Stepperators

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1. Introduction

As stepper motors tend to have big coils, they can be used to generate electrical power just as well as consuming it.

The reason for me to create this article was pure curiosity and the idea to build a wind turbine without having any previous knowledge of generators. I honestly must admit that the practical sense of using such motors as generators is low or not existent at all as it will be demonstrated in the curse of this article. However, I see it as a small mathematical problem that shows what should be considered when building generators.

2. Inductivity basics

Using the general formula for inductivity

$$\mathrm{u}(t) = \frac{d\Phi}{\mathrm{dt}} = \mathrm{L}\frac{\mathrm{di}}{\mathrm{dt}}$$

and defining the current magnetic flux Φ dependent on the position of the rotor ϕ as it determines the position of the permanent magnets, one can determine the time dependent formula of the voltage

$$\Phi(t) = \widehat{\Phi}\sin\big(\phi_{\mathrm{M}}(t)\big)$$

$$\phi(t) = \int \omega_{\mathrm{M}}(t)\,\mathrm{dt}$$

For a constant omega the final time-dependent formula ends as

$$\mathrm{u(t)} = \widehat{\Phi}\omega_{\mathrm{M}}\cos(\omega_{\mathrm{M}}\mathrm{t} + \phi_0)$$

As we now are interested in the amplitude of the voltage, the cosine of the formula can be assumed as one, which when converting from the *magnetizing omega* to the *real omega* gives us our final formula

$$\hat{u} = \widehat{\Phi}\omega\frac{n_R}{2\pi}$$

the parameter n_R will be dealt with in the following chapter.

3. Known data from stepper motors

For common stepper motors, a lot of values and data about the motor are given to the user which we can use now. The following parameters are required for the calculation

- I_{max}, the maximum amperage of each phase
- n_R, the number of magnetization cycles per revolution, in most cases it can be calculated using $\frac{n_S}{n_C}$ with
  - n_S as the number of steps per revolution
  - n_C the number of steps in a step cycle
- L, the inductivity of the stepper motor

- R_C, coil resistance

Out of these parameters, it makes sense to introduce a constant that defines the relation between generated voltage to rotor speed.

$$N_{SR} = LI_{max}\frac{n_R}{2\pi}$$

$$\hat{u}(\omega) = N_{SR}\,\omega$$

Additionally, the total resistance R_T depends on all resistances in the circuit R_A and the coil resistance of the stepperator R_C:

$$R_T = R_C + R_A$$

4. Resistance torque

To get the resistance torque we can use a power equation, which means we directly correlate mechanical input power to electrical output power:

$$P_{mech} = P_{el}$$

$$\overline{T_R}\omega = \frac{\hat{u}^2}{2R_T} = \frac{N_{SR}^2\omega^2}{2R_T}$$

$$\overline{T_R} = \frac{N_{SR}^2\omega}{2R_T}$$