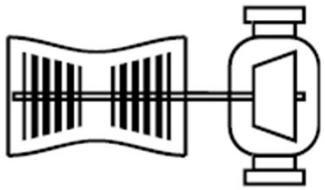
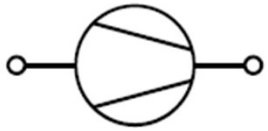
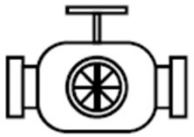
COMPRESSOR STATION

Facility	Control Modes	Constraints
Compressor Station 	inlet pressure ($p_{i,set}$) outlet pressure ($p_{o,set}$) pressure ratio (Π_{set}) ~~pressure difference (Δp_{set})~~ flow rate (Q_{set}) ~~volumetric flow ($Q_{vol,set}$)~~ ~~flow velocity (V_{set})~~ shaft power (PWS_{set}) ~~driver power (PWD_{set})~~ ~~driver fuel ($Q_{f,set}$)~~ closed (OFF) bypass (BP)	internal hard limits: $p_o \geq p_i$ & $Q \geq 0$ user defined limits: max. outlet pressure ($p_{o,max}$, 80 bar-g) min. inlet pressure ($p_{i,min}$, 25 bar-g) max. volumetric flow ($Q_{vol,max}$, 100 m^3/s) max. flow rate (Q_{max}) max. pressure ratio (Π_{max}, 2) max. driver power (PWd_{max}, 100 MW)

MODEL

compressor 	models a compressor station with generic constraints, allows the specification of a control mode of the station (e.g. outlet pressure control, inlet pressure control, flow rate control etc.)

REGULATOR STATION

Regulator Station 	inlet pressure ($p_{i,set}$) outlet pressure ($p_{o,set}$) pressure difference (Δp_{set}) flow rate (Q_{set}) volumetric flow ($Q_{vol,set}$) flow velocity (V_{set}) closed (OFF) bypass (BP)	internal hard limits: $p_i \geq p_o$ & $Q \geq 0$ user defined limits: max. outlet pressure ($p_{o,max}$, 80 bar-g) min. inlet pressure ($p_{i,min}$, 25 bar-g) max. volumetric flow ($Q_{vol,max}$, 100 m^3/s) max. flow rate (Q_{max})

MODEL

regulator 	models a pressure reduction and metering station located at the interface of two neighbouring networks with different maximum operating pressures, allows the specification of a control mode of the station (e.g. outlet pressure control, inlet pressure control, flow rate control etc.)

VALVE STATION

Valve Station 	closed (OFF) opened (BP)	<u>internal hard limit</u>: $V \leq 60$ m/s <u>user defined limits:</u> max. flow velocity (V_{max}, 30 m/s)

