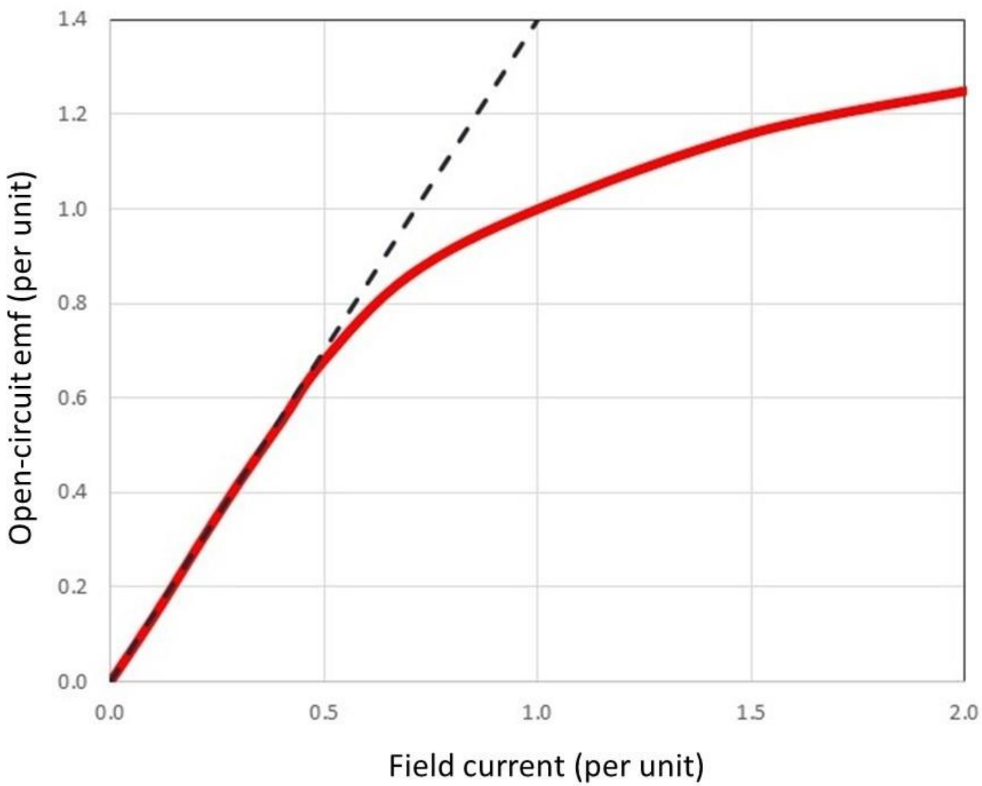
Open-circuit characteristic - saturation effects

Consider a typical open-circuit emf versus field current characteristic.

