RiskTopics

Diesel generator operations and maintenance

Diesel engines comprise the vast majority of prime movers for stand by power generators because of their reliability, durability and performance under load.

Introduction

Diesel powered generators are depended on for back-up power systems in the most critical locations: hospitals, airports, government buildings, telecommunications facilities, and nuclear power plants. In standby power applications, diesel generators can start and assume full-rated load in less than 10 seconds, and they typically can go 30,000 hours or more between major overhauls.

Discussion

A diesel generator is the combination of a diesel engine with an electric generator (often an alternator) to generate electrical energy. A diesel compression-ignition engine often is designed to run on fuel oil, but some types are adapted for other liquid fuels or natural gas.

Diesel generating sets are used in places without connection to a power grid, or as emergency power-supply if the grid fails, as well as for more complex applications such as peak-lopping, grid support and export to the power grid.

Sizing of diesel generators is critical to avoid low-load or a shortage of power and is complicated by modern electronic equipment. In size ranges around 50 MW and above, an open cycle gas turbine is more efficient at full load than an array of diesel engines, and far more compact, with comparable capital costs; but for regular part-loading, even at these power levels, diesel arrays are sometimes preferred to open cycle gas turbines, due to their superior efficiencies.

The packaged combination of a diesel engine, a generator and various ancillary devices (such as base, canopy, sound attenuation, control systems, circuit breakers, jacket water heaters and starting system) is referred to as a "generating set" or a "genset" for short.

Set sizes range from 8 to 30 kW (also 8 to 30 kVA single phase) for homes, small shops and offices with the larger industrial generators from 8 kW (11 kVA) up to 2,000 kW (2,500 kVA three phase) used for large office complexes, factories.

A 2,000 kW set can be housed in a 40 ft. (12 m) ISO container with fuel tank, controls, power distribution equipment and all other equipment needed to operate as a standalone power station or as a standby backup to grid power. These units, referred to as power modules are gensets on large triple-axle trailers weighing 85,000 pounds (38,555 kg) or more. A combination of these modules is used for small power stations and may use from one to 20 units per power section, and these sections can be combined to involve hundreds of power modules. In these larger sizes the power module (engine and generator) are brought to site on trailers separately and are connected together with large cables and a control cable to form a complete synchronized power plant. A number of options also exist to tailor specific needs, including control panels for autostart and mains paralleling, acoustic canopies for fixed or mobile applications, ventilation equipment, fuel supply systems, exhaust systems, etc. Diesel generators, sometimes as small as 200 kW (250 kVA) are widely used not only for emergency power, but also many have a secondary function of feeding power to utility grids either during peak periods, or periods when there is a shortage of large power generators.

Failure of Emergency generators to start when needed

Battery failure

The single most frequent service call for generator failure is related to battery failure. Eighty percent of all battery failure is related to sulfation buildup — the accumulation of lead sulfates on the plates of lead-acid batteries. This buildup occurs when the sulfur molecules in the electrolyte (battery acid) become so deeply discharged that they begin to coat the battery's lead plates. When enough plate area has sulfated, the battery will not be able to provide enough current and will normally need to be replaced. Battery failure is commonly the result of low electrolyte levels — battery plates exposed to air will immediately sulfate.

Low coolant levels

The most obvious cause for a low coolant level is either an external or internal leak. Close attention should be paid to any visible puddles of coolant during weekly inspections of the unit(s). The color of the coolant varies by manufacturer and may look like red-dyed diesel fuel. Inspect oil for any signs of color change or a milky texture and hoses for "crusties" — the sign of coolant seeping and additives drying up at the connection. While many generators are equipped with low coolant level alarms, few have a dedicated alarm indicator for low coolant. Commonly, this alarm will be tied in to a high coolant temp shutdown circuit.

Low coolant temp alarms

Low coolant temp alarms are mainly the result of faulty block heaters. Given the fact that they run 24 hours a day, seven days a week, they're going to fail periodically. A block heater will normally not cause the engine not to run. The generator should be allowed to run for a few minutes at no load after startup so that the temperature comes up.