MODEL

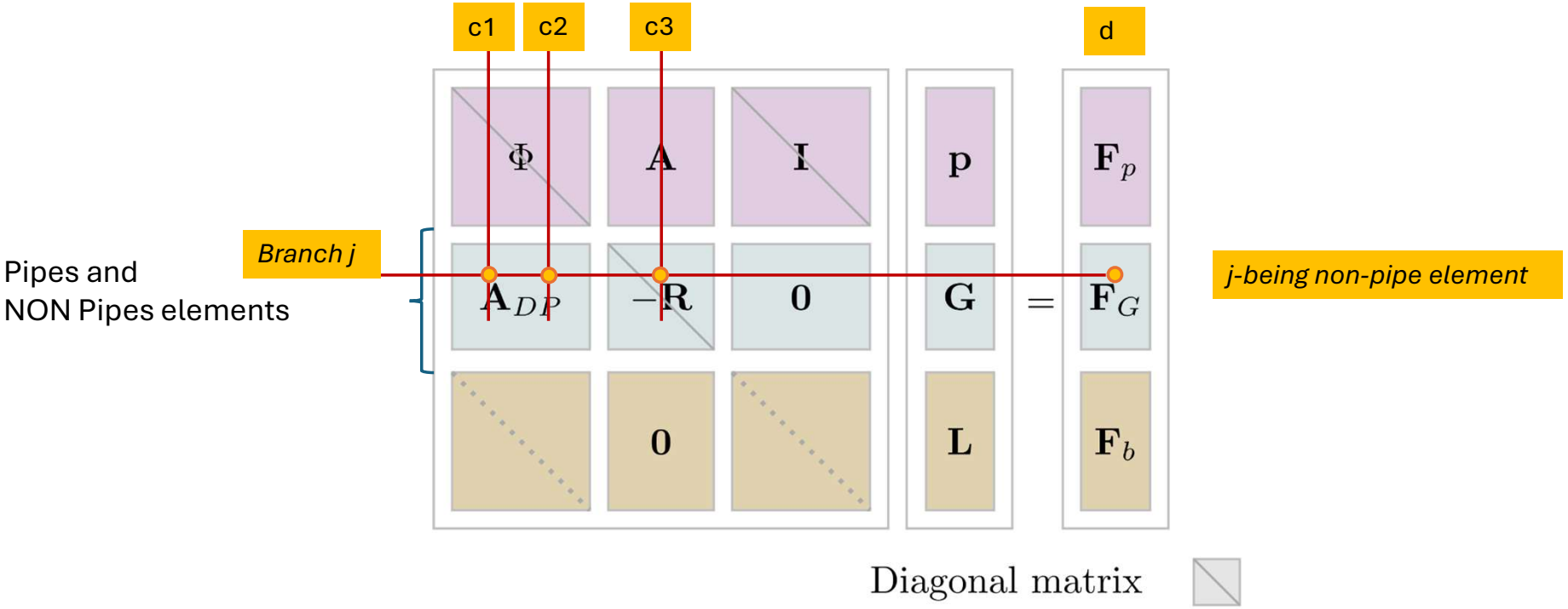
valve 	models a valve station, which is is either opened or closed

COMPRESSOR ON

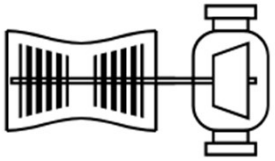
Control Mode	**Equation**	**Coefficients** $c_1 \cdot p_1 + c_2 \cdot p_2 + c_3 \cdot Q = d$
inlet pressure ($p_{i,set}$)	$p_i = p_{i,set}$	$c_1 = 1,\ c_2 = 0,\ c_3 = 0,\ d = p_{i,set}$
outlet pressure ($p_{o,set}$)	$p_o = p_{o,set}$	$c_1 = 0,\ c_2 = 1,\ c_3 = 0,\ d = p_{o,set}$
pressure ratio (Π_{set})	$\frac{p_o}{p_i} = \Pi_{set}$	$c_1 = -\Pi_{set},\ c_2 = 1,$ $c_3 = 0,\ d = 0$
flow rate (Q_{set})	$Q = Q_{set}$	$c_1 = 0,\ c_2 = 0,\ c_3 = 1,\ d = Q_{set}$
shaft power (PWs_{set})	$PWs_{set} = \frac{K_i Q}{c_\kappa}\left[\Pi^{c_\kappa} - 1\right]$ $K_i = \frac{Z_i T_i R \rho_n}{\eta_{ad}},\ \Pi = \frac{p_o}{p_i},$ $c_\kappa = \frac{\kappa - 1}{\kappa}$	$c_1 = -\frac{K_i Q}{p_i}\Pi^{c_\kappa},\ c_2 = \frac{K_i Q}{p_o}\Pi^{c_\kappa},$ $c_3 = \frac{K_i}{c_\kappa}\left[\Pi^{c_\kappa} - 1\right],\ d = PWs_{set}$

COMPRESSOR OFF

Control Mode	Equation	Coefficients $c_1 \cdot p_1 + c_2 \cdot p_2 + c_3 \cdot Q = d$
bypass (BP)	$p_i = p_o$	$c_1 = -1,\ c_2 = 1,\ c_3 = 0,\ d = 0$
off (OFF)	$Q = 0$	$c_1 = 0,\ c_2 = 0,\ c_3 = 1,\ d = 0$

