AC VS. DC TECHNOLOGY COMPARISON

A common sense comparison of alternators

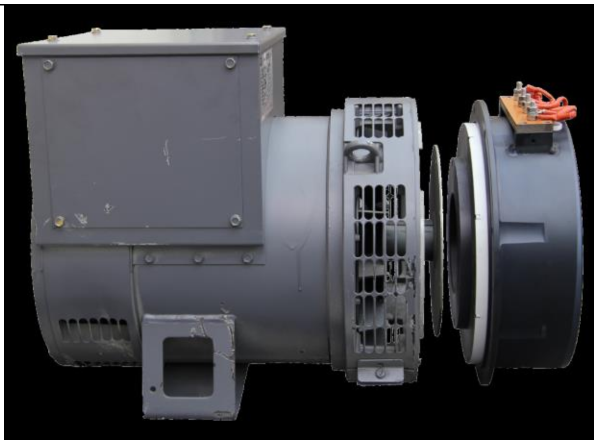

Figure 1, a Leroy Somer Alternator rated at 20 kVA (16 kW), popularly used by Caterpillar and other major AC Generator producers, next to the Polar model 8220 "DC" alternator, rated at 16 to 22 kW (depending on RPM).

It is easy to argue numbers but difficult to make sense of all of it. This is particularly true if the presenter is arguing "apples with oranges".

The purpose of this paper is to analytically examine the differences in Polars' technology versus Caterpillar Cummins and Generac technologies. For those with some mechanical and electrical backgrounds, common sense will prove the point.

The Caterpillar and Cummins White Papers argue in favor of AC generators, but the examples they used in the comparison with DC generator technologies left Polars' technology out of the picture.

There are many types of AC and DC alternators; the Caterpillar and Cummins White Papers implied that all DC generators use the same technology and have the same efficiencies. This is not the case.

Decades ago, Polar coined the term DC alternator for a brush-less permanent magnet alternator with low voltage and high frequency output (400 to 800 Hz) optimized for conversion into DC current. Polars' optimization did not require switch mode power supply as illustrated by Caterpillar and Cummins. The high frequency AC current passes through a simple diode bridge circuit then connects to and charges the battery directly, requiring no other electronics.

In Telecom, the term *rectifier* refers to a battery charger/power supply. In other engineering fields, a rectifier refers to a diode bridge. This is where some confusion arises, the Polar DC generator uses a simple diode bridge and few other DC generator systems use a switch mode circuit to regulate voltage and current.

The best fuel efficiency data is from field trials, not laboratory testing. Typically, laboratory testing fails at simulating real world use of generators. There are too many variables to account for in simulating the real world and at the same time laboratory engineers tend to simplify testing parameters. Also it is unreasonable to compare two manufacturers' equipment performance by using product data sheets. For an accurate comparison, both tests should use the same test technicians, fuels, weather conditions, loads, test equipment, and operate in actual field conditions.

For efficient electric motors and alternators, most engineers their design efficiencies between 90% to 96%. Designers o electromagnetic machinery and power supplies very rarely i parasitic losses into their performance.

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The differences in technology are readily visible from the photograph in Figure 2.

Both machines are designed for approximately 94% efficiency. The design efficiencies are primarily centered about resistance and core losses in the stator and do not include the parasitic losses.

For alternators and motors, parasitic losses include: bearing friction, wind friction (windage), excitation and magnetic field generation, voltage drops through diodes, terminal connection resistance, and cooling blower mechanical loads.

The Polar alternator is brush-less and uses 32 rare earth Neodymium Iron Boron magnets to generate a strong magnetic field in the rotor. The 32 poles at 1800 RPM provide 480 Hz current into a simple diode bridge, which transforms it into DC current. We vary the engine speed to provide voltage and current regulation. The high frequency allows us to “shrink” the size of the alternator. Using rare earth permanent magnets to generate the rotor’s magnetic field eliminates the parasitic loss encountered in AC alternators using electro-magnets. As evidenced by Figure 2, permanent magnets simplifies the alternator design greatly and reduces its size and weight.

