Telega tuning procedure in RPM control mode

In order to improve the step response characteristics of the speed control loop, perform the following adjustments:

- Set the acceleration rate to **10 000 ~ 15 000 electrical radian per second per second**, depending on the needs of your application.
- Set the deceleration rate close to **10 000 electrical radians per second per second** or lower (higher values should be avoided).
- Set the maximum current to **1.5 times** of the maximum continuous current of the motor, but **not higher than max current for the hardware.**
- Set the current ramp (`m.current_ramp`) to 1000 - 10000 Amps/sec and the voltage ramp (`m.voltage_ramp`) to 1000 V/sec. It will push all the rate limits except the acceleration/deceleration rates which were set above.
- Set the inner current loop bandwidth (`m.current_ctl_bw`) to 0.1 value. If at low loads or at low speeds the electric motor makes a humming sound, or if the motor doesn't work stably at high speeds and loads, decrease this parameter until these effects disappear.
- Increase the P gain of the speed controller (more info below).
- Increase the I gain of the speed controller (more info below). If during braking the motor makes the sound of a dying animal and restarts, decrease the P or I gain or deceleration rate.

The relationship between electrical angular velocity and mechanical RPM is defined as follows:

$$\mathrm{RPM}_M = \frac{60\,\omega_E}{\pi\,P}$$

$$\omega_E = \frac{1}{60}\,\pi\,P\,\mathrm{RPM}_M$$

where:

- **RPMM** - mechanical RPM,
- **ωE** - electrical angular velocity, in radian per second,
- **P** - number of rotor poles.

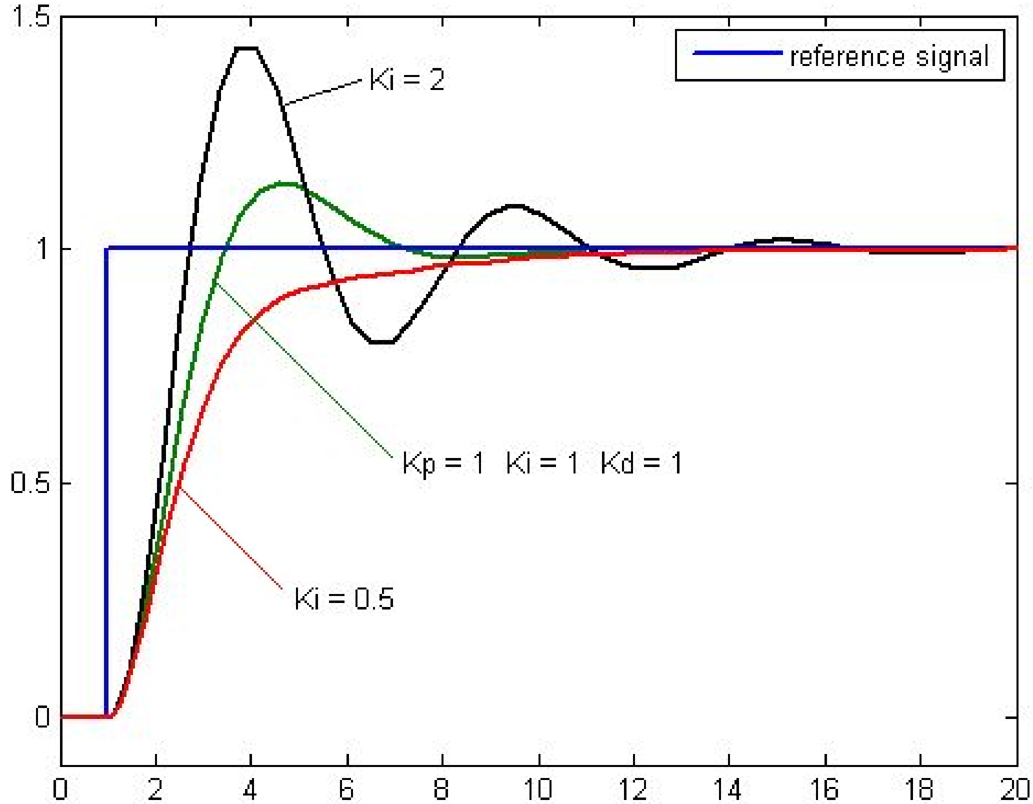
The transfer function of the speed PID controller can be approximated as follows:

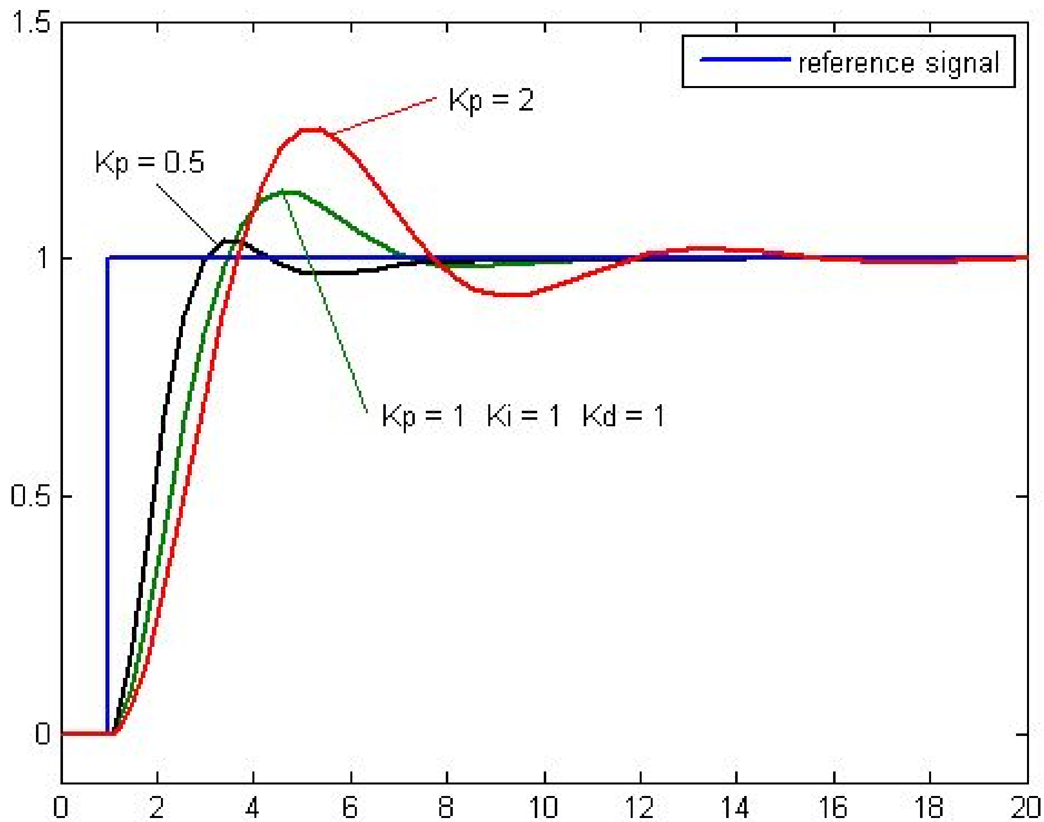
$$A = \sum_{s=0}^{n} 4\, K_i\, T_{\mathrm{PWM}}\,(\omega_{E\,s} - \Omega_{E\,s}) + \frac{K_d\,(-\omega_{E\,n-1} + \omega_{E\,n} + \Omega_{E\,n-1} - \Omega_{E\,n})}{4\,T_{\mathrm{PWM}}} + K_p\,(\omega_{E\,n} - \Omega_{E\,n})$$