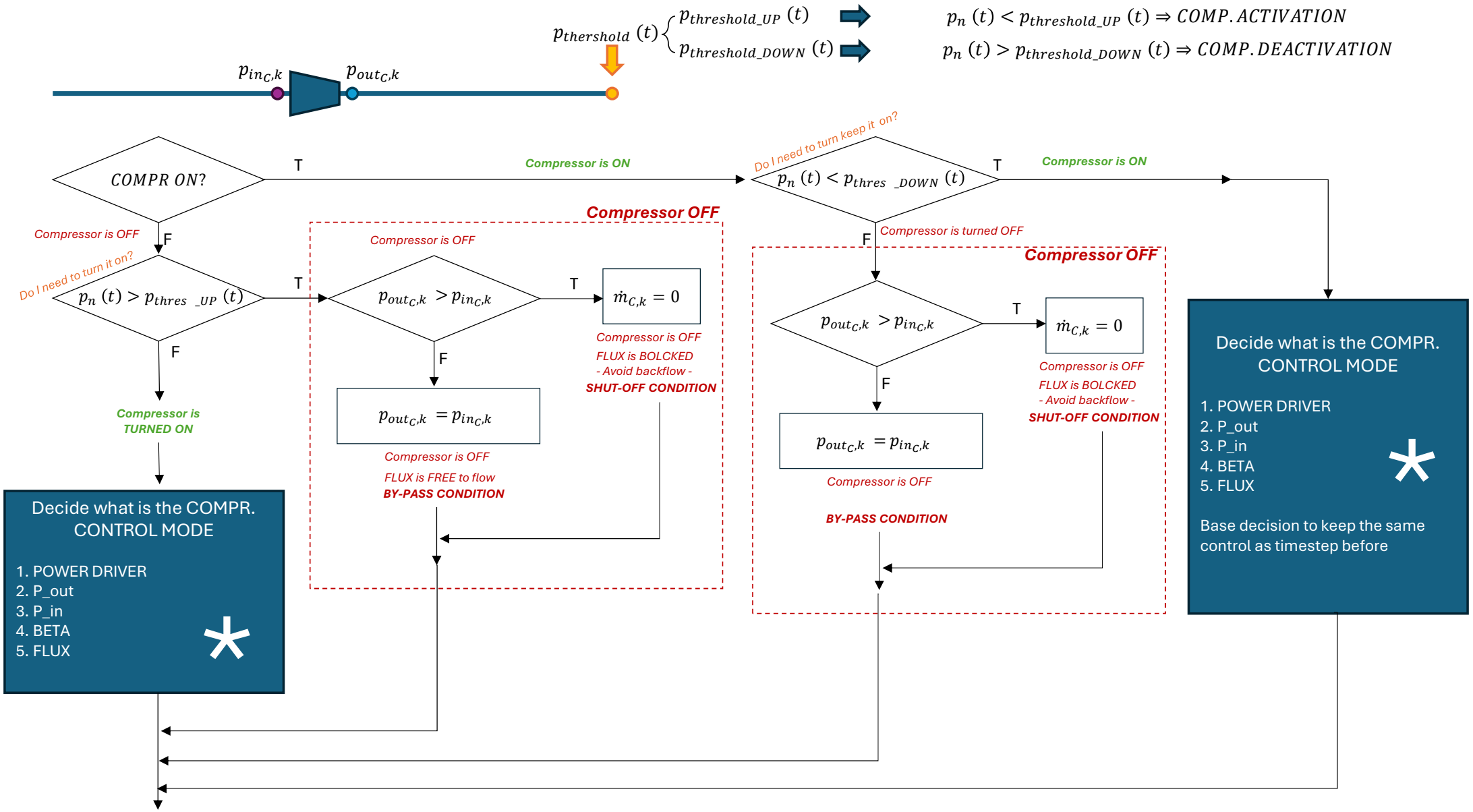


FOCUS ON: COMPRESSOR STATION

Facility	Control Modes	Constraints
Compressor Station 	inlet pressure ($p_{i,set}$) outlet pressure ($p_{o,set}$) pressure ratio (Π_{set}) pressure difference (Δp_{set}) flow rate (Q_{set}) volumetric flow ($Q_{vol,set}$) flow velocity (V_{set}) shaft power (PWS_{set}) driver power (PWD_{set}) driver fuel ($Q_{f,set}$) closed (OFF) bypass (BP)	internal hard limits: $p_o \geq p_i$ & $Q \geq 0$ user defined limits: max. outlet pressure ($p_{o,max}$, 80 bar-g) min. inlet pressure ($p_{i,min}$, 25 bar-g) max. volumetric flow ($Q_{vol,max}$, 100 m^3/s) max. flow rate (Q_{max}) max. pressure ratio (Π_{max}, 2) max. driver power (PWd_{max}, 100 MW)

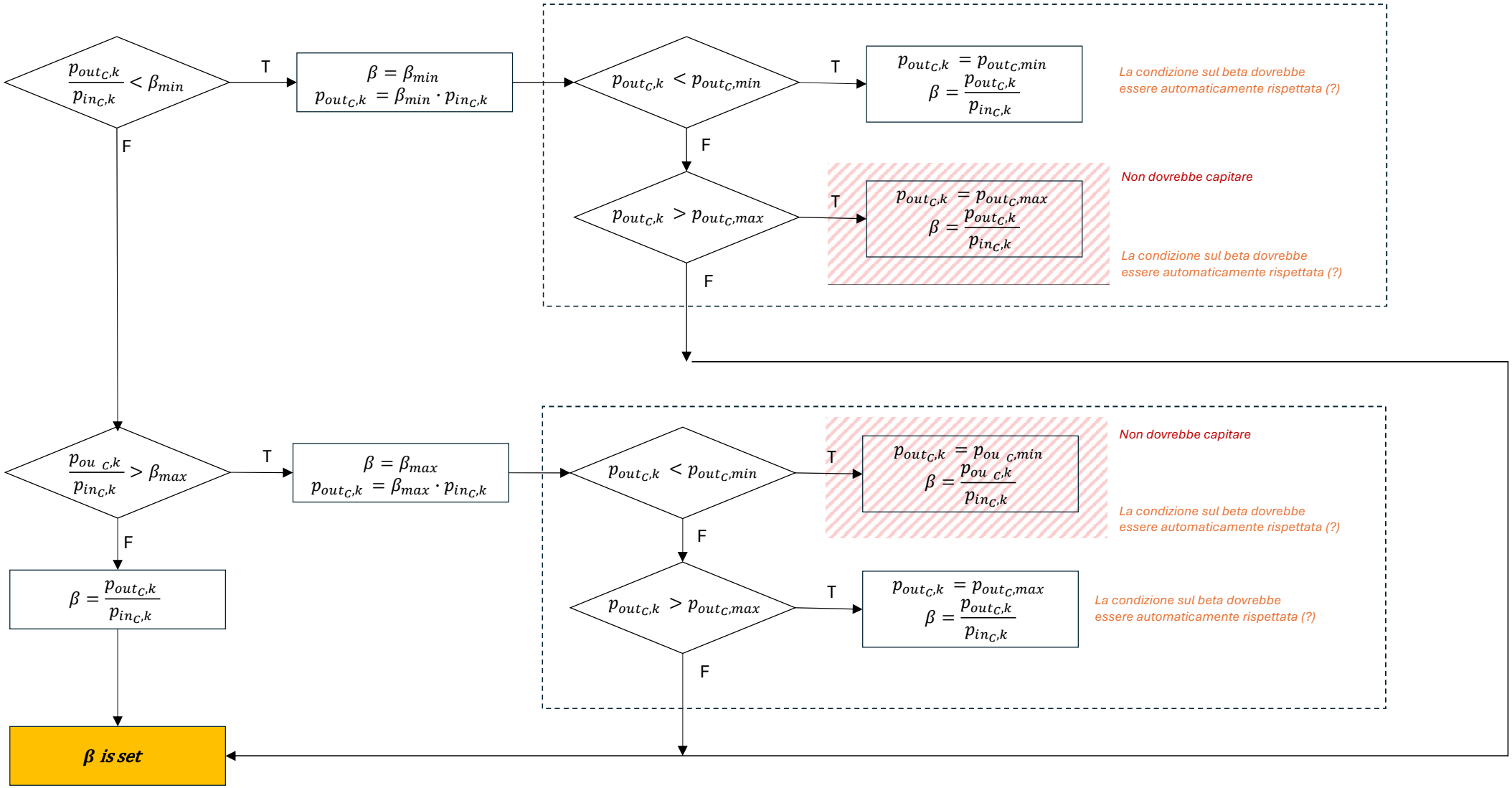
FIRST layer:
activation/deactivation of the compressor

