

EFFICIENCY IN SMALL PERMANENT MAGNET DC GENERATORS

The overall efficiency of small permanent magnet dc generators is determined by several independent factors, so there is no single efficiency figure that can be specified for any particular generator. Efficiencies range from 75% to 95%, with a mean of about 85%.

Efficiency is affected by the following factors:

1. **Magnet type and strength** - low cost generators use ceramic C8 magnets, and higher cost, higher efficiency generators use neodymium (“rare earth”) magnets.
2. **Magnetic gap** - the smaller the clearance between armature poles and magnets, the better the magnetic flux path and the higher the efficiency (but also see “windage” in item 5 below).
3. **Winding resistance** - the lower the internal electrical resistance of the winding, the less energy is dissipated as heat that results from current flow through the winding resistance. Accordingly, the larger the magnet wire diameter in the armature windings, the lower the resistance and the higher the electrical efficiency, but the larger the generator (the same number of turns of the larger wire gauge are required to generate the same output voltage). The internal resistance and wire gauge is given in the specifications of each generator type.
4. **Heat** - both ambient heat and heat generated by current flow through the windings - the higher the temperature, the higher the resistance and the lower the efficiency. Air cooling of windings, both convective and forced air, improves the generator efficiency.
5. **Windage** - the resistance to rotation caused by air friction around the rotating armature - is higher for very narrow magnetic gaps, and is also higher at higher shaft rpms as well as larger armature diameters.
6. **Load characteristics** - the nature of the generator load, a completely external factor, influences the overall efficiency. Generally, the maximum efficiency occurs when the source (generator) impedance is matched to the external load impedance. In dc generators, impedance effects occur when the inductance of the generator windings interacts in any way with the load. A non-inductive load such as a battery or a resistance heater can be considered purely resistive, while the generator impedance is then simply its internal dc resistance.

Given that the final precise efficiency of a dc generator in a particular application is affected in some way by all the above factors - rpm, load characteristics, internal resistance, voltage, power output and temperature, as well as generator size, magnet type and magnetic gap, the only way to determine the exact efficiency is to measure it in the application and conditions it is to be used. If the input torque and rpm are known or can be measured, and the output power measured at the steady-state loaded temperature, in those conditions, the efficiency is simply the quotient of input over output power:

Calculation of efficiency E - efficiency $E = \frac{P_{OUT}}{P_{IN}}$ ($E \times 100 =$ percent efficiency)

The input power $P_{IN} = 6.28 \times$ shaft torque T (in Newton-meters) \times rotational frequency f (in Hertz or revolutions per second). If the rotational frequency is in rpm, multiply by 60.

The output power P_{OUT} in watts = output voltage $V_o \times$ output current I_o as measured by a voltmeter and ammeter.