# CIGRÉ GT model for Combined Cycle Power Plants

This model is located at system bus #_____IBUS
Machine #_____I
This model uses CONs starting with #_____J
and STATEs starting with #_____K
and VARs starting with #_____L

| CON | # | value | DESCRIPTION |
|---|---|---|---|
| J | | | $R_p$ (s) Electrical power feedback droop |
| J+1 | | | $T_p$ (p.u.) Electrical power feedback time constant (>0) |
| J+2 | | | $R_v$ (p.u.) Governor feedback droop |
| J+3 | | | $K_{mwp}$ (p.u.) Proportional gain for outer loop MW control |
| J+4 | | | $K_{mwi}$ (s) Integral gain for outer loop MW control |
| J+5 | | | rfmax (p.u.) Maximum limit on outer loop MW control loop |
| J+6 | | | rfmin (p.u.) Minimum limit on outer loop MW control loop |
| J+7 | | | dbd (p.u.) Intentional deadband |
| J+8 | | | err (p.u.) intencional error limit |
| J+9 | | | $T_a$ ( >0) (p.u.) Acceleration control time constant |
| J+10 | | | $a_{set}$ (p.u.) Acceleration limit set-point (see note 2) |
| J+11 | | | $K_{pg}$ (>0) Speed governor proportional gain (p.u.) |
| J+12 | | | $K_{ig}$ (>0) Speed governor integral gain (p.u.) |
| J+13 | | | $K_{dg}$ (p.u.) Speed governor derivative gain |
| J+14 | | | $T_{dg}$ (p.u.) Speed governor derivative time constant |
| J+15 | | | $K_{pa}$ (>0) Acceleration control proportional gain (p.u.) |
| J+16 | | | $K_{ia}$ (p.u.) Acceleration control integral gain |
| J+17 | | | $K_{pt}$ (>0) (p.u.) Temperature control proportional gain |
| J+18 | | | $K_{it}$ (p.u.) Temperature control integral gain |
| J+19 | | | Fmax (p.u.) Maximum fuel flow command |
| J+20 | | | Fmin (p.u.) Minimum fuel flow command |
| J+21 | | | Tlimit (p.u.) Temperature limit (see note 4) |

| CON | # | value | DESCRIPTION |
|---|---|---|---|
| J+22 | | | $T_{thcp}$ (p.u.) Thermocouple time constant |
| J+23 | | | $T_n$ (p.u.) Heat transfer lead time constant |
| J+24 | | | $T_d$ (p.u.) Heat transfer lag time constant |
| J+25 | | | $T_v$ (>0) (p.u.) Fuel system time constant |
| J+26 | | | $V_{max}$ (p.u.) Maximum valve opening |
| J+27 | | | $V_{min}$ (p.u.) Minimum valve opening |
| J+28 | | | $F_m$ (p.u.) Fuel flow multiplier (see note 2) |
| J+29 | | | $W_{fo}$ (p.u.) Full-speed no-load fuel flow |
| J+30 | | | $K_t$ ( >0) (p.u.) Turbine gain |
| J+31 | | | $T_{tn1}$ (p.u.) Turbine numerator time constant 1 |
| J+32 | | | $T_{tn2}$ (p.u.) Turbine numerator time constant 2 |
| J+33 | | | $T_{td1}$ (p.u.) Turbine denominator time constant 1 |
| J+34 | | | $T_{td2}$ ( >0) (p.u.) Turbine denominator time constant 2 |
| J+35 | | | $x_1$ – 1st point of turbine characteristic curve (see note 3) |
| J+36 | | | $F(x_1)$ |
| J+37 | | | $x_2$ – 2nd point |
| J+38 | | | $F(x_2)$ |
| J+39 | | | $x_3$ – 3rd point |
| J+40 | | | $F(x_3)$ |
| J+41 | | | Trate – turbine rating (MW) (see note 1) |