SECOND layer:
control mode(s) sequence


$p_{thershold}\ (t)$
$p_{threshold\_UP}\ (t)$
$p_{threshold\_DOWN}\ (t)$
$p_n\ (t) < p_{threshold\_UP}\ (t) \Rightarrow COMP.ACTIVATION$
$p_n\ (t) > p_{threshold\_DOWN}\ (t) \Rightarrow COMP.DEACTIVATION$
$p_{in_C,k}$
$p_{out_C,k}$
COMPR ON?
T
Compressor is ON
Do I need to turn keep it on?
$p_n\ (t) < p_{thres\ \_DOWN}\ (t)$
T
Compressor is ON
Compressor is OFF
F
Compressor is turned OFF
Do I need to turn it on?
$p_n\ (t) > p_{thres\ \_UP}\ (t)$
T
F
Compressor OFF
Compressor is OFF
$p_{out_C,k} > p_{in_C,k}$
T
$\dot{m}_{C,k} = 0$
Compressor is OFF
FLUX is BOLCKED
- Avoid backflow -
SHUT-OFF CONDITION
F
$p_{out_C,k} = p_{in_C,k}$
Compressor is OFF
FLUX is FREE to flow
BY-PASS CONDITION
Compressor OFF
$p_{out_C,k} > p_{in_C,k}$
T
$\dot{m}_{C,k} = 0$
Compressor is OFF
FLUX is BOLCKED
- Avoid backflow -
SHUT-OFF CONDITION
F
$p_{out_C,k} = p_{in_C,k}$
Compressor is OFF
BY-PASS CONDITION
Compressor is TURNED ON
Decide what is the COMPR. CONTROL MODE
1. POWER DRIVER
2. P_out
3. P_in
4. BETA
5. FLUX
Decide what is the COMPR. CONTROL MODE
1. POWER DRIVER
2. P_out
3. P_in
4. BETA
5. FLUX
Base decision to keep the same control as timestep before

DRIVER POWER CONTROL MODE

Inside the blue box



DRIVER POWER CONTROL MODE

Inside the blue box

β is set

SHAFT POWER NOMINAL

RAMP coefficient

Esempio:
Arriva alla potenza nominale in x h
*Ramp_coeff = dt [s]/(x * 3600) [s]*

$PW_{driver} < PW_{driver_{nom}}$

T

$PW_{driver} = PW_{driver}\,(t-1) + ramp_{coeff} \cdot PW_{driver_{nom}}$

F

$PW_{driver} = PW_{driver_{nom}}$

$K_i = \frac{1}{\eta_{ad}\eta_m} Z_i T_i \frac{R_0}{MM}$ $\quad c_k = \frac{\gamma-1}{\gamma}$