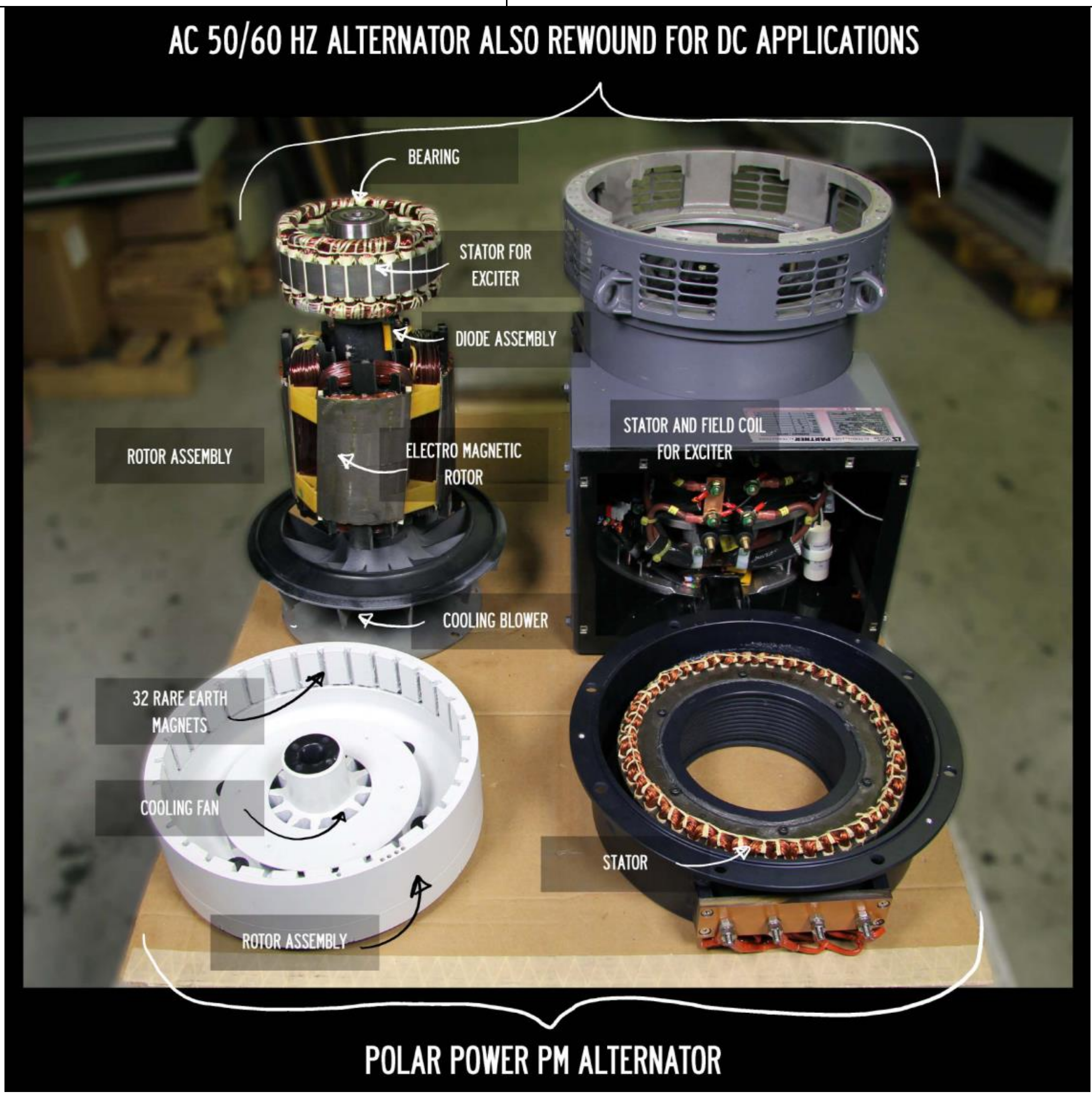

Figure 2

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POLAR POWER INC.

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The mechanical power supplied by the engine is converted into electricity via the stationary stator cutting the magnetic field of the spinning rotor.

The parasitic losses in the Polar model 8000 DC Alternator are:

- Wind friction (windage) of the rotor
- Cooling blower
- Voltage drop through the output diode bridge

Note: due to the "pancake" design, a bearing is not required in the Polar Alternator reducing parasitic losses due to friction.

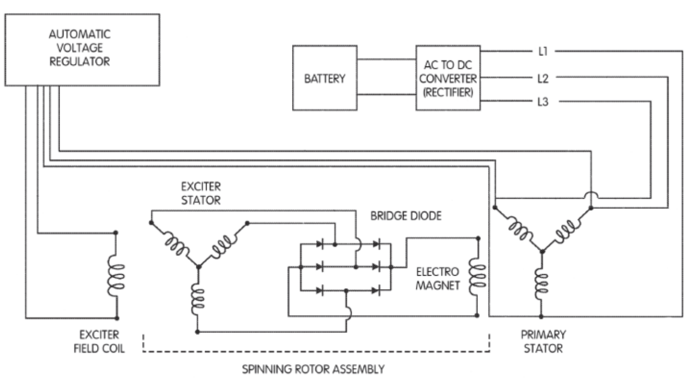
The alternator used by Caterpillar or Cummins (the AC alternator in Fig 2) has 4 poles and generates 60 Hz at 1800 RPM. It is brush-less and uses 4 electromagnets to generate the magnetic field in the rotor instead of permanent magnets. Brushes are not desired in prime power applications alternators because they require service.

