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Dynamic braking resistors (DBR's) for inverters and DC drive systems

A drive motor can also act as a generator. If the drive system is built so as to allow reverse power to flow then this power can be fed into a resistor, thus taking energy out of the system and causing whatever is driving the motor to slow down. The rate of braking is determined by how fast the energy is put into the DBR.

The DC link capacitance of any inverter drive can itself absorb 3-5% of the regenerated power. For non-critical applications these losses, together with the mechanical losses in the drive system, may provide enough braking. Higher powers, up to 100% or more of the motor's full load torque rating, can be absorbed and then dissipated by a DBR connected across the DC bus.

Where the braking power is only a few tens or hundreds of watts a resistor mounted internally to the drive itself may be suitable, but above these levels the amount of heat generated means that a separately mounted DBR with appropriate cooling provision is needed.

The DBR is switched on by a separate control unit, activated by a sensor which is monitoring the voltage level of the DC bus and switching on the DBR when this voltage rises above some preset trigger level as a result of the reverse power flowing into the drive. There may be temperature sensing in the DBR to prevent overloading of the drive.

All the energy is used in heating the resistor; some is dissipated at once, the rest after the stop while the resistor cools. This is why we must know the characteristics of the duty cycle before we can specify the right size for the DBR.

What is the stopping energy?

The DBR turns the stop energy into heat. Both types of energy are measured in Joules (J); one Joule is a very small quantity, so we usually talk about kJ or MJ.
In order to design a braking system we have to consider both the *amount* of heat (in Joules) and the *rate* at which it is generated. This is Joules/second, usually known as watts, and for the same reason usually measured in kW or MW.

We therefore need to know the quantity of energy per stop, and the stop frequency.

Energy per stop: determines the DBR **peak** power
Energy per stop + frequency: determines the DBR **average** power

We all have a good idea of what any given length, weight or time interval represents; this is usually not so for energy. By way of illustration here are some everyday examples:

Man on a bike stopping:	2kJ
Lift with four people in it:	25kJ
Car stopping from 50mph:	250kJ
Flywheel 600mm x 300mm thick, 1500rpm:	375kJ
40’ container lowered on to a ship:	2MJ
Eddie Stobart’s lorry from 65mph	15MJ
London Underground train from 50mph	50MJ

How do you calculate the stopping energy put into a DBR?

Stop energy (Remember friction, drag, etc all work in your favour)
Remember first of all to convert everything into the right units: metres, kilograms, seconds and (for rotational energy) radians.

Kinetic energy $= m\,v^2/2$
e.g. man on bike (60kg man, 20kg bike, 15mph or 7m/s)

$$= 80 \text{ x } 7 \text{ x } 7 / 2$$
$$\approx 2000\text{J}$$
$$\approx 2\text{kJ}$$

Rotating energy $= J.\omega^2/2$
eg flywheel 600mm diameter x 300mm thick at 1500rpm
(J is the moment of inertia of the flywheel)

$$= (m.r^2 /2) \text{ x } \omega^2/2$$
$$= (\rho\pi r^2 d \text{ x } r^2/2) \text{ x } \omega^2/2$$
$$= (8000 \text{ x } \pi \text{ x } 0.34 \text{ x } 0.3/2) \text{ x } (2\pi \text{ x } 1500/60)^2/2$$
$$\approx 375{,}000\text{J}$$
$$\approx 375\text{k}$$

Potential energy $= m.g.h$
e.g. crane with a10ton container lowered 20m on to a ship

$$= 10{,}000 \text{ x } 10 \text{ x } 20$$
$$= 1{,}000{,}000\text{J}$$
$$= 2\text{MJ}$$

How do you calculate the size of a DBR?

To specify the resistor we need to know three things: the energy per stop, the duty cycle and the ohmic value. The first two are usually combined into one variable, the power of the resistor.

Power

In an ideal world you calculate the mechanical energy involved in each stop, using one or more of the above formulae. This will be the sum of the kinetic, rotational and potential energies, less any friction losses if these are significant, less the electrical losses in the motor/inverter system.

Unfortunately the real world is different and it is much more likely that you will have little or no hard information about the application. As resistor manufacturers we like this – for safety you will probably order a bigger DBR than you really need – but you still need to make a decision. Our suggestion is as follows: if you know what the drive is being used for and can guess at the run-up time, then:

stop energy = start energy (approximately)
= start time x power during starting
= start time x max. power/2
= start time x drive power/2

Knowing the stop energy and the duty cycle you can calculate the *average* power into the resistor and for most duty cycles this will be the right power to specify.

When the stop time is short in relation to the total duty cycle we may also need to consider the thermal capacity of the resistor, to ensure that it does not overheat during a single stop. This is tabulated graphically below, showing the short-term power ratings for different sizes of our resistor range.

Ohms

The ohmic value sets the rate at which we put the energy into the resistor – the braking power. The lower the ohmic value, the higher the power.

The minimum ohms are set by the drive manufacturer, and will produce braking power at the peak rating of the drive (or its braking module).

Ohms = $(\text{DC bus volts})^2/(\text{Peak power})$

Higher ohmic values can be used; they will reduce the braking power proportionally, and hence increase the stop times for any given load.