Oil, fuel, or coolant leaks

Most often, oil leaks are not in fact leaks but the result of "wet stacking" (or "engine slobber") caused by excessive no-load run time. Diesel engine generators are designed to operate with a load — most effectively in the 70% to 80% range of rated output. When generators operate considerably below the rated output level, the engine can start to over-fuel or "wet stack" and damage the engine.

Air in the fuel system

This is a common problem with newer generators that are not run on a regular basis. Closer tolerances within the fuel systems to meet today's emission requirements make fuel systems more susceptible to air affecting startup. This is not as common with older generators — many of which may have a leak in a line or check valves that are not properly holding the fuel in the engine.

Ran out of fuel

Mechanical fuel level gauges may not always be accurate. Unlike a vehicle that is moving and using a higher percentage of its tank's capacity, a generator tank has no movement, causing the fuel to become stagnant. Mechanical gauges may also stick in a position until vibrations break them free.

High fuel level alarm

High fuel level alarms are required by government regulations to prevent the overfilling of a fuel tank. The alarm should activate when the fuel tank reaches between 90% and 95% capacity. This lets the person fueling the tank know when he or she should stop filling.

Breaker trip

If a breaker trips after the automatic transfer switch (ATS), the generator will not start. The status of the automatic transfer switch should be checked during a power outage. The ATS should have lights or a display showing the switch position and source availability. If you find a breaker tripped, make sure you can determine the cause of the trip prior to resetting.

Failure modes while in operation

Diesel engines can suffer damage as a result of misapplication or misuse - namely internal glazing (occasionally referred to as bore glazing or piling) and carbon build-up. Ideally, diesel engines should be run at least 60% to 75% of their maximum rated load. Short periods of low load running are permissible providing the set is brought up to full load, or close to full load on a regular basis.

Internal glazing and carbon build-up are due to prolonged periods of running at low speeds or low loads. Such conditions may occur when an engine is left idling as a 'standby' generating unit, ready to run up when needed, (misuse); if the engine powering the set is over-powered (misapplication) for the load applied to it, causing the diesel unit to be under-loaded, or as is very often the case, when sets are started and run off load as a test (misuse).

Running an engine under low loads causes low cylinder pressures and consequent poor piston ring sealing since this relies on the gas pressure to force them against the oil film on the bores to form the seal. Low cylinder pressure causes poor combustion and resultant low combustion pressures and temperatures.

This poor combustion leads to soot formation and unburnt fuel residues which clogs and gums piston rings, causing a further drop in sealing efficiency and exacerbates the initial low pressure. Glazing occurs when hot combustion gases blow past the now poorly-sealing piston rings, causing the lubricating oil on the cylinder walls to 'flash burn', creating an enamel-like glaze which smooth’s the bore and removes the effect of the intricate pattern of honing marks machined into the bore surface which are there to hold oil and return it to the crankcase via the scraper ring.

Hard carbon also forms from poor combustion and this is highly abrasive and scrapes the honing marks on the bores leading to bore polishing, which then leads to increased oil consumption (blue smoking) and yet further loss of pressure, since the oil film trapped in the honing marks is intended to maintain the piston seal and pressures.

Unburnt fuel then leaks past the piston rings and contaminates the lubricating oil. Poor combustion causes the injectors to become clogged with soot, causing further deterioration in combustion and black smoking.

The problem is increased further with the formation of acids in the engine oil caused by condensed water and combustion by-products which would normally boil off at higher temperatures. This acidic build-up in the lubricating oil causes slow but ultimately damaging wear to bearing surfaces.

This cycle of degradation means that the engine soon becomes irreversibly damaged and may not start at all and will no longer be able to reach full power when required.

Under-loaded running inevitably causes not only white smoke from unburnt fuel but over time will be joined by blue smoke of burnt lubricating oil leaking past the damaged piston rings, and black smoke caused by damaged injectors. This pollution is unacceptable to the authorities and neighbors.

Once glazing or carbon build up has occurred, it can only be cured by stripping down the engine and re-boring the cylinder bores, machining new honing marks and stripping, cleaning and de-coking combustion chambers, fuel injector nozzles and valves. If detected in the early stages, running an engine at maximum load to raise the internal pressures and temperatures allows the piston rings to scrape glaze off the bores and allows carbon build-up to be burnt off. However, if glazing has progressed to the stage where the piston rings have seized into their grooves, this will not have any effect.