To transfer current to the 4 pole electro-magnets mounted on the spinning rotor (without using brushes and slip rings), a "secondary" alternator of smaller capacity is incorporated into the "primary" alternator design. This design feature is referred to as an exciter. The exciter also regulates the voltage to compensate for changing loads. So, to make one large alternator work brush-less, you need a smaller, secondary alternator in the circuit to provide DC current to the rotating field coil. The exciter circuit has a non-rotating (electromagnetic) field coil mounted in the body of the Alternator and is energized by a voltage regulator. This creates a stationary magnetic field. There is a small rotating stator located on the alternator shaft (rotor). When this stator spins, an AC current is generated (this process consumes mechanical energy from the engine). The AC current flows through a diode bridge mounted on the rotating shaft and is converted to DC current. The DC current now energizes the large rotating filed coil which causes the primary magnetic field on the rotor. The mechanical energy from the engine is converted into electricity through the large stationary stator cutting the primary magnetic field of the spinning rotor.

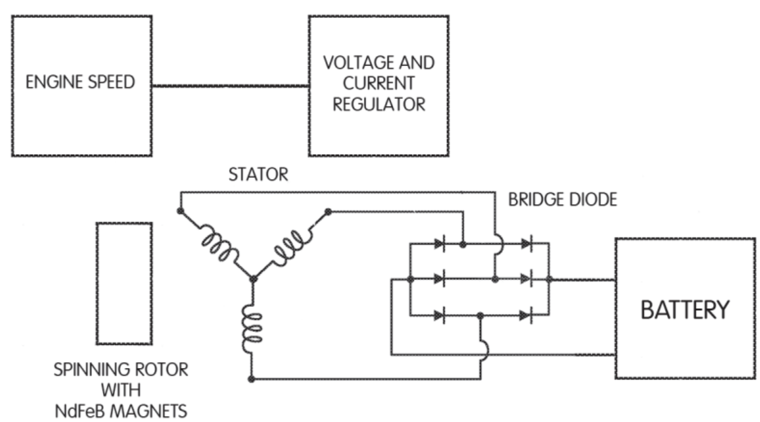
The parasitic losses in the typical AC brush-less alternator include:

Secondary Alternator - Exciter circuit.

- Energy into the voltage regulator to power the exciter stationary field coil



AC alternator



DC alternator

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• Mechanical losses generating electrical power in the exciter's stator coil
• Resistance loss in the winding of the exciter stator coil
• Voltage drop through the exciter diode bridge

Primary Alternator:

• Resistance losses in the stator
• Bearing friction
• Windage
• Cooling fan

Comments:

Engine fuel efficiency is dependent on:

1. Alternator efficiency. From visual observation, it is readily apparent that the size of the AC alternator's blower wheel, the exciter assembly, the rotor's shape, and presence of a bearing, that friction losses will be considerably higher. The losses in the exciter circuit is relatively large in order to power the large windings in the rotor.

2. Does the alternator and control allow variable speed? AC generators are fixed speed while Polars' DC generator is variable speed. There should be no argument that reducing engine speed as electrical loads decrease saves fuel. Most programs assume the loads are constant, though in the field, we have rarely seen a constant load or the load match the numbers the generator was sized for.

3. The engine speed required to drive the alternator. Certain speed ranges offer ideal fuel efficiencies from the engine.

4. Torque ripple on the engine. The four-pole alternator creates a large power demand (torque) on the engine, four times per revolution. To provide a stable frequency, the engine's flywheel must increase in mass, or a larger displacement engine is selected. Some smaller 2-cylinder engines have both pistons move up and down at the same time (even fire) to drive 50 / 60 Hz Alternators; these engines generate high vibration. Polars' 32 pole DC alternator has 32 smaller power demands on each revolution; the torque ripple is smaller and more evenly distributed over each engine revolution.

In actual fuel consumption, the difference is between 15 to 20% for equal and constant loads.

Fuel savings up to 70% are realized when a Polar DC generator rated at 10 kW – 15 kW replaces a 20 kVA – 40 kVA AC generator. Larger AC generators are used in applications powering smaller loads because the larger AC generators are built to be more robust than smaller standby AC generators. Also, AC generators need to be over-sized to handle surge or start up currents from the load.

Polars' small DC Generators are also built to service prime power applications.

Polars' DC Generators do not need to be oversized, having a generator that can limit the output power by regulating both current and voltage allows a 10 kW generator to be used for a 10 kW load without circuit breakers tripping, alternators or engines overheating.

Imagine yourself on a cold night when the starting battery voltage has dropped and the engine oil is thick due to low temperature. Which alternator would you prefer to place on an engine? (Hint the heavier the load, and greater the friction, the more the starter motor must overcome).