Back electromotive force (Back EMF) explained

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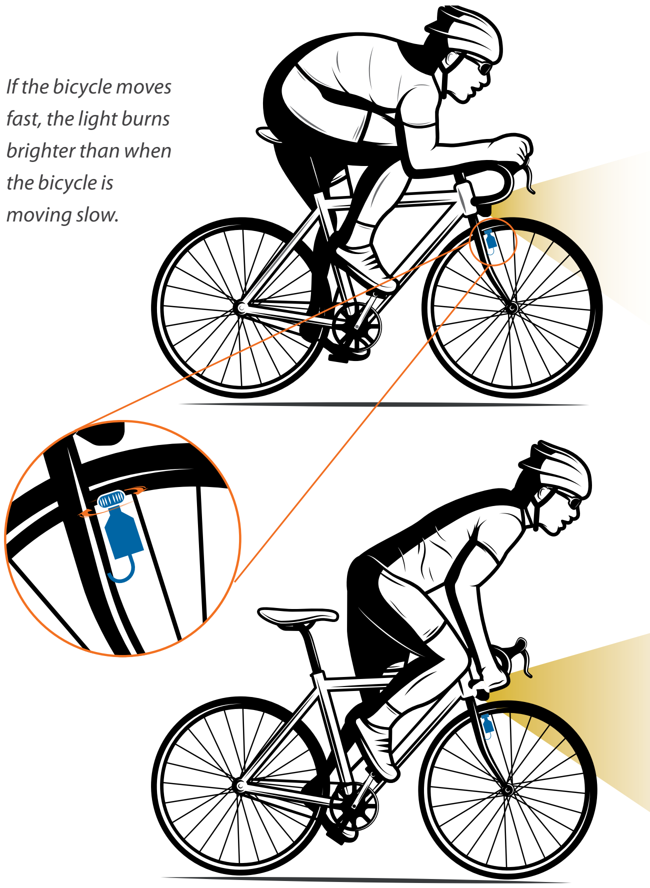
Introduction

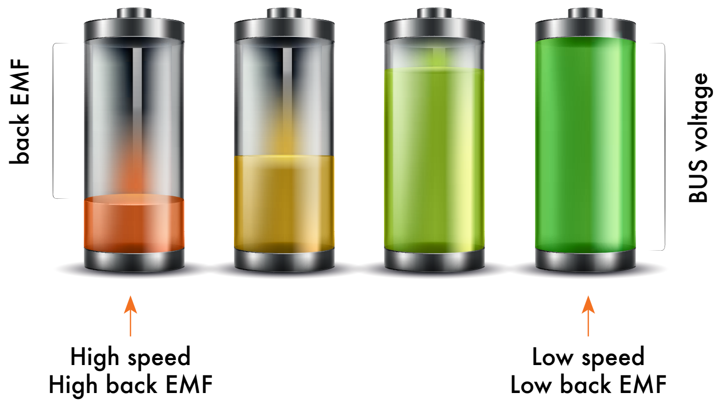
Back electro motive force (EMF) is known under a variety of other names. The most common alternative name is counter electromotive force. It is a voltage that opposes the change in current that induced it, as is described by Lenz's law. In a motor the changing of a magnetic field, or change in current, is caused by a relative movement of its coil, with respect to alternating magnetic poles. This can either be by moving the coil past a static magnet (linear motors) or moving magnets past a static coil (torque motors).

If the bicycle moves fast, the light burns brighter than when the bicycle is moving slow.



The unit for this constant is typically Volts per meter per second (V/m/s) or volts per angular velocity (V/kRPM). In our datasheets it is given as an RMS value and a peak-to-peak value and has the parameter name K_e. Back EMF can also be viewed in the context of generators, as motors and generators are very similar. The former converts electrical

When moving the motor also acts as a generator.
High speeds means a high back EMF



The back EMF is opposite the bus voltage and reduces the available voltage for creating movement

energy into mechanical energy and the latter vice versa. When the motor is for instance moving at a certain speed, a voltage is generated that is proportional to this speed. A practical example of this phenomenon is the bicycle dynamo.

Maximum speed and winding types

The maximum speed of the motor depends largely on the back EMF. While the motor is moving, the motor also behaves like a generator. The voltage that is generated is in series with, and is opposite to the bus voltage. As a result the available bus voltage for generating speed is reduced.

Our Tecnotion S-type motor is developed to have a lower back EMF, which increases the maximum speed but increases the required current, as opposed to our N-type motor.

The maximum available voltage for a motor is the bus voltage. During movement, there are two other voltages to acknowledge. Normally we use the term Uph-ph,peak for the necessary voltage for a certain motion. However, in this document it is called UR. The difference is that in this document the voltage component due to self-inductance is left out for simplicity.

Leaving only the voltage component due to resistance, which typically is much greater than the self-inductance voltage component. The second voltage to be aware of is the back EMF. And so:

$$U_{bemf} = K_e * v$$

$$U_R = I_{rms} * R_{ph} * \sqrt{6}$$

$$U_{bus} = U_R + U_{bemf}$$

The √6 – term is because it is necessary to go from a single phase to a phase to phase value and from RMS to a peak value.

At a certain speed the addition of these two components will equal the bus voltage, if the speed of the motor is further increased the current through the motor will be limited by the back EMF component. This in turn will cause the force to decrease.

Conversely, the maximum speed can be roughly approximated:

Figure - U_{bus}, U_R and E

Another way to check the maximum motor speed more accurate, is to use the Simulation tool, which is available on our website, Tecnotion.com/simtool. The tool displays the maximum voltage needed for a given motion profile, which can be immediately compared to the available supply voltage.

Low back EMF

The lower back EMF for the S-type coil is due to its lower resistance and inductance. The induced voltage will be lower for the S-type than the N-type, but to provide the same amount of force, you need more current to induce the same electric magnetic field as the motor with the N-type coils. The N-type is the common type of coil because this motor needs less current to generate a big force. This results in a smaller amplifier in relation to the S-type. The S-type can be used when the N-type motor does not provide enough speed.

[Example]

An UL9 ironless linear motor with a N-winding is moving with 4 meter per second. The maximum speed of our UL9N is roughly the bus voltage divided by the back EMF.

$$v_{max} = U_{bus}/K_e$$

$$v_{max} = 300\ V\ /\ 55.5\ \frac{V}{m/s} \cong 5\ m/s$$

If we take the same motor, but now with a S-winding:

$$v_{max} = 300\ V\ /\ 22.5\ \frac{V}{m/s} \cong 13\ m/s$$

When you multiply the back EMF by the specified maximum speed, the voltage doesn't reach the bus voltage. This is because a little voltage is always required to build up a current for the electric-magnetic field, that is necessary to move the motor at that certain speed. The above calculations are an accurate estimate.

[End note]

Our team of Application Engineers can support in your challenges with back EMF. Please contact us at:

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About Tecnotion
Tecnotion direct drive motors are seamlessly integrated into a wide range of applications such as semiconductors, machine tooling, robotics, display applications, and the printing industry.

As the independent supplier of linear- and torque motors, we provide specialized motor technology to place in customers motion solutions. With a wealth of experience, we are accustomed to designing and building any motion question, from catalog to customized products.

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