The situation can be prevented by carefully selecting the generator set in accordance with manufacturers printed guidelines.

Guidance

Preventive maintenance schedule

It is generally a good idea to establish and adhere to a schedule of maintenance and service based on the specific power application and the severity of the environment. For example, if the generator set will be used frequently or subjected to extreme operating conditions, the recommended service intervals should be reduced accordingly.

Some of the factors that can affect the maintenance schedule include:

- • Using the diesel generator set for continuous duty
- • Extreme ambient temperatures
- • Exposure to weather
- • Exposure to salt water
- • Exposure to dust, sand or other airborne contaminates

The following are recommended preventive maintenance activities to be considered:

Daily:

Perform general inspection

Check coolant heater

Check coolant level

Check fuel level

Check charge-air piping

Weekly:

Check/clean air cleaner

Check battery charger

Drain fuel filter

Drain water from fuel tank

Monthly:

Check coolant concentration

Check drive belt tension

Drain exhaust condensate

Check the battery charger

Every 6 months:

Change oil and filter

Change coolant filter

Clean crankcase breather

Check radiator hoses

Change fuel filters

Check battery cables and connections

Check the battery electrolyte level and specific gravity

Inspect air induction piping and connections

Inspect the DC electrical system, control panel, and accessories

Inspect the AC wiring and accessories

Annually:

Clean cooling systems

Change the spark plugs

Change the air filter

Perform load bank test

General inspection

When the generator set is running, operators need to be alert for mechanical problems that could create unsafe or hazardous conditions. Following are several areas that should be inspected frequently to maintain safe and reliable operation.

- • ***Exhaust system*:** With the generator set operating, inspect the entire exhaust system, including the exhaust manifold, muffler, and exhaust pipe. Check for leaks at all connections, welds, gaskets, and joints — and make sure that the exhaust pipes are not heating surrounding areas excessively. Repair any leaks immediately. Check for excessive smoke upon starting: It can indicate possible performance and air quality issues that may require immediate attention.
- • ***Fuel system*:** With the generator set operating, inspect the fuel supply lines, return lines, filters, and fittings for cracks or abrasions. Make sure the lines are not rubbing against anything that could cause an eventual failure. Repair any leaks or alter line routing to eliminate wear immediately.
- • ***DC electrical system*:** Check the terminals on the starting batteries to make sure the connections are clean and tight. Loose or corroded connections create resistance, which can hinder starting.
- • ***Engine*:** Monitor fluid levels, oil pressure, and coolant temperatures frequently. Most engine problems give an early warning. Look and listen for changes in engine performance, sound, or appearance that will indicate that service or repair is needed. Be alert for misfires, vibration, excessive exhaust smoke, decreases in power, or increases in oil or fuel consumption.
- • ***Control system*:** Inspect the control system regularly, and make sure it is logging data properly during engine exercise. Be sure to return the control system back to normal automatic standby when testing and maintenance are completed.

Lubrication service

Check the engine oil level when the engine is shut down at the interval specified by the manufacturer. For accurate readings on the engine's dipstick, shut off the engine and wait approximately 10 min. to allow the oil in the upper portions of the engine to drain back into the crankcase. Follow the engine manufacturer's recommendations for API oil classification and oil viscosity. Keep the oil level as near as possible to the "full" mark on the dipstick by adding the same quality and brand of oil.

Change the oil and filter at the intervals recommended by the manufacturer. Check with the engine manufacturer for procedures for draining the oil and replacing the oil filter. Used oil and filters must be disposed of properly to avoid environmental damage or liability.

Cooling system service

Check the coolant level during shutdown periods at the interval specified by the manufacturer. Remove the radiator cap after allowing the engine to cool, and, if necessary, add coolant until the level is about 3/4 in. below the radiator cap's lower sealing surface. Heavy-duty diesel engines require a balanced coolant mixture of water, antifreeze, and coolant additives. Use the coolant solution recommended by the engine manufacturer.

Inspect the exterior of the radiator for obstructions and remove all dirt or foreign material with a soft brush or cloth. Use care to avoid damaging the fins. If available, use low-pressure compressed air or a stream of water in the opposite direction of normal air flow to clean the radiator. Check the operation of the coolant heater by verifying that hot coolant is being discharged from the outlet hose.

