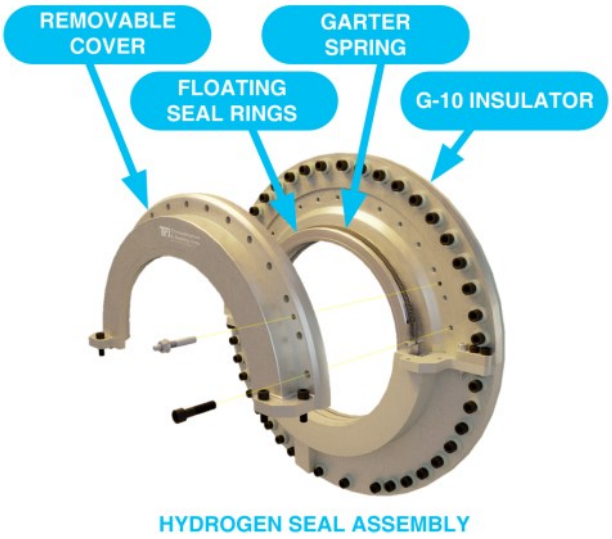
Motors using variable frequency electronic drives are built on solid state electronics. As such, they can suffer an instantaneous shutdown from loss of a solid-state component, and they tend to become obsolete in a few years.

- For Variable Speed Fluid Drives, TRI provides these products and services:
- Remanufacture rotating elements to TRI standards.
- Remanufacture Complete Fluid Drives to TRI standards.
- Manufacture new spare parts.
- Field Service for inspection, repair, and refurbishment.
- Manufacture complete new Fluid Drives for almost any application up to 40,000 hp.

Lube Oil and Lift Oil Systems:

- TRI designs and manufactures lube oil systems in a full-size range for normal operation.
- For emergency lube oil supply, TRI offers and has developed a system that is an AC-DC hybrid. The motor, switchgear and Variable Frequency Drive are all standard AC. A conventional UPS package contains adequate batteries to supply the DC power required by the UPS inverter to provide AC power for the specified period of time. This eliminates all DC power apparatus, other than the internals of the UPS.
- TRI designs and manufactures Lift Oil Pumping systems for turbine and generator bearings.

Hydrogen Seals for GE Style Generators:



HYDROGEN SEAL ASSEMBLY

Most of the GE style generators in service still use Hydrogen seal rings that are made of Bronze and are segmented into 4 quadrants. While these are reasonably effective, many have higher hydrogen gas loss than desired, sometimes due to vibration that displaces the seal quadrants. These original seal rings are somewhat difficult to assemble, to install, and to maintain. A very skilled technician is required, one who has considerable experience and attention to detail.

TRI manufactures a newer version of these Hydrogen seals that use steel rings with Babbitted bores. Each ring is split into two parts which are bolted and doweled at the joints permitting a rounder and flatter seal ring and a more effective shaft seal. The clearances between the journal and these steel seal rings when set cold are intentionally larger than those for bronze seal rings when cold due to the difference in thermal expansion coefficients. Note that at operating temperature, the design clearances for the bronze and steel rings are intentionally identical.

With improved shaft seals, there is less gas leakage, so higher gas pressures can be used providing improved cooling. The operating results are that higher MW and MVars can be obtained with less overall generator maintenance.

A critically important feature of the TRI hydrogen seal design is that the housing has a removable outer top half that permits much easier installation, removal, and maintenance of the seal rings and associated garter springs.

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The TRI Hydrogen Seal housing and ring assemblies replace existing Hydrogen seal assemblies - as complete assemblies. The TRI Hydrogen Seal housings at both ends of the generator are insulated from the frame.

Conclusion:

For help with upgrades, modifications, or simple repairs that you are pursuing today, please let us work with you to optimize the solutions to your equipment issues. With the administration change and a new attitude in Washington, let's start making the upgrades.

This Technical Note was written by Dr. Melbourne F. Giberson, P.E., President of TRI Transmission & Bearing Corp., Turbo Research, Inc. The objectives of Technical Notes are to disseminate information and experience on understanding problems and how to solve them. We attempt to send this Technical Note only to those people for whom the information might be useful. Over the years, many people have asked to be added to the distribution list (see our website). Occasionally, a few individuals inform us that they do not wish to receive the information. Should you desire not to receive future Technical Notes, please advise TRI by info@turboresearch.com or click visit the removal page on the TRI web site MFG 05/2017