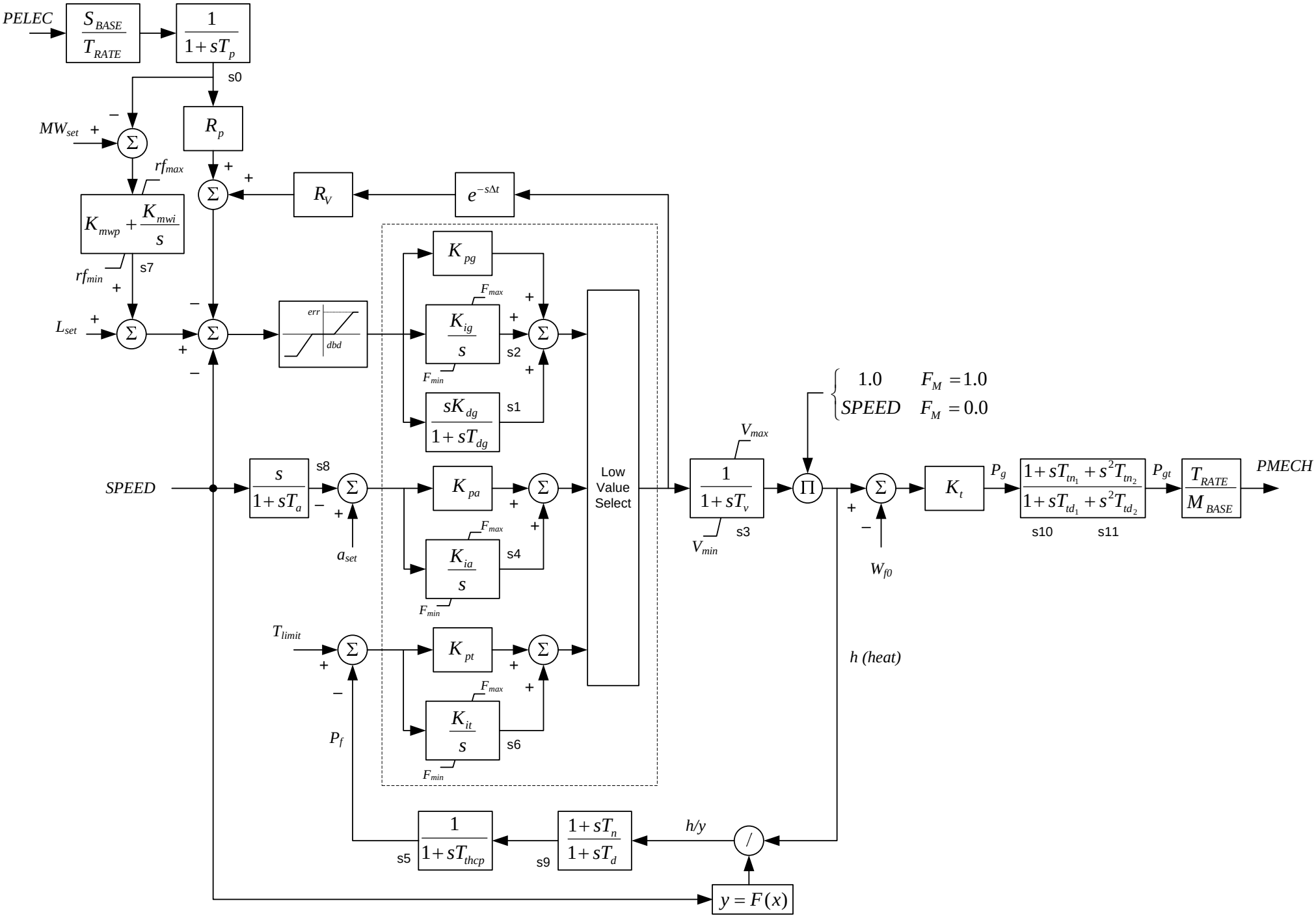
| STATEs | # | Description |
|---|---|---|
| K | | Machine electrical power measurement |
| K+1 | | Governor differential control |
| K+2 | | Governor integral control |
| K+3 | | Turbine actuator |
| K+4 | | Turbine acceleration limiter integral control |
| K+5 | | Turbine load limiter measurement |
| K+6 | | Turbine load limiter integral control |
| K+7 | | Supervisor load control |
| K+8 | | Acceleration control |
| K+9 | | Temperature detection lead-lag |
| K+10 | | First state of turbine second order transfer function |
| K+11 | | Second state of turbine second order transfer function |