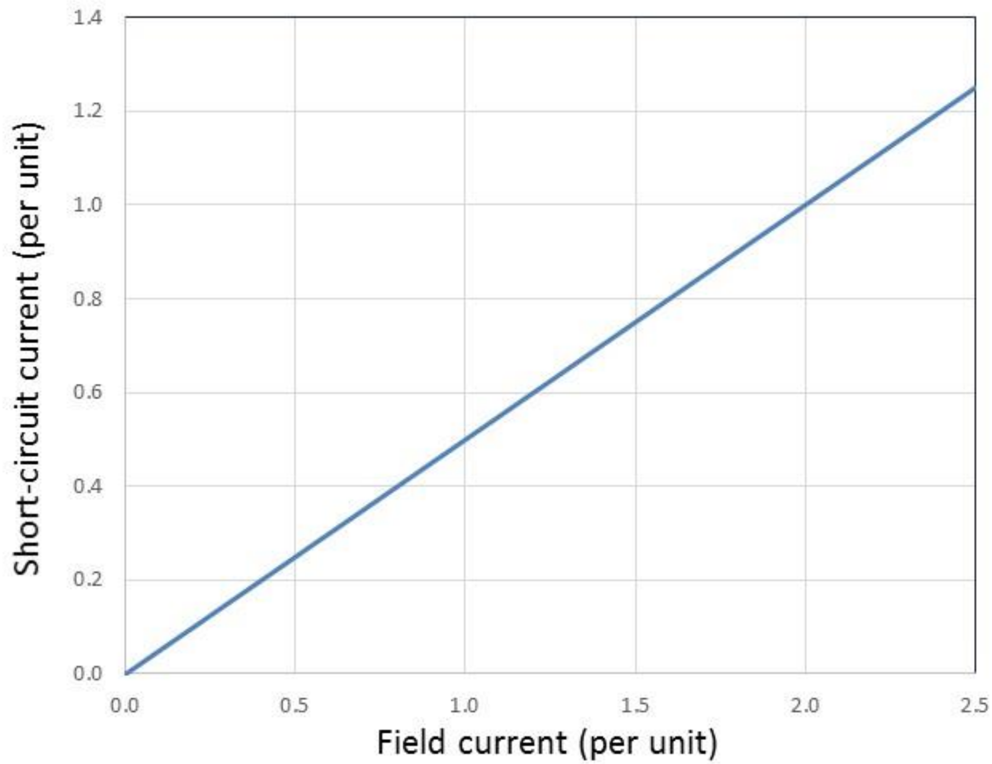


N. B Not all designs are operated below saturation at rated emf – trade off with slot area in stator

- At low to medium values of the field excitation, the effective magnetic reluctance is dominated by the airgap and the characteristic is essentially linear – (this region is often, and arguably unhelpfully referred to as the 'air-line').
- Beyond a certain point (which is determined by a combination of material characteristics and core dimensions) some degree of core magnetic saturation becomes evident and the reluctance of the core beings to increase.
- Following the onset of magnetic saturation in the core, the rate of rise of the induced stator emf with field current begins to diminish.

Short-circuit characteristic

- Another key characteristic is the so-called short-circuit current characteristic



- This characteristic remains linear to much higher levels of field current than the emf characteristic (due to reaction field produced by short-circuit currents)

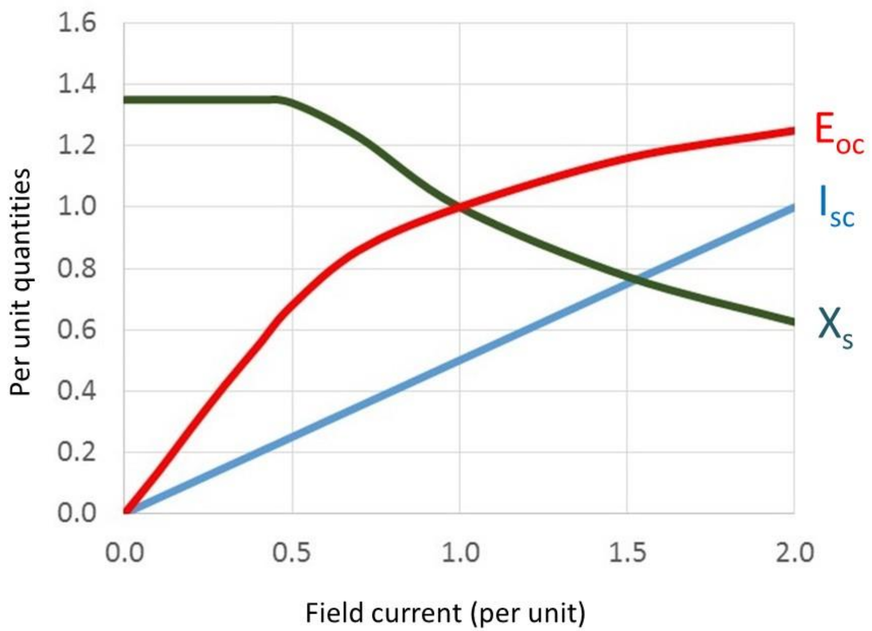
Synchronous reactance – non-salient machine

The preceding analysis has demonstrated that the performance of a synchronous machine is strongly influenced by the magnitude of the synchronous reactance.

At any value of field current, The synchronous impedance is given by: $z_s = \frac{E_{oc}}{I_{sc}}$

In a large machines (100s of KW and above) the resistance is typically <1% of the reactance and hence to a good approximation: $z_s \approx x_s \approx \frac{E_{oc}}{I_{sc}}$

However, the value of x_s is a function of field current because of the onset of magnetic saturation. By way of example:



1.0 per unit reactance is defined as reactance at 1.0 per unit E_{oc}

An often quoted single value of reactance is the unsaturated value x_{su} which is ~1.25 per unit in the example shown

Synchronous reactance – salient pole machines

The exact values of x_{sd} and x_{sq} (and which will vary to some degree with field current) will depend on the specific design features of the generator

These can be measured with appropriate procedures or calculated to a reasonable level of precision with advanced modelling methods such as finite element analysis

However, reasonable estimates for many practical synchronous machines can be derived using:

$$x_{sd} = k_d x_s$$

$$x_{sq} = k_q x_s$$

Where x_s is the synchronous reactance of an equivalent non-salient machine

Typical values for practical salient-pole machines are: $k_d = 0.85$ and $k_q = 0.35$