Lifecycle Cost Considerations when Choosing a Power Generation System

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INTRODUCTION

Power generation systems are essential to the way we live today. People around the world rely on electricity for a variety of reasons, and they expect an uninterrupted supply of energy that meets their power needs. The utilities that produce energy in the most efficient manner are also the ones that provide the most cost-effective solutions to their customers.

Efficient power plants are those that are designed, operated and maintained properly. The design elements of a power plant differ from case to case, but what remains consistent is the amount of planning and thought put into the system's overall efficiency. Each component in the system should work cohesively with the rest of the plant because even the smallest change will have a dramatic effect on the overall output. Poor power output means lower efficiency and consequently, higher lifecycle costs because components work harder to produce less.

Reciprocating internal combustion engines (RICEs) have become a popular prime mover option for many power generation companies due to their fuel flexibility, high efficiency and rapid response to grid variations. For this reason, RICEs are particularly suited for grid stabilization or wind firming projects. Energy providers often consider capital costs as a critical decision factor, but, in most cases, the lifecycle costs should be used just as much to determine the viability of a project. Although many of the lifecycle costs discussed in this article are generic to all plants, the focus will be on those utilizing RICEs.

Several factors contribute to the lifecycle costs of a power generation system. Anticipated costs like operation and maintenance planning must be taken into consideration at the very early stages of the project to ensure viability. Unanticipated costs could be detrimental to project profitability and proper planning is needed to minimize their impact. Fortunately, steps can be taken to prepare for both the anticipated and unanticipated costs of a power generation system by creating a proper preventative maintenance program, conducting regular emergency training and having solid contingency plans in place.

LIFECYCLE COSTS

Any costs associated with the operation and maintenance of the power plant during its lifetime are considered lifecycle costs. These include expenses related to fuel, scheduled and unscheduled maintenance, labor, lube oil, and other incidentals. The better the upfront planning for these lifecycle costs, the better the mitigation of risk of any unplanned costs occurring.

Fuel Costs

Fuel is the highest lifecycle cost, but it is also the easiest to predict and calculate. Fuel costs depend on the specific fuel oil consumption (SFOC) at different loads, the operating profile of the plant and the fuel price. There are other less significant factors, such as the efficiency degradation over time as engine components wear, that contribute to fuel costs, which can be minimized through a proper preventative maintenance program. Figure 1 illustrates typical efficiency losses over time and the importance of maintenance to minimize those efficiency losses.

A more significant factor to overall fuel costs is the operating profile. New engine designs allow the efficiency to be optimized at 100 percent load, but if the load falls below 60 percent, the SFOC increases dramatically and the overall plant efficiency is affected.

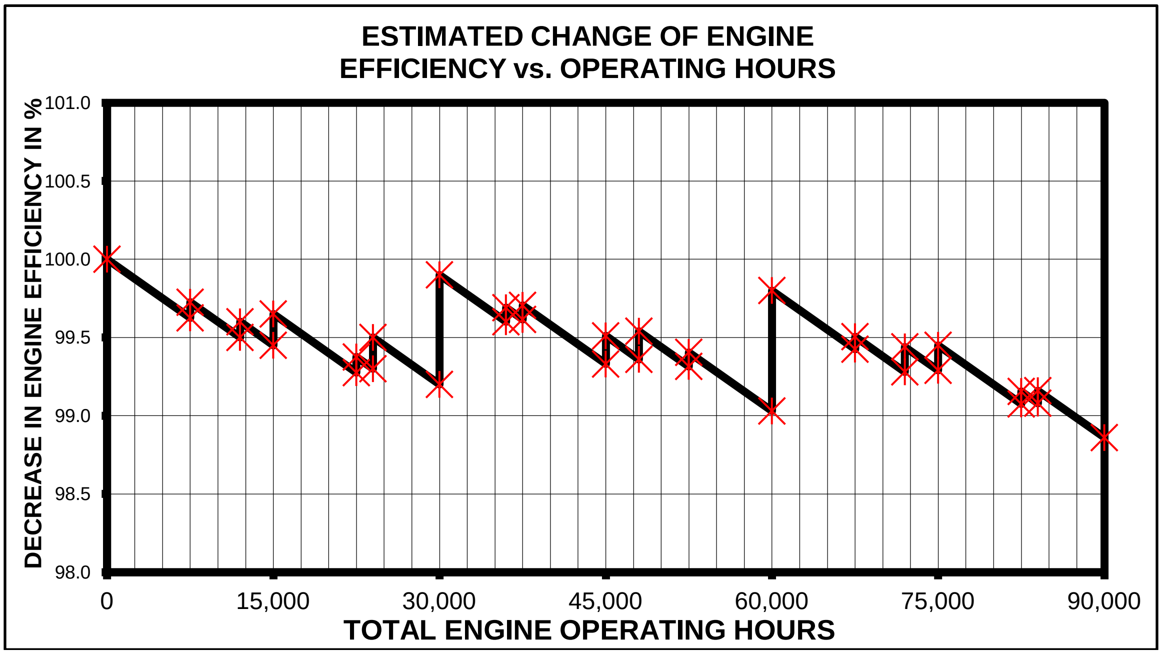

Figure 1

Different fuel options allow system designers to create specific solutions for individual energy needs, budget concerns and fuel availability. Each fuel type has its benefits and disadvantages, so it's important to research the best option for specific energy needs during the system design process. For example, natural gas burns cleaner, lengthens maintenance intervals and component lifetimes, and, as seen lately, is a cost-effective solution. However, depending on local resources and infrastructure, it's not always a viable option.