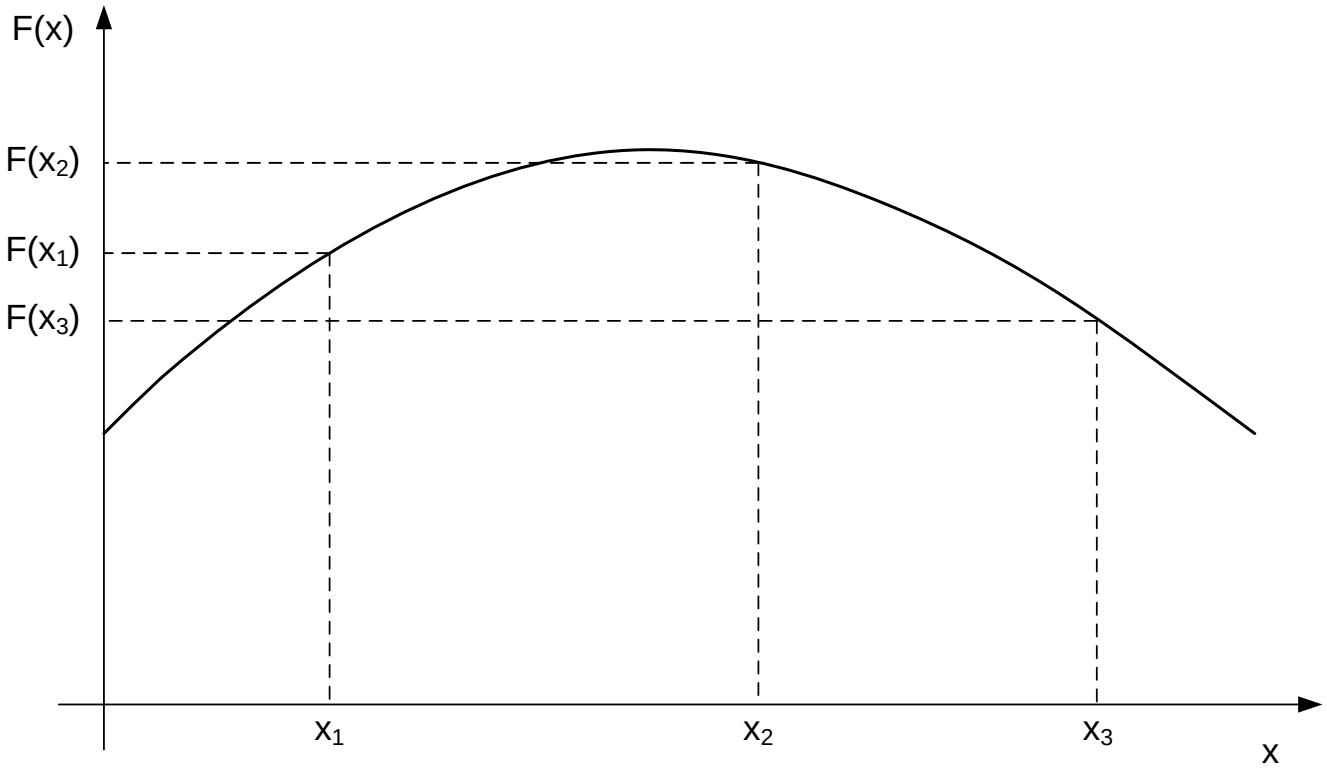
| VARs | # | Description |
|---|---|---|
| L | | Lset Load Reference |
| L+1 | | Output of load limiter PI control |
| L+2 | | Output of governor PID control |
| L+3 | | Low value select ouptut |
| L+4 | | Output of acceleration limiter PI control |
| L+5 | | Pf |
| L+6 | | Supervisory load controller setpoint, MWset |
| L+7 | | Input of deadband block |
| L+8 | | output of deadband block |
| L+9 | | Pg |
| L+10 | | h (heat) |
| L+11 | | A - coefficient of F(x) |
| L+12 | | B – coefficient of F(x) |
| L+13 | | C – coefficient of F(x) |

