STARTUP TORQUE IN PERMANENT MAGNET DC GENERATORS

The torque required to start a permanent magnet dc generator is influenced by the following five mechanical factors, as well as by the ambient temperature.

1. Load

Any electrical load connected to the generator at the time of startup contributes to the startup torque inversely according to the impedance of the load.

Resistive loads add to the torque at any rpm, including startup. Inductive or capacitive loads can influence the startup torque because the increase of output voltage from zero rpm to the operating rpm is equivalent to a very low frequency ac waveform. During startup, energy absorbed by reactive load elements contributes to startup torque.

Normally, generator startup torque is rated with no load, that is, open circuit output, to avoid the complications of external loading.

2. Bearings

Generator bearings (typically two) contribute to startup torque through rotating friction: the ball rolling friction, lubricant viscosity, and seal or shield friction.

Typically the front (exposed) generator bearings are sealed, and the internal rear bearings are shielded.

The lubricant viscosity depends on the ambient temperature. Generator startup in extreme cold requires more torque due to lubricant viscosity. As the bearings warm up, due to friction, this initial torque decreases.

New bearings exhibit higher startup torque until they have been "run in" over a period of hours. Side pressure on the generator shaft, such as a pulley adds to bearing friction, so also to startup torque.

3. Brushes

The carbon brushes (two or more) are spring-loaded against the rotating commutator, causing friction at any rpm, but most at startup (breaking static friction). Bearing friction is minimized in generator design by shaping the brushes to match the curvature of the commutator, thus minimizing the pressure required for a given current flow, by micro-finishing the commutator surface, and by using low-friction carbon brush material.

4. Inertia

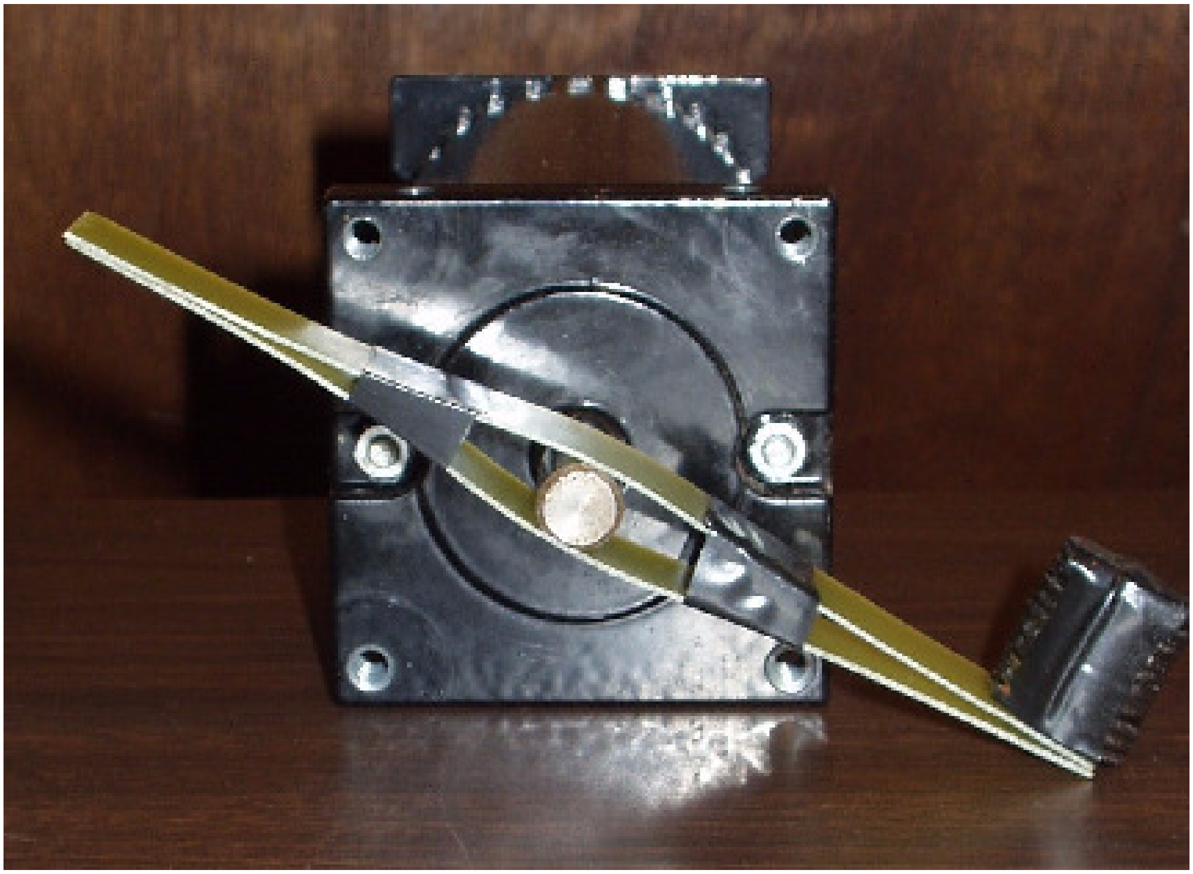
The moment of inertia, i.e. the amount of energy required to start the mass of the armature rotating up to the operating speed, contributes to the startup torque. A soft (slow) start minimizes this element of startup torque.

5. Magnetic Cogging

Magnetic cogging - attraction of pole-pieces to magnet edges - is most evident at startup, but can be minimized in generator design either by skewing the armature laminations or by designing the width of armature poles to cause matching of positive to negative cogging forces. At operating rpm, cogging does not typically add to running torque because the inertia of the armature tends to smooth out torque ripple.

The startup torque of any generator is unique to that generator design and size, and is inversely proportional to the pre-startup temperature. An analytical determination of startup torque would be extremely complex, so to find out the startup torque of a generator at a given temperature, the simplest way is to attach a light balanced horizontal arm to the generator shaft, and add weights, such as coins or washers, to one side until the generator turns.

Startup torque measurement, using a Windstream 443541 permanent magnet dc generator.



Construct a light balance beam as shown, using two thin plastic strips taped together so that one of the strips engages the flat on the generator shaft.

Set the balance beam in a horizontal position. Add weights to one end of the beam until the generator starts to turn. Measure the distance between the center of the generator shaft and the center of the weights, and accurately weigh the total weight added.

In this instance, the weight was ten washers each weighing 6g, for a total of 60g (=0.06Kg), and the lever arm (radius) was 75mm (=0.075m).

The startup torque **T = Fr**, where **F** is the rotational force in Newtons and **r** is the lever arm radius in meters.

F = mg, where **m** is the mass of the weight and **g** is the gravitational constant 9.8.
F = 0.06 x 9.8 = **0.588 Newton**

Startup torque **T** = 0.588 x 0.075 = **0.044 Newton-meter** (equivalent to 0.032 pound-feet or 0.38 pound-inches.