White Paper

A Future for Proactive Power Producers: Conditional Based Major Maintenance

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Shareables

- End users can employ innovative strategies—in particular, conditional based maintenance (CBM)—to extend the service life of combustion turbine generators' (CTG) major components substantially.
- By increasing the life of CTG major components—and deferring inspection intervals—end users potentially reduce major maintenance expenses and increase incremental availability over the useful life of a facility.
- To minimize risk of component failure, end users should be diligent in conducting frequent internal inspections of their CTGs to confirm the condition of key parts or components. Failure to do so can be costly in many ways.

Executive Summary

Taking a proactive approach in the maintenance strategy of generation investments can improve the position of any project. The upkeep of CTGs, steam turbine generators, and other power generation-related equipment can be perceived as complex and lead to an attitude of complacency when choosing a maintenance strategy. However, choosing the correct maintenance approach from a programmatic perspective can have significant financial and time

benefits for power producers. Employing a CBM strategy can allow end users to significantly extend the service life of components and/or parts. Further benefits may be realized when end users consider the use of rotable components or parts. To ensure that these benefits are achieved, it takes a consistent, rugged, and thorough internal inspection program that may, upon occasion, involve the use of a third-party provider who is skilled at delivering these inspection services and identifying which strategy is most likely to be effective.

Given the cost of major maintenance on prime movers in operating generation facilities, optimization of a CBM program can often save end users substantial amounts of capital on these expenses. Ignoring the possibility of a CBM approach can make substantial differences in the fixed costs of a generating project.

Advantages of Conditional Based Maintenance Strategy

End users are increasingly employing a nontraditional approach—in particular, a CBM strategy—to extend the life of components in the CTG beyond the recommended Original Equipment Manufacturer (OEM) intervals. A conditional based major maintenance strategy allows end users to diagnose the status of CTG components, identifying existing abnormalities as well as predicting when specific elements may degrade and ultimately fail if not removed from service. The conditionally based major maintenance approach is designed to defer combustion inspections, hot gas path (HGP) inspections, or major inspections, thus forgoing or delaying inspection-related expenses and, as a side effect, increasing the availability of the machine. Lengthening the useful life of critical CTG components as a result of a CBM approach is the most logical way to accomplish these results.

Overall, employing a conditional based approach can allow end users to significantly extend the service life of components or parts. The following example compares the frequency of combustion, HGP inspection and major inspections over a 30-year period when a facility follows the OEM-recommended intervals and, in a conservative scenario, when the facility extends the service life interval by 10% (Table 1). While this approach might not be applied to newer, more advanced technology, there are large fleets of CTGs in the marketplace that can take advantage of third-party part providers, refurbishers, inspectors, and service providers.

For the purposes of our discussion we assume that the example CTG is subject to a combustion inspection (CI), an HGP, and a major overhaul (Major).

TABLE 1. EXAMPLE CASE COMPARING INSPECTION INTERVALS OVER 30 YEARS

OEM Recommended Cycles				Conditionally Based MM Cycles (10% extra life)				Inspection Duration	
Inspection	I	II	III	Inspection	I	II	III		Days
CI (hours)	12,000	60,000	108,000	CI	13,200	66,000	118,800	CI	7
HGP (hours)	24,000	72,000	120,000	HGP	26,400	92,400	145,200	HGP	14
Major (hours)	48,000	96,000	144,000	Major	52,800	105,600	158,400	Major	28

Capacity Factor: 50%
Annual Service Hours: 4,380

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Cumulative Hours	4,380	8,760	13,140	17,520	21,900	26,280	30,660	35,040	39,420	43,800
OEM Recommendation			CI			HGP				
Conditionally Based Case				CI			HGP			

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Cumulative Hours	48,180	52,560	56,940	61,320	65,700	70,080	74,460	78,840	83,220	87,600
OEM Recommendation	Major			CI			HGP			
Conditionally Based Case		Major				CI				

	Year 21	Year 22	Year 23	Year 24	Year 25	Year 26	Year 27	Year 28	Year 29	Year 30
Cumulative Hours	91,980	96,360	100,740	105,120	109,500	113,880	118,260	122,640	127,020	131,400
OEM Recommendation		Major			CI			HGP		
Conditionally Based Case		HGP			Major			CI		

Source: GEK 3620

In this scenario, using the CBM strategy pushes the inspection intervals further out over the assumed 30-year useful life of the facility. As shown in Table 1, an end user could potentially avoid an HGP inspection altogether, which in this example could result in potential savings of several million dollars. Decreasing the number of inspections by extending the length of time between inspections also reduces downtime, which can increase capacity payments for independent power producer (IPP) facilities or, particularly in the case of the investor owned utilities (IOUs) decrease expenses associated with replacement power.