IBUS 'USRMDL' ID 'UCBGT' 5 0 0 42 12 14 CONs from (J) to (J+41) /

notes:

1) model adopts generator MVA base as turbine rating if parameter TRATE = 0.0
2) the parameter CON(J+10) = $a_{set}$ should be set to +99 to disregard the acceleration limit control loop
3) the CIGRÉ document suggests implementing F(x) as a look-up table or a piecewise linear function, that would require specific manufacturer's data to be defined. The present implementation of this model assumes a quadratic approximation of the characteristics similar to the one given in Figure C-1 of the CIGRÉ document. The user should enter three points [$x_i$, $F(x_i)$] of the turbine characteristics curve and the model will determine the coefficients of a quadratic equation given as $F(x)= A\ x^2 + B\ x + C$. The characteristic in Figure C-1 can be approximated by using the following points: [0.95, 0.95575], [1.0, 1.001], and [1.05, 0.97568].
4) Tlimit corresponds to fuel demand required for 1 p.u. turbine power i.e. = (1/Kt+Wfo). Conversely, Tlimit determines the (steady state) maximum power output of the turbine: Pmax = (Tlimit – Wf0 ) x Kt, expressed in per unit of turbine rating Trate.
5) This model was proposed in CIGRÉ Technical Brochure on Modeling of Gas Turbines and Steam Turbines in Combined-Cycle Power Plants, Task Force 25 of Advisory Group 02 of Study Committee 38, April 2003.


PELEC
$\frac{S_{BASE}}{T_{RATE}}$
$\frac{1}{1+sT_p}$
s0
$MW_{set}$
$R_p$
$rf_{max}$
$K_{mwp}+\frac{K_{mwi}}{s}$
$rf_{min}$
s7
$R_V$
$e^{-s\Delta t}$
$L_{set}$
err
dbd
$K_{pg}$
$\frac{K_{ig}}{s}$
$F_{max}$
$F_{min}$
s2
$\frac{sK_{dg}}{1+sT_{dg}}$
s1
SPEED
$\frac{s}{1+sT_a}$
s8
$a_{set}$
$K_{pa}$
$\frac{K_{ia}}{s}$
s4
$T_{limit}$
$K_{pt}$
$\frac{K_{it}}{s}$
s6
$P_f$
Low Value Select
$\frac{1}{1+sT_v}$
$V_{max}$
$V_{min}$
s3
1.0 $F_M=1.0$
SPEED $F_M=0.0$
$W_{f0}$
h (heat)
$K_t$
$P_g$
$\frac{1+sT_{tn_1}+s^2T_{tn_2}}{1+sT_{td_1}+s^2T_{td_2}}$
s10
s11
$P_{gt}$
$\frac{T_{RATE}}{M_{BASE}}$
PMECH
h/y
$\frac{1}{1+sT_{thcp}}$
s5
$\frac{1+sT_n}{1+sT_d}$
s9
$y=F(x)$




$$T_{\lim} = \frac{1.0}{1.5} + 0.25 = 0.91666$$

$$T_{\lim} = \frac{P_{mech_{\max}}}{K_t} + W_{f0}$$

$$T_{\lim} = \frac{0.8}{1.5} + 0.25 = 0.78333$$