Fuel system service

Diesel is subject to contamination and deterioration over time, and one reason for regular generator set exercise is to use up stored fuel before it degrades. In addition to other fuel system service recommended by the engine manufacturer, the fuel filters should be drained at the interval indicated by the manufacturer. Water vapor accumulates and condenses in the fuel tank — and also must be periodically drained from the tank along with any sediment present. Bacterial growth in diesel fuel can be an issue in warm climates. Consult the generator set manufacturer or dealer for recommendations on treating stored fuel with a biocide.

Regular testing and fuel polishing may be required if the fuel is not used and replenished in three to six months.

The charge-air cooler piping and hoses should be inspected regularly for leaks, holes, cracks, or loose connections. Tighten the hose clamps as necessary. In addition, inspect the charge-air cooler for dirt and debris that may be blocking the fins. Check for cracks, holes, or other damage.

The engine air intake components should be checked at the intervals recommended by the manufacturer. The frequency of cleaning or replacing air cleaner filter elements is primarily determined by the conditions under which the generator set operates. Air cleaners typically contain a paper cartridge filter element that can be cleaned and reused if not damaged.

Considerations: Starting, testing, cleaning and checking batteries

- ***Starting batteries:*** Weak or undercharged, starting batteries are a common cause of standby power system failures. Even when kept fully charged and maintained, lead-acid starting batteries are subject to deterioration over time and should be replaced approximately every 24 to 36 months — or when they no longer hold a proper charge. NiCad starting batteries require less maintenance than lead-acid and are often used in mission-critical applications. However, they are also subject to deterioration and need to be regularly tested under load.
- ***Testing batteries:*** Merely checking the output voltage of the batteries is not indicative of their ability to deliver adequate starting power. As batteries age, their internal resistance to current flow goes up, and the only accurate measure of terminal voltage must be done under load. On some generators, this diagnostic test is performed automatically each time the generator is started. On other generator sets, use a manual battery load tester to verify the condition of each starting battery.
- ***Cleaning batteries:*** Keep the batteries clean by wiping them with a damp cloth whenever dirt appears excessive. If corrosion is present around the terminals, remove the battery cables and wash the terminals with a solution of baking soda and water (¼ lb. baking soda to 1 quart of water). Be careful to prevent the solution from entering the battery cells and flush the batteries with clean water when finished. After replacing the connections, coat the terminals with a light application of petroleum jelly.
- ***Checking specific gravity:*** In open-cell lead-acid batteries; use a batter hydrometer to check the specific gravity of the electrolyte in each battery cell. A fully charged batter will have a specific gravity of 1.260. Charge the battery if the specific gravity reading is below 1.215.
- ***Checking electrolyte level*:** In open-cell lead-acid batteries, check the level of the electrolyte at least every 200 hr. of operation. If low, fill the battery cells to the bottom of the filler neck with distilled water.

Generator set exercise

Generator sets on continuous standby must be able to go from a cold start to being fully operational in a matter of seconds. This can impose a severe burden on engine parts. However, regular exercising keeps engine parts lubricated, prevents oxidation of electrical contacts, uses up fuel before it deteriorates, and, in general, helps provide reliable engine starting. Exercise the generator set at least once a month for a minimum of 30 minutes loaded to no less than one-third of the nameplate rating. Periods of no-load operation should

be held to a minimum because unburned fuel tends to accumulate in the exhaust system. Whenever possible, test the system with actual building loads in order to exercise the automatic transfer switches and verify performance under real-world conditions. If connecting to the normal load is not convenient for test purposes, the best engine performance and longevity will be obtained by connecting it to a load bank of at least one-third the nameplate rating. Be sure to return the generator control to AUTO at the conclusion of any maintenance.

Conclusion

Diesel generators perform many important roles in many different types of commercial businesses. An understanding of how this equipment should be operated and maintained is critical to many businesses. Paying attention to the issues addressed within this article will help enhance the understanding of the risks involved, and the considered measures needed to reduce the severity and impact of a probable machinery breakdown event.

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May 2020

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RiskTopic_Diesel_generator_operations_maintenance_May_2020

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