Overall, deferring maintenance over the lifecycle of the project can result in significant cost savings. One study estimates that in the United States, widespread adoption of a conditional based major maintenance approach could result in annual savings of $35 billion[1].

Real World Implementations

Not including avoided availability hits, depending on the size and configuration of their generating assets, some projects can extract as much as 4% to 10% from their annual capital costs associated with major maintenance on an annual basis. The most successful entities that are employing CBM strategies are conducting their business with an "attention to detail" focus allowing them to know exactly what the physical condition of their prime movers is at any given time. Dispatching these generators in a logical pattern (most fit for to least fit for dispatch) can allow the project participants the ability to time and execute inspection intervals at opportune times (shoulder months or other fortuitous periods in the dispatch profile) in an effort to extract the most value from these assets. In addition, these end users can

[1] http://www.sciencedirect.com/science/article/pii/S2288430014000141

manage complex risk scenarios far into the future such that they can foresee how to make best use of timing-related events.

As we move into the future, markets become more competitive, and margins shrink, end users who capitalize on strategies such as CBM and other innovative approaches are much more likely to find themselves reaping the rewards of their disciplined approach. Actual results are truly dependent on how much the end user is willing to invest in the application of CBM strategies.

Original Equipment Manufacturer Recommended Major Maintenance Intervals

Major maintenance intervals are usually dependent upon the recommendations of the CTG OEM and vary by CTG model. For this analysis, the calculations will be based on a typical General Electric (GE) Frame 7E.03 combustion turbine, also called the 7EA model, which is one of the most common CTGs in the North American marketplace. For the Frame 7EA CTG operating only on natural gas fuel, GE's publication manual GEK 3620 M: Heavy Duty Gas Turbine Operating and Maintenance Considerations (GEK 3620) recommends that a CI, HGP, and Major occur at specific intervals. The intervals for the GE 7EA CTG are illustrated in Table 2. For the purposes of our example cited above, we chose to follow an hours-based approach, but a similar methodology can be applied to a starts-based service life as it relates to inspection intervals.

"DLN"-Dry Low NOx

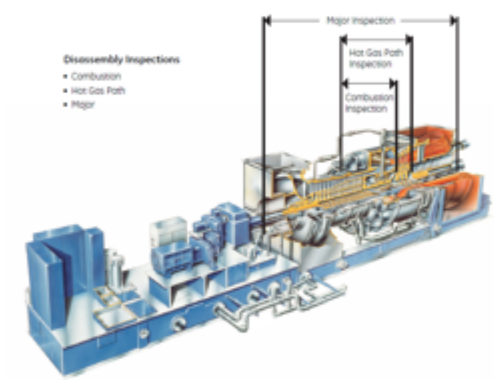

TABLE 2: MAINTENANCE INTERVAL TYPES AND TIMING FOR A GE 7EA CTG

Inspection Type	Inspection Timing Interval	Inspection Timing Interval
	Hours Based	Starts Based
Combustion Inspection (Non-DLN)(1)	8000	900
Combustion Inspection (DLN)	12000	450
Hot Gas Path Inspection	24000	1200
Major Inspection	48000	2400

Source: GEK 3620

In this example, inspection intervals can be driven by either hours or starts. If a CTG is used for base-loaded, high-capacity factor operations, the inspection intervals would likely be hours based. Conversely, if a CTG is used for peaking operations, the inspection intervals would likely be starts driven. Whichever milestone—starts or hours—is reached first determines when the inspection should occur.

Additional Strategies to Extend Combustion Turbine Generator Component Life

To foster this conditionally based maintenance scenario, end users may consider using rotable components or parts. A rotable part is one that has been repaired or reconditioned to some level of serviceability and is available at the time that an inspection interval occurs. Although actual savings depend on a range of factors, reconditioning or repairing a part is often less expensive than procuring a new part. This strategy may help reduce the long lead times associated with components or parts and reduce the downtime a CTG may experience.