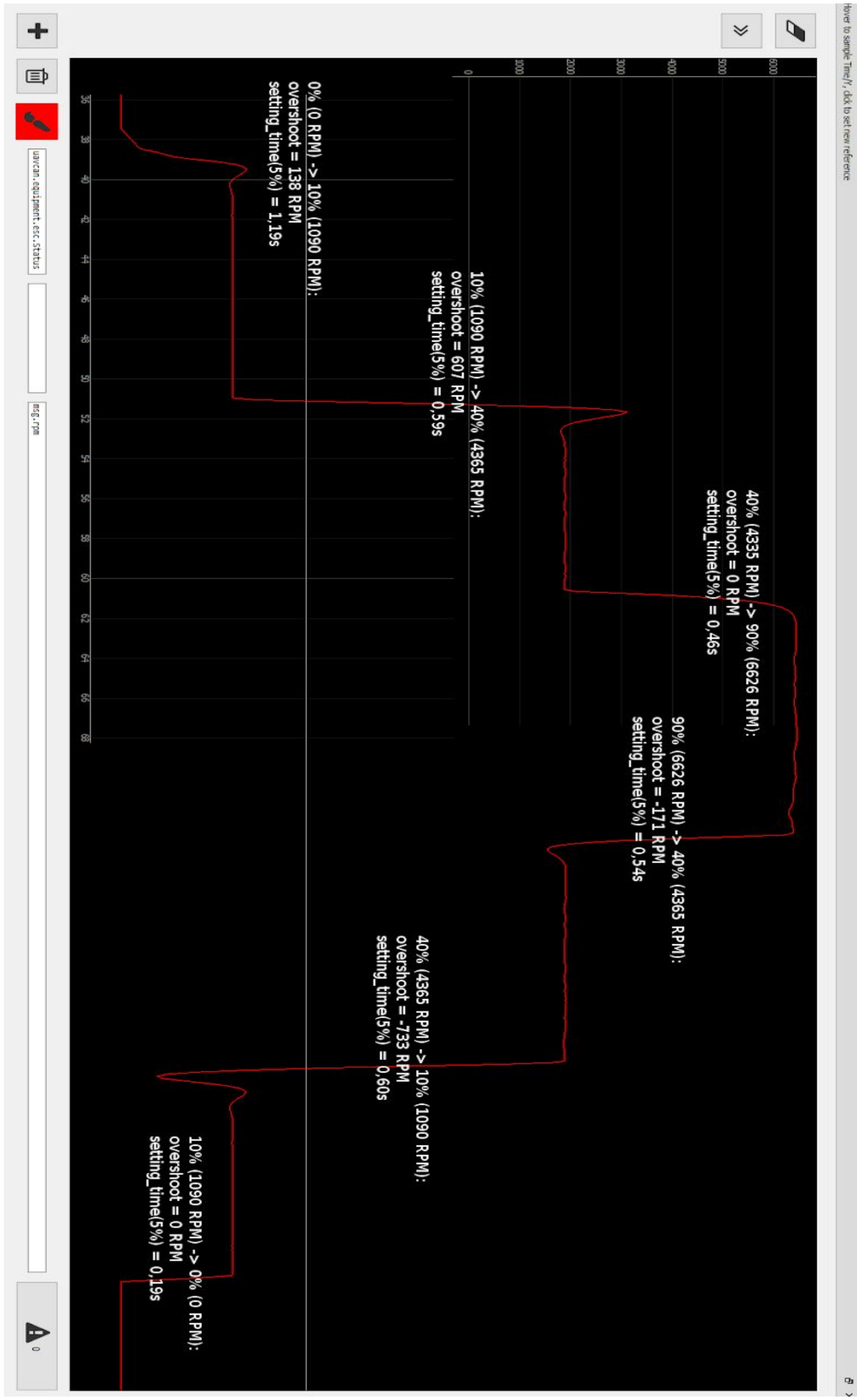
where:

- **A** - current setpoint [ampere]
- **Kp** - proportional gain [ampere*second/electrical_radian]
- **Ki** - integral gain [ampere/electrical_radian]
- **Kd** - integral gain [ampere*second2/electrical_radian]
- **n** - sample index
- **ωE** - electrical angular velocity [radian/second]
- **ΩE** - electrical angular velocity setpoint [radian/second]
- **TPWM** - PWM period [second]

The standard PID tuning principles apply. Generally, the proportional gain should be increased until a satisfactory short-term performance of the controller is achieved. After that, the integral gain should be increased until the convergence is satisfactory yet the system doesn't trigger self-induced oscillations. The response of a generic PID controller to Kp and Ki is shown on the images below, respectively.


reference signal
Ki = 2
Kp = 1 Ki = 1 Kd = 1
Ki = 0.5
1.5
1
0.5
0
0 2 4 6 8 10 12 14 16 18 20


reference signal
Kp = 2
Kp = 0.5
Kp = 1 Ki = 1 Kd = 1
1.5
1
0.5
0
0 2 4 6 8 10 12 14 16 18 20



The example of motor speed diagram after tuning