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(54) **Title:** TUNING METHOD OF PI AND PID CONTROLLERS

$$T = \frac{\sqrt{k_p^2 k^2 - \omega_{osc}^2}}{\omega_{osc}^2} \quad (I)$$

$$k_u = 10^{-0.7847} \cdot 10^{0.7942/\sqrt{\theta}} \\ \tau = 0.99 + 0.389 \cdot \theta + 0.00115 \cdot \theta^2 \\ \delta = -0.1467 + 0.4734\sqrt{\theta} \quad (II)$$

$$k_{pN} = \frac{k_u}{k} \quad (III) \\ T_{iN} = \tau \cdot T, \\ T_{dN} = \delta \cdot T$$

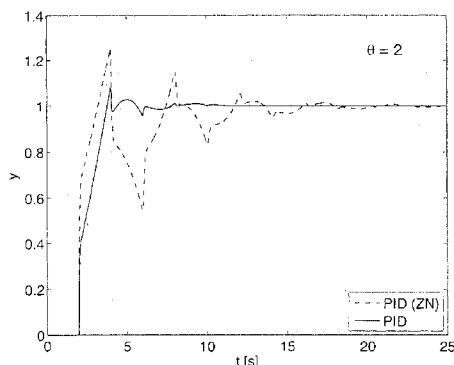


Fig. 3

(57) **Abstract:** The invented controller tuning method relies on the following procedure. To the controlled system with known proportional gain the integral type controller is connected in series. The controller gain k_I is increased to get the closed loop system to the stability limit. At this stage the controller ultimate gain k_u and the sustained oscillation period T_{osc} of the controlled value are assessed. It is assumed that the controlled system dynamics can be approximated by the first order filter with dead time model. The following formulas allow to estimate the first order filter time constant F (1) and the coefficient $\theta = L/T = (\arctg(\omega_{osc} T))/(\omega_{osc} T)$ where L is the dead time constant of the controlled system model. From the formulas: F (2) the controller model parameters are calculated. After that on the basis of the calculated controller model parameters values the real controller parameters are calculated from the formulas: F (3) the proportional controller gain, the T_{iN} is the integral controller time constant and the T_{dN} is the derivative controller time constant.



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AMENDED CLAIMS

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1. The tuning methods of the PI controller parameters in the closed loop control system of the object, which the transfer function may be approximated as the first order filter with time constant T and dead time L , and known gain k , comprising the steps of:

(a) connecting in series the input of the controlled object with the output of the integral part of the controller which the proportional part is disconnected, setting the lowest gain value and closing the control loop,

(b) increasing the controller gain up to the stability limit with stable oscillations of the controlled variable and describing the period of the oscillations T_{osc} and fixed value of the controller gain k_U ,

(c) calculating of the first order lag T of the controlled system model using the

following formula $T = \frac{\sqrt{k_U^2 k^2 - \omega_{osc}^2}}{\omega_{osc}^2}$ where $\omega_{osc} = 2\pi / T_{osc}$ and the coefficient

$\theta = (\arccos(\omega_{osc} T)) / (\omega_{osc} T) = L / T$ where L is the controlled system model dead time,

(d) calculating the settings of the PI controller from the following formula

$k_o = 10^{-0.67+0.49/\sqrt{\theta}}$ and determine the physical settings of the real PI
 $\tau = 0.91 + 0.31 \cdot \theta + 0.0058 \cdot \theta^2$

controller from the relations $k_{pN} = \frac{k_o}{k}$ where k_{pN} is the proportional controller
 $T_{iN} = \tau \cdot T$

gain and the T_{iN} is integral controller time constant.

2. The tuning methods of the PID controllers parameters in the closed loop control system of the object, which the transfer function may be approximated as the first order filter with time constant T and with dead time L , and known gain k , comprising the step of:

(a) connecting in series the input of the controlled object with the output of the integral part of the controller which the proportional and the differential parts are disconnected, setting the lowest gain value and closing the control loop,

(b) increasing the controller gain up to the stability limit with stable oscillations of the controlled variable and describing the period of the oscillations T_{osc} and fixed value of the controller gain k_U ,

(c) calculating of the first order lag T of the controlled system model using the

following formula $T = \frac{\sqrt{k_U^2 k^2 - \omega_{osc}^2}}{\omega_{osc}^2}$ where $\omega_{osc} = 2\pi / T_{osc}$ and the coefficient

$\theta = (\text{arctg}(\omega_{osc} T)) / (\omega_{osc} T) = L / T$ where L is the controlled system model dead time,

(d) calculating the settings of the PID controller from the following formula

$$k_o = 10^{-0.79 + 0.81/\sqrt[3]{\theta}}$$

$\tau = 0.97 + 0.4 \cdot \theta$ and determine the physical settings of real PI controller from

$$\delta = -0.16 + 0.48\sqrt{\theta}$$

$$k_{pN} = \frac{k_o}{k}$$

the relations $T_{iN} = \tau \cdot T$ where k_{pN} is the proportional controller gain and the T_{iN}

$$T_{dN} = \delta \cdot T$$

is the integral controller time constant and the T_{dN} is derivative controller time constant.