A Basic PID Algorithm

Definition of terms (memory elements in *Italics*)**:**

Counting indices:
j = represents the index of the current cycle
$j-1$ = represents the index of the previous cycle

Temperature measurement:
T_j = current temperature of this cycle [^oC], also can be written as just T
T_{j-1} = temperature of the last cycle [^oC]
δT = $T_j - T_{j-1}$ temperature change since the last cycle

Time measurement:
t_j = current time of this cycle (sec), also can be written as just t
t_{j-1} = time of the last cycle (sec)
δt = $t_j - t_{j-1}$ elapsed time since the last cycle

Control Parameters:
T_s = Setpoint (desired temperature) [^oC]

allowing us to define the error signal :
ε_j = $T_j - T_s$ Error Signal [^oC], also can be written as just $\varepsilon = T - T_s$
ε_{j-1} = $T_{j-1} - T_s$ Error Signal for the previous cycle [^oC]
$\delta\varepsilon$ = $\varepsilon_j - \varepsilon_{j-1} = T_j - T_{j-1}$ error change since the last cycle [^oC], equal to the temperature change since the last cycle

Δ = Control bandwidth [^oC]
S = Settle bandwidth [^oC]
τ_i = Integral time (sec)
I_{on} = Integral control on, Boolean, True = on, False = off
τ_d = Derivative time (sec)
D_{on} = Derivative control on, Boolean, True = on, False = off
t_s = Settle time [sec]
T_H = $T_s + \Delta/2$ High limit of control band
T_L = $T_s - \Delta/2$ Low limit of control band
T_{SH} = $T_s + S/2$ High limit of settle band
T_{SL} = $T_s - S/2$ Low limit of settle band

Power terms:
P_p = Proportional power [normalized]
k_j = current count of the number of cycles outside the control band
k_{j-1} = count of the number of cycles outside the control band on the last cycle
P_{Ij} = current integral power [normalized], also can be written as just P_I
P_{Ij-1} = integral power of last cycle [normalized]
P_d = Derivative power [normalized]
P_r = $P_p + P_{Ij} + P_d$ Raw total power [normalized]
P_t = Final total power [normalized 0-1]

Settle terms:

G_o = Temperature is settled, Boolean, True = on, False = off

t_{ej} = current elapsed running time in the settle band [sec]

t_{ej-1} = elapsed running time in the settle band of the previous cycle [sec]

Power Algorithm:

Proportional power:

$Pp = 1/2 - \varepsilon/\Delta$ if $T_L \leq T_j \leq T_H$ or

$= 1$ if $T_j < T_L$ or

$= 0$ if $T_H < T_j$

Derivative power:

$P_d = -[\tau_d/\Delta]*[\delta\varepsilon/\delta t]$ if D_{on} = True or

$= 0$ if D_{on} = False

Out counter:

$k_j = k_{j-1} + 1$ if $Tj < T_L$ or $T_H < T_j$

$= 0$ and $k_{j-1} = 0$ if $T_L \leq T_j \leq T_H$

Integral power:

$P_{Ij} = P_{Ij-1} - [(\varepsilon*\delta t]/[\Delta*\tau_i]$ if $T_L \leq T_j \leq T_H$ and I_{on} = True

$= 0$ and $P_{Ij-1} = 0$ if $k_j > 1$ or I_{on} = False

Raw power:

$P_r = P_p + P_{Ij} + P_d$

Final total power:

$P_t = P_r$ if $0 < P_r < 1$

$P_t = 1$ if $1 < P_r$

$P_t = 0$ if $P_r < 0$

Settle Algorithm:

Settle time tracking:

$t_{ej} = t_{ej-1} + \delta t$ if $T_{SL} < T_j < T_{SH}$

$= 0$ if $T_j < T_{SL}$

$= 0$ if $T_{SH} < T_j$

Determination of settled condition:

G_o = True if $t_s < t_{ej}$

Initialization:

$T_{j-1} = T_j$

$t_{j-1} = t_j$

$k_{j-1} = 0$

$P_{Ij-1} = 0$

t_{ej-1} = 0
P_d = 0
P_{Ij} = 0

Reasonable Starting Values for the “bug”:

Δ	=	4	Control bandwidth [^{o}C]
S	=	1	Settle bandwidth [^{o}C]
τ_i	=	30	Integral time (sec)
τ_d	=	0.5	Derivative time (sec)
t_s	=	60	Settle time [sec]