Brüel & Kjær Vibro

A member of the NSK Group

Diagnostic service with the VIBROPORT 8000 in a combined cycle plant

Case Study

Power

After many hours of successful operation, an overhaul and upgrade of the two 501F gas turbines at a combined cycle plant in the U.S. was planned. However, during the first gas turbine start-up, the protection system tripped, so a Brüel & Kjær Vibro (B&K Vibro) diagnostic specialist was called in to investigate. As no condition monitoring or diagnostics were performed at the plant, he brought the VIBROPORT 8000 with him for analysis. Looking at the data, he determined that there was a complete seal and/or blade tip rub. But what was the cause? He discovered that the upgrade did not match what was documented in the overhaul report.

Figure 1. Typical combined cycle power plant in the U.S.

Combined cycle plant gas turbines overhauled

The CC plant in this case study was a typical installation in the U.S., a 2-to-1 configuration (two gas turbines and a single steam turbine) with an installed capacity of 604 MW. The 501F gas turbines in this plant also included supplemental firing duct burners for the heat recovery steam generators, offering baseload as well as peaking operation capability.

The 501F gas turbines, installed in 2008, had accumulated 400 starts and 80,000 hours at the time of an outage for an overhaul and to be upgraded from 150 to 160 MW. New compressor blades, new inter-stage seals, new bearings, and an upgraded control system were installed.

Introduction

Natural gas-fired combined cycle plants in the U.S. (CC) have increased generating capacity in the U.S. over a period of several years and have now exceeded coal-fired power plants. Today, CC plants are expected to be the dominant source of electricity generation in the U.S. for years to come.

Nearly all CC plants in the U.S. are monitored for protection, but a surprising number of them have little or no condition monitoring capability. Although industrial gas and steam turbines are very reliable and can operate thousands of hours with minimal maintenance intervention, there are situations where a comprehensive condition monitoring and diagnostic solution is imperative. Start-up after a rebuild is just one example.

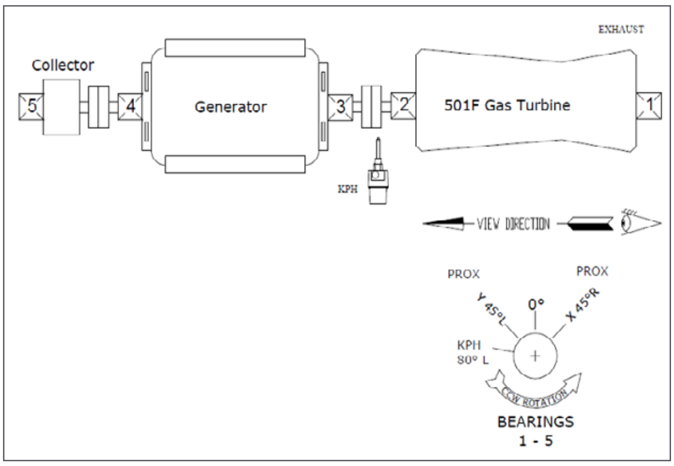

Figure 2. First gas turbine train in the case study combined cycle power plant.