$$c_1 = -K_i\, \dot{m}_{C,k} \frac{1}{p_{in_{C,k}}, k} \beta^{c_k}$$

$$c_2 = +K_i\, \dot{m}_{C,k} \frac{1}{p_{out_{C,k}}} \beta^{c_k}$$

$$c_3 = \frac{K_i}{c_k}\,(\,\beta^{c_k} - 1\,)$$

$$d = PW_{driver}$$

$\dot{m}_{C,k}$, $p_{in_{C,k}}$, $p_{out_{C,k}}$, β
ARE DEFINED AFTER k-cycle

CHECKS on m_dot, pressures

$p_{ou\ C,k} > p_{out_{C,MAX}}$ T → P_out CONTROL

$p_{out_C,SET} = p_{out_{C,MAX}}$

$p_{in_{C,k}} < p_{in_{C,min}}$ T → P_in CONTROL

$p_{in_C,SET} = p_{in_{C,MAX}}$

$\frac{p_{out_{C,k}}}{p_{in_{C,k}}} < \beta_{min}$ T

$\frac{p_{out_{C,k}}}{p_{in_{C,k}}} > \beta_{MAX}$ T

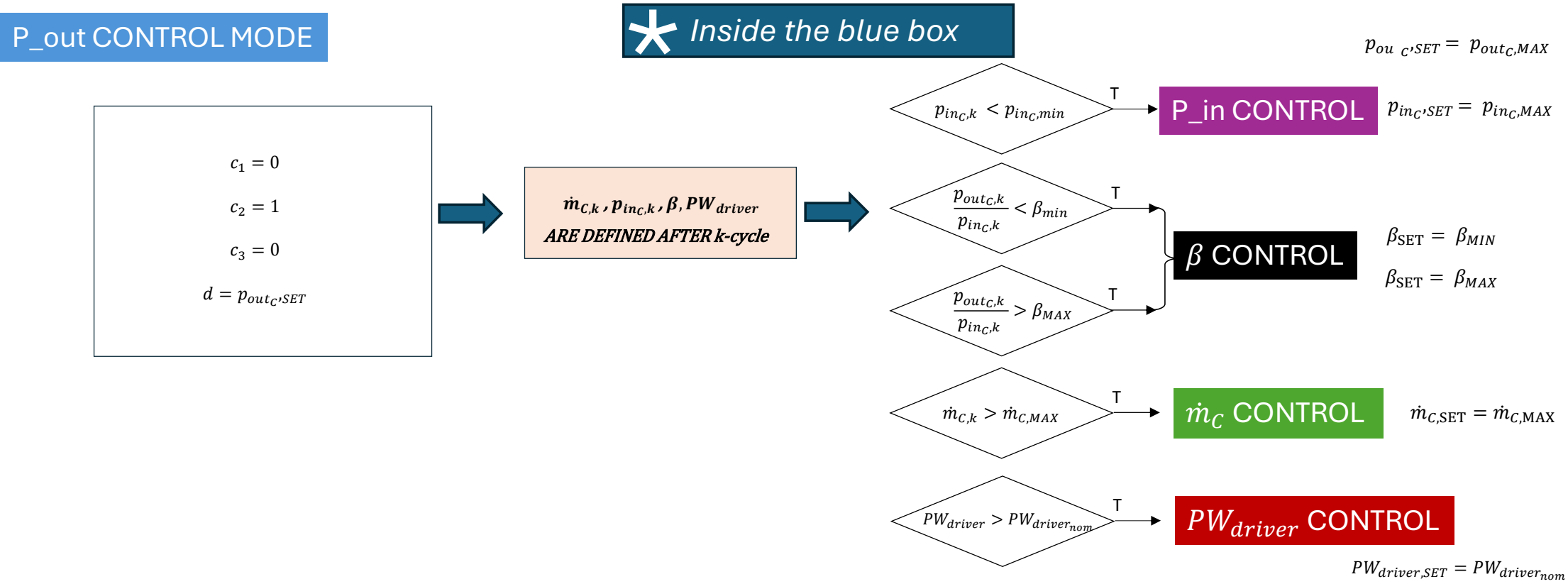
→ β CONTROL

$\beta_{SET} = \beta_{MIN}$

$\beta_{SET} = \beta_{MAX}$

$\dot{m}_{C,k} > \dot{m}_{C,MAX}$ T → $\dot{m}_C$ CONTROL

$\dot{m}_{C,SET} = \dot{m}_{C,MAX}$


P_out CONTROL MODE
$c_1 = 0$
$c_2 = 1$
$c_3 = 0$
$d = p_{out_C,SET}$
Inside the blue box
$\dot{m}_{C,k}$, $p_{in_C,k}$, β, PW_{driver}
ARE DEFINED AFTER k-cycle
$p_{in_C,k} < p_{in_C,min}$
T
P_in CONTROL
$p_{ou\ C,SET} = p_{out_C,MAX}$
$p_{in_C,SET} = p_{in_C,MAX}$
$\frac{p_{out_C,k}}{p_{in_C,k}} < \beta_{min}$
T
$\frac{p_{out_C,k}}{p_{in_C,k}} > \beta_{MAX}$
T
β CONTROL
$\beta_{SET} = \beta_{MIN}$
$\beta_{SET} = \beta_{MAX}$
$\dot{m}_{C,k} > \dot{m}_{C,MAX}$
T
$\dot{m}_C$ CONTROL
$\dot{m}_{C,SET} = \dot{m}_{C,MAX}$
$PW_{driver} > PW_{driver_{nom}}$
T
PW_{driver} CONTROL
$PW_{driver,SET} = PW_{driver_{nom}}$

P_in CONTROL MODE

$c_1 = 0$

$c_2 = 1$

$c_3 = 0$

$d = p_{in_C,SET}$

$\dot{m}_{C,k}$, $p_{out_C,k}$, β, PW_{driver}
ARE DEFINED AFTER k-cycle

Inside the blue box