On the other hand, heavy fuel oil (HFO) engines are quite common and the fuel is available worldwide, but bunker fuels are not always allowed in local markets due to increased emissions levels. HFO also has fuel contaminants that increase component wear directly, as well as indirectly, through the contamination of the lube oil. This increased component wear leads to reduced component life and higher scheduled and unscheduled maintenance costs as compared to other clean-burning fuels.

Dual-fuel engines are another option to be considered. These engines typically have higher capital cost than single-fuel engines, but they provide the fuel flexibility some operators require. There are some increased maintenance costs due to the added system complexity, but in areas where natural gas is readily available, it may be justifiable. In addition, with the current price of natural gas, the fuel savings may outweigh any increased maintenance costs.

Alternative, renewable fuels like vegetable oils, animal fats and bio-diesel can also be used but require fuel treatment equipment. This additional equipment increases initial capital costs and maintenance costs because it adds system complexity, and requires constant monitoring and specialized maintenance. Some alternative fuels are very acidic causing decreased engine component life, which leads to increased scheduled maintenance costs.

A general rule of thumb says that the cleaner the fuel, the longer the component life, which means less performance degradation over time. Natural gas is the cleanest fuel, but it is not always available. Diesel is also clean but is more expensive than natural gas and HFO has also become increasingly more expensive as the price of oil rises. HFO has contaminants including water, ash, sand and minerals such as sulfur that cause faster component wear. Although most of the contaminants are removed during the purification and filtration processes, it is impossible to remove everything.

Maintenance Costs

Another significant lifecycle cost is maintenance. Some engine and auxiliary equipment parts are designed to be wear components. Examples of these are fuel injection nozzles, piston rings and bearings. In most cases, wear components are replaced based on the standard component life, but in some cases are replaced based on condition monitoring. Under condition-based maintenance, these wear components are only replaced if wear limits are exceeded or other replacement criteria deem it necessary. Each component must be monitored closely because once a component's useful life has been reached, risk for failure increases dramatically.

Contributors to premature component wear include dirty lube oil and poor fuel quality. These both result in increased friction, heat and contaminants. Following a proper predictive maintenance program allows for early detection of problems. Maintenance intervals, or the amount of time in between each system evaluation, should be considered during the planning phase to establish a strong preventative maintenance program early on. Maintenance intervals vary among component parts, fuel type and engine type and are typically based on run hours, but as mentioned above, can also be condition based.

Figure 2 lists the expected lifetime of major components in a generator set run on HFO. For example, the injection nozzle is expected to perform 7,500 running hours. This run-hour projection is provided to help operators reduce the risk of efficiency loss and/or downtime. Routine maintenance during regular intervals can help reduce the risk of more expensive repairs later.

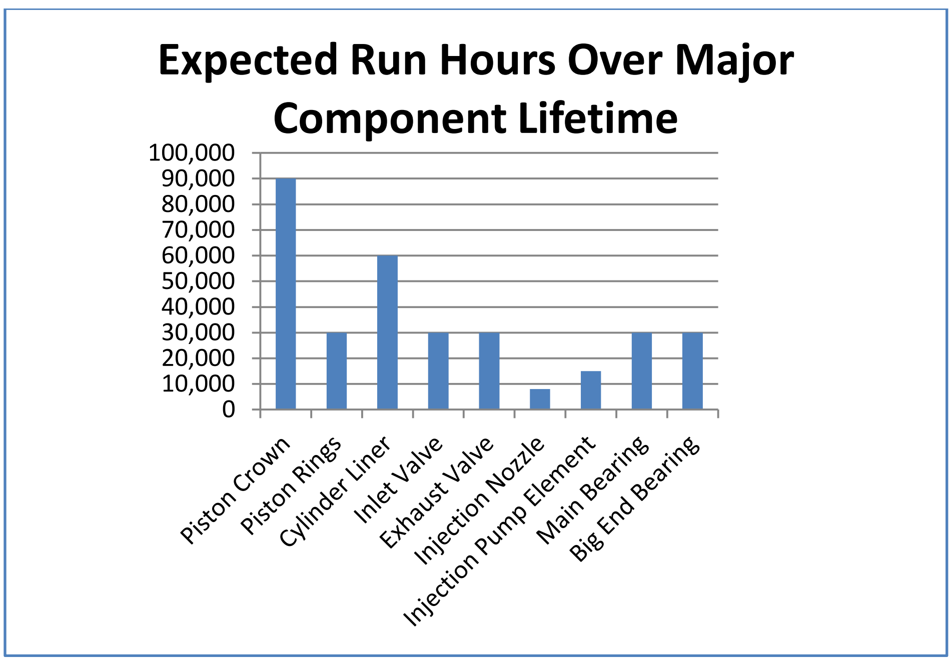

Figure 2

Maintenance Schedule

Scheduled maintenance planning is a preventative strategy that enables engineers to effectively plan for repairs, costs and system downtime. Each maintenance program is unique to its specific system, location and manager. A proper maintenance program should set maximum run hours for each component in the system. It should also account for maintenance intervals, manpower, spares required, routine analysis and inspection details.