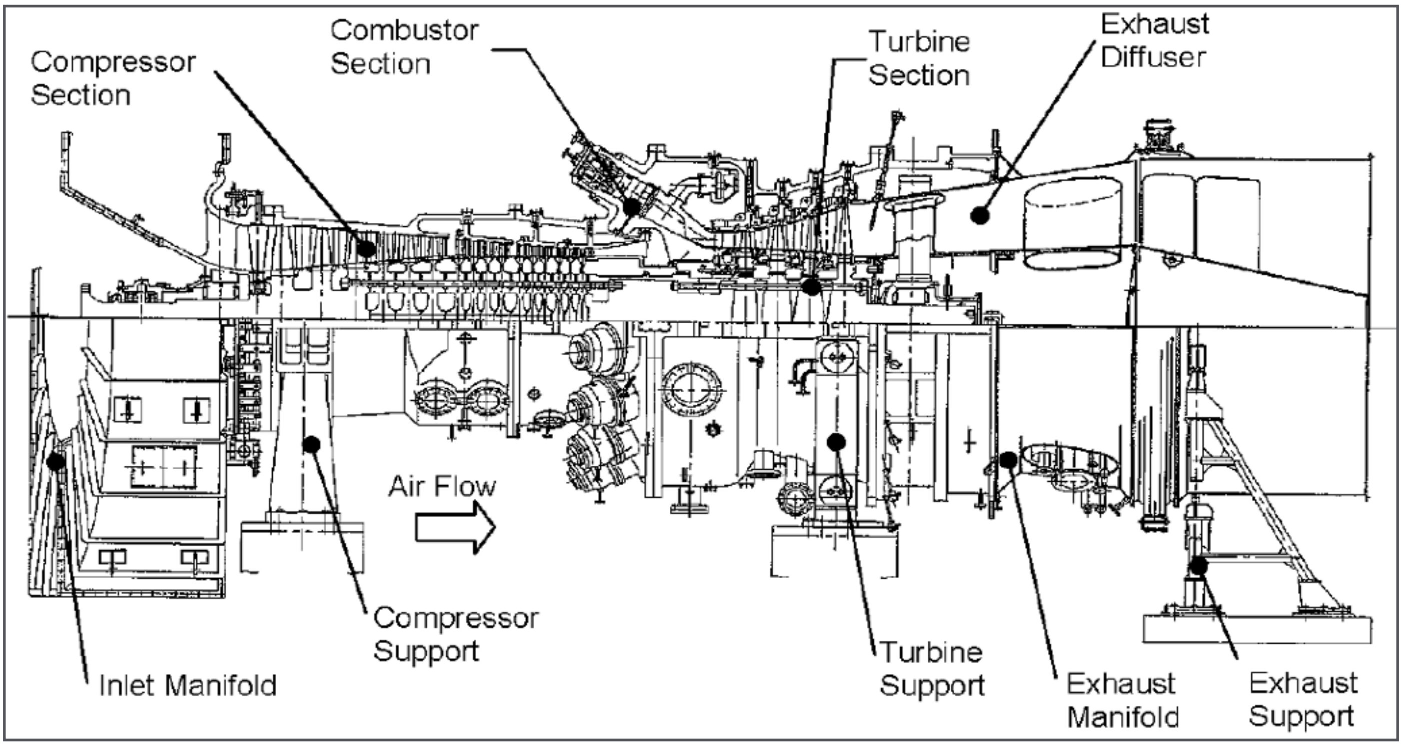

Figure 3. Cross section of the 501F gas turbine.

Shutdown

The first gas turbine fired up for testing tripped within one half-hour during unloaded run-up to speed, so a B&K Vibro diagnostic specialist was called in to find the problem and determine if the turbine could be restarted. A start-up was initiated to collect data using the B&K Vibro multi-channel portable analysis system, VIBROPORT 8000 .

Diagnostics

The VIBROPORT 8000 provided shaft centreline, orbit, and frequency spectrum plots during the second start-up (Figure 4).

The diagnostic specialist's analysis included the following assessments:

- The orbit plot for the exhaust end of the gas turbine was flattened, while that for the inlet end was more open and with a larger amplitude. Both were forward precessed (see Figure 5).
- High amplitude second balance resonance, i.e., critical speed (not shown).
- Second resonance occurs at a higher frequency than normal for 501F units.
- Little change in slow roll conditions between cold start-up and warm coast-down.
- Little phase change with large amplitude increase at inlet.
- Very shortened coast down time ~14 min. versus 30 min. typical.
- Internal and coupling alignment and bearing loading appear acceptable.

From this analysis, he concluded the following:

- There is an indication from the plots that there was continuous contact hard rotor rubbing, i.e., a complete 360-degree rub. This could be the inner stage seal rubbing and possibly also blade tip rubbing.
- High rotor unbalance was evident, but it was not likely the result of rubbing-induced rotor bowing.

The diagnostic specialist then proposed the following to the Plant Manager:

- Use a borescope to find evidence of blade and seal rubbing issues.
- Review all blade mass-moment weight and sequencing results.
- Verify installed blade sequencing matches calculations.
- Verify installed seal clearances.