$p_{out_C,k} > p_{out_C,MAX}$ — T → P_out CONTROL

$p_{out_C,SET} = p_{ou\ C,MAX}$

$\frac{p_{ou\ C,k}}{p_{in_C,k}} < \beta_{min}$ — T →

$\frac{p_{ou\ C,k}}{p_{in_C,k}} > \beta_{MAX}$ — T → β CONTROL

$\beta_{SET} = \beta_{MIN}$

$\beta_{SET} = \beta_{MAX}$

$\dot{m}_{C,k} > \dot{m}_{C,MAX}$ — T → $\dot{m}_C$ CONTROL

$\dot{m}_{C,SET} = \dot{m}_{C,MAX}$

$PW_{driver} > PW_{driver_{nom}}$ — T → PW_{driver} CONTROL

$PW_{driver,SET} = PW_{driver_{nom}}$

β CONTROL MODE

*Inside the blue box

$c_1 = -\beta$

$c_2 = 1$

$c_3 = 0$

$d = 0$

$\dot{m}_{C,k}$, $p_{in_C,k}$, $p_{out_C,k}$, PW_{driver}
ARE DEFINED AFTER k-cycle

$p_{out_C,k} > p_{out_C,MAX}$ T → P_out CONTROL
$p_{out_C,SET} = p_{out_C,MAX}$

$p_{in_C,k} < p_{in_C,min}$ T → P_in CONTROL $p_{in_C,SET} = p_{in_C,MAX}$

$\dot{m}_{C,k} > \dot{m}_{C,MAX}$ T → $\dot{m}_C$ CONTROL $\dot{m}_{C,\mathrm{SET}} = \dot{m}_{C,\mathrm{MAX}}$

$PW_{driver} > PW_{driver_{nom}}$ T → PW_{driver} CONTROL
$PW_{driver,SET} = PW_{driver_{nom}}$

$\dot{m}_C$ CONTROL MODE

*Inside the blue box

$c_1 = 0$

$c_2 = 0$

$c_3 = 1$

$d = \dot{m}_{C,SET}$

$\dot{m}_{C,k}$, $p_{in_{C,k}}$, $p_{out_{C,k}}$, PW_{driver} *ARE DEFINED AFTER k-cycle*

$p_{out_{C,k}} > p_{ou\ C,MAX}$ T → P_out CONTROL

$p_{ou\ C,SET} = p_{out_{C,MAX}}$

$p_{in_{C,k}} < p_{in_{C,min}}$ T → P_in CONTROL $p_{in_{C,SET}} = p_{in_{C,MAX}}$

$\frac{p_{ou\ C,k}}{p_{in_{C,k}}} < \beta_{min}$ T

$\frac{p_{ou\ C,k}}{p_{in_{C,k}}} > \beta_{MAX}$ T

→ β CONTROL

$\beta_{SET} = \beta_{MIN}$

$\beta_{SET} = \beta_{MAX}$

$PW_{driver} > PW_{driver_{nom}}$ T → PW_{driver} CONTROL

$PW_{driver,SET} = PW_{driver_{nom}}$