Maintenance intervals are the time periods between each system inspection/overhaul and should be scheduled in sync with the component run hour lifetime and operating requirements. The timeline can vary from plant to plant if a condition-based maintenance program is utilized. Under a condition-based maintenance program, the component lifetime is adjusted based on the operating parameters and regular inspections providing analytical data for trending. Some component maintenance intervals may require specialists at the time of maintenance, which may affect costs and downtime planning. Including as many details as possible in the schedule about what kind of maintenance is needed, how long it should take and how many engineers are required will help organize the budget and maintenance timeline, and anticipate system downtime costs. During all inspections/overhauls, every detail should be recorded for later reference and trending analysis.

As part of a predictive maintenance program, engineers assess component wear as seen during regularly scheduled inspections. They also record operating data on a regular basis and trend data points to provide an indication of any necessary adjustments to maximize efficiency as well as help predict any possible failures. This, in turn, helps the operator to mitigate the risk of costly unscheduled outages. A predictive maintenance program is also a key element of a good condition-based maintenance program.

The plant systems are also equipped with a safety alarm system that alerts the plant manager when an operating parameter is out of limits and needs attention. Some of the most critical parameters are also tied to shutdown functions to avoid major catastrophes and possible injury to operating personnel.

System Downtime

System downtimes include all periods in which the system is not running. Like lifecycle fuel costs, downtimes depend on engine type, hours run and fuel type. Estimated engine downtimes for scheduled maintenance over a period of 80,000 running hours, for example, would range between 6 and 7 percent. This covers scheduled maintenance inspections/overhauls as well as factors for any unscheduled maintenance outages.

Although a good maintenance program will minimize the unscheduled system downtime, unscheduled outages will sometimes occur. While extensive planning will cover most of the downtime during the system’s lifecycle, it is impossible to foresee all issues. To financially prepare for these outages, breakdown insurance coverage is recommended.

Other Costs

Other common lifecycle costs to consider include labor (operations and maintenance) and lube oil. Labor costs are dependent on local labor rates and regulations, operation profile, plant availability requirements and required skill level. These are all factors that help to prepare a strategy for plant staffing needs. The planning team must be knowledgeable of current local standards and practices to accurately forecast labor costs.

Lube oil costs vary based on specific lube oil consumption, quality and change intervals. Some lube oil consumption should be expected because it’s used to lubricate the combustion chamber during operation. The goal is to achieve a balance by minimizing the lube oil consumption and cost without jeopardizing the lifetime of the engine components.

Lube oil consumption is not the only critical factor. Ensuring oil cleanliness should be incorporated into the maintenance schedule because dirty lube oil can cause premature component wear. In systems without an installed lube oil purifier, regular oil change intervals must be performed. The oil change intervals are based on regular oil sample analysis. Lube oil purifiers will typically extend the oil change intervals assuming the lube oil consumption is high enough that the added oil helps to “freshen” the oil sump. This is an added element to the consumption balance mentioned above.

CONCLUSION

Certain costs are unavoidable over the course of a power generation system’s lifecycle, but a proper predictive and preventive maintenance program can help reduce unnecessary costs. Considering fuel options, scheduled maintenance and proper programs for cleaning and testing electrical equipment are all preventative steps to take in lowering expected lifecycle costs. A contingency plan will allow for more flexibility when dealing with unscheduled outages. Because numerous factors contribute to the overall lifecycle cost of a power generation system, detailed and consistent monitoring and trending are essential to accurately analyze the power system and keep lifecycle costs in check.

Reduced overall costs are not the only benefit from proper maintenance programs. System inspection and planned maintenance provides early detection of problems and mitigates the risk of major failure while optimizing system efficiency. The goal is simple: to operate effectively for as long as possible while reducing costs and maximizing profit over the duration of the power generation system lifecycle.

ABOUT

Caterpillar Power Generation Systems
Caterpillar Power Generation Systems, a part of the Electric Power Division of Caterpillar, is a leading, global supplier of complete, electric power generation solutions. Utilizing highly efficient, medium-speed reciprocating engine technology, its power plants range in output from one to over 200 megawatts (MW), offering customers the flexibility of burning various fuels including: natural gas, heavy fuel oil, diesel oil or renewables. With major installations in every part of the world, Caterpillar has the expertise to provide customized solutions ranging from simple equipment supply to full turnkey power plants. Operations and maintenance agreements, and project financing are also available. For more information, please visit http://www.cat.com/power-plants.

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