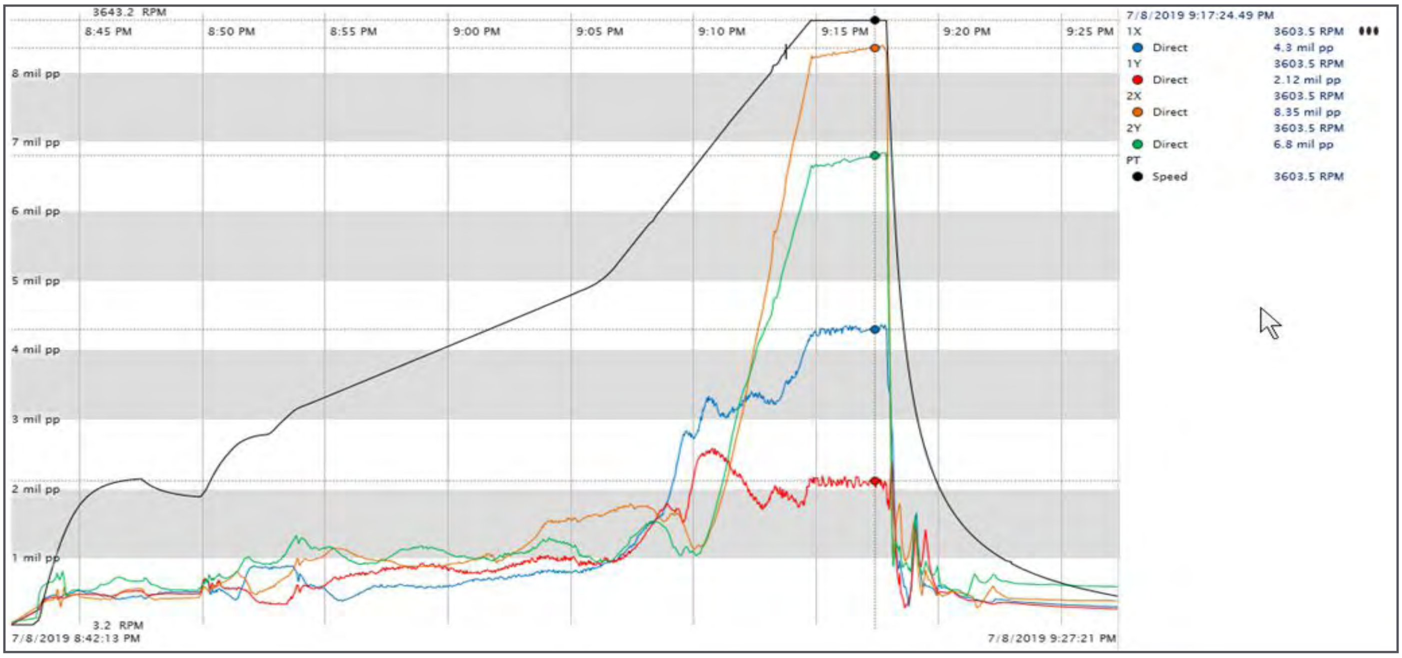

Figure 4. Initial post outage start-up for the gas turbine showing vibration trend during second start-up.

Results

Maintenance work after the analysis confirmed the diagnostic results, showing that the seals were improperly installed and there were miscalculations in the blade sequencing, despite the fact that the paperwork for the blade mass-moment and sequencing stated everything was in order regarding balance.

It was also noted after the inspection and maintenance that:

- The borescope inspection indicated enough rubbing evidence to top-case the unit for further inspection.
- There was evidence of hard inner-stage seal and honeycomb seal rubs. Seal installation and fit issues suspected.
- Verification of new blade mass-moment weights and blade sequencing confirmed.
- Rotor restart largely free of rubbing evidence.
- Rotor remaining unbalance high, requiring both inlet and exhaust end balance weights.
- Rotor successfully balanced.