End users can also work together to extend the life of CTG components. By sharing or pooling major components—such as rotors, turbine blade sets, and combustion system components—end users can share in the upside in an engineered and constructive manner. If certain timing synergies exist, the removal, repair, or refurbishment of components or parts can diminish lead times associated with procuring new ones. End users with smaller fleets of similar CTG models may join user groups to achieve the same objective as end users with larger fleets. User groups, usually formed among smaller fleets of CTGs, often meet annually to discuss common issues with the CTG models. End users who have the same CTG model may petition to borrow a part they need from another end user with the promise to pay for the part or replace the part with a like or identical one.

Mitigating Risks of Conditionally Based Major Maintenance Strategies

Despite the many benefits of this strategy, implementing this system can introduce complexities. The single largest risk of a conditional based major maintenance approach is the possibility of experiencing a CTG failure. Should the condition of a component or part be incorrectly assessed or overlooked, the component or part could fail, which may result in significant collateral damage to other components or parts within the CTG. In addition, the approach does not work for some industrial equipment[2], and current technologies have limited accuracy for diagnosing and predicting all potential equipment problems.

Given these shortcomings and potential risks, end users need to be methodical about how they employ a conditional based approach. One way to ensure that targeted components and parts are in optimal condition is for end users to increase the frequency of their own internal inspections, beyond what OEMs recommend, to identify issues early and therefore mitigate potential risks of component failure. End users can do so by employing a skilled technician within their company who can conduct visual and dimensional inspections of the CTG components or by hiring an OEM field representative or a third-party provider skilled in this area. These technicians must follow approved inspection procedures—as provided by the OEM—and use only the highest quality borescope equipment. Although increasing borescope inspections of CTGs may be perceived as an added expense, the effort is relatively inexpensive as compared to the expense incurred if a component were to fail and cause a major, expensive, and time-consuming (spoken "not available") CTG-forced outage.

Considering the pedigree of components and parts when conducting the major maintenance intervals is another key factor. A computerized maintenance management system can assist in this complicated and labor-intensive task by helping to track part or component serial numbers, hours or starts-based service

[2] http://www.sciencedirect.com/science/article/pii/S2288430014000141

life, and replacement and repair history in an effort to manage the useful life of the components or parts. Inspectors may want to focus inspections on hot section components—those exposed to high temperatures and pressures—using advanced metallurgy and design, which are more expensive to repair or replace than components located in other areas of the CTG.

During an inspection, a technician may find that certain components need to be replaced, repaired, or both. When a component or part is no longer considered serviceable, end users must decide whether to conduct a formal OEM inspection interval and repair or replace the parts. By identifying and correcting problems sooner, a facility may be able to defer formal OEM inspections and postpone significant expenses related to major maintenance of the CTG.

Discovering the Best and Most Risk Averse Approach for a Facility Employing Conditional Based Maintenance

More and more, conditionally based major maintenance strategies represent an appealing option for project participants in the marketplace. However, given the range of options and potential risks, participants will need to choose the approach that best suits their specific needs and circumstances. Project participants can potentially incur substantial financial and operation-related rewards by employing a conditionally based major maintenance strategy on their project's prime movers. This strategy is particularly useful for IPPs who generally do not have the ability to pass on costs associated with major maintenance to the rate base. Although there are distinct advantages to such an approach, project participants should contemplate the approach carefully. Power producers need to keep a close tab on CTG components they hope to use for longer than their recommended service lives. Risk assessment of the useful life components can be a delicate art, which is why it is critical that end users employ highly qualified individuals or utilize experienced service providers to ensure that these elements are safe and viable. Further, end users should maintain strong relationships with the OEMs, third-party parts and service providers, and project insurers to encourage harmonious and mutually beneficial collaboration when employing conditionally based major maintenance strategies.

About the Author

Paul Paxson is an operations and maintenance (O&M) consultant with 31 years of experience in power generation, plant systems operations, staff management, power program administration, and environmental health and safety (EH&S) systems, and computer maintenance management systems (CMSS). Mr. Paxson applies a deep understanding of plant supervision, administration, operations, and maintenance, as well as contracts and service agreements, to the practice of independent engineering. As an Independent Engineer, he has supported project finance, refinance, and sell- and buy-side due diligence for a wide range of generation technologies, including combustion turbines (frame and aeroderivative), solid fuel (biomass and coal), solar (PV and CPS), and reciprocating engines. Mr. Paxson began his power career while enlisted with the U.S. Navy, where he supervised reactor and steam plant operations and instructed Naval officers and enlisted personnel in the theory and practical application of nuclear power plant operations

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