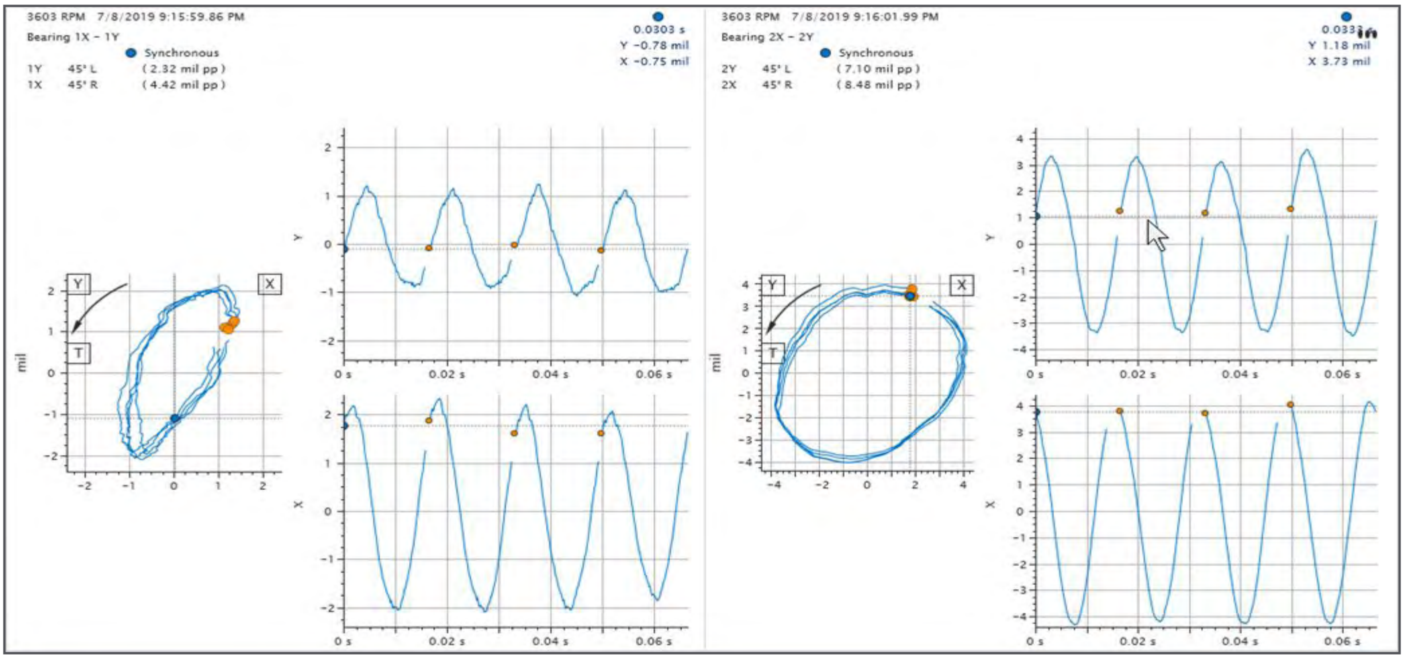

Figure 5. Orbit pots on the gas turbine inlet bearing (left) and the exhaust end bearing (right).

Conclusion

This case study demonstrates the importance of using an advanced portable multi-channel analyzer, especially for a re-start after an overhaul, when a permanently-installed condition monitoring system is not used. The portable system requires the same comprehensive diagnostic functionality found in the permanent systems, in identifying seal rub conditions as an example. To get the full potential value out of a portable system like the VIBROPORT 8000, an agile, quick diagnostic service is needed to minimize downtime, as demonstrated by the diagnostic expert in this case study.

Although the VIBROPORT 8000 played a crucial role in this case study, it is important to note that a portable analyzer in no way replaces a continuous condition monitoring solution. Oftentimes, power plant operators feel their reliable machines do not require a condition monitoring system, especially when operating at baseload conditions, since components can be conveniently replaced during planned overhauls. However, condition monitoring systems are not just for detecting worn components. They can also be used for detecting assembly errors, manufacturing faults as well as maintenance errors. Moreover, if a turbo-generator has been upgraded to produce more power, it is very important to monitor the machine continuously to ensure no components are over-stressed.

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