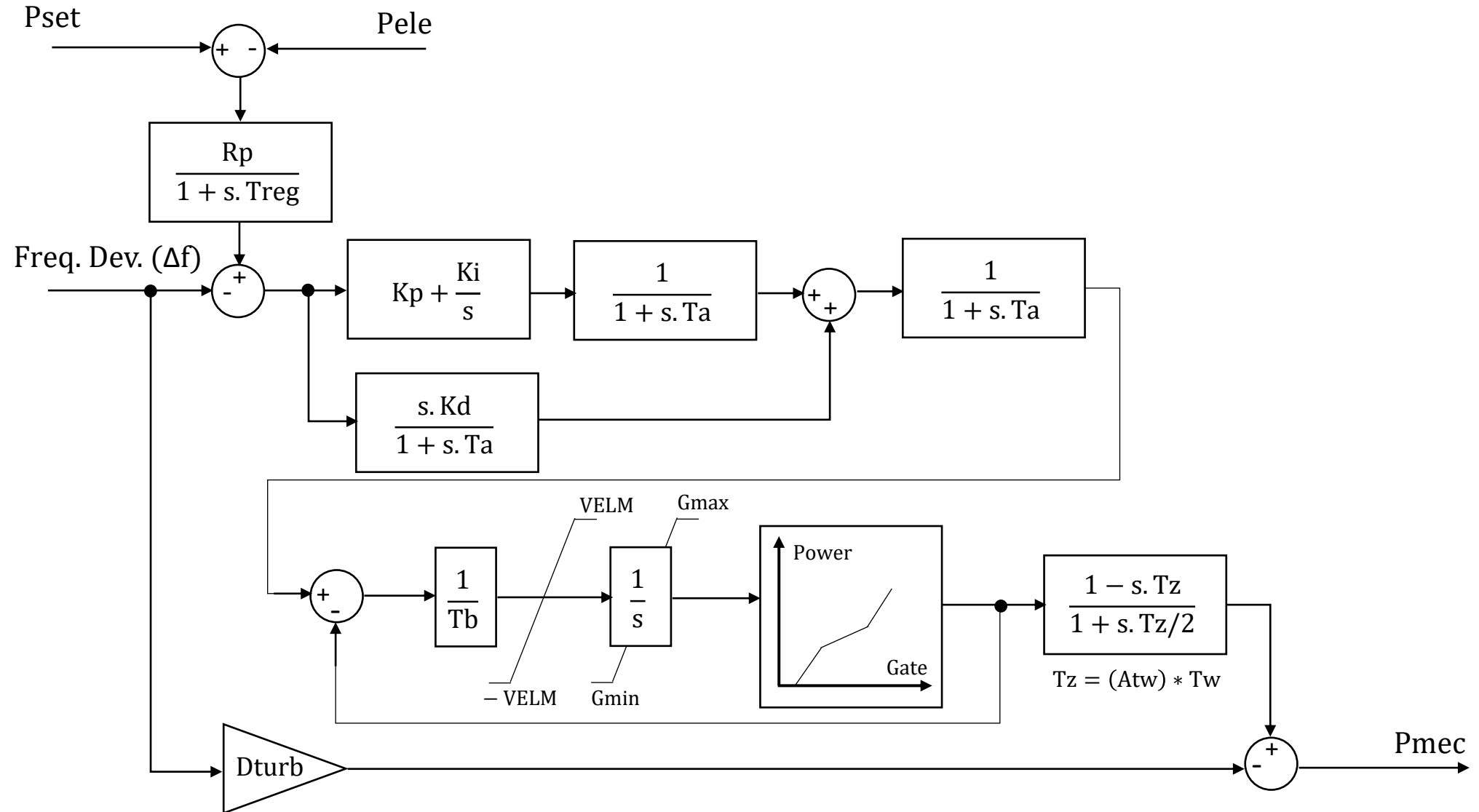


Z'Mutt – Fixed speed model without SPPS

Block Diagram for FCR and aFRR provision (based on PIDGOV model)



Z'Mutt – Fixed speed model without SPPS

Input signals and output signals (based on PIDGOV model)

Input signals:

- Δf – grid frequency deviation from setpoint, given by $f_{grid} - f_{set}$ (p.u.)
- P_{set} – active power setpoint (p.u.)

Output signals:

- P_{mec} – mechanical power (p.u.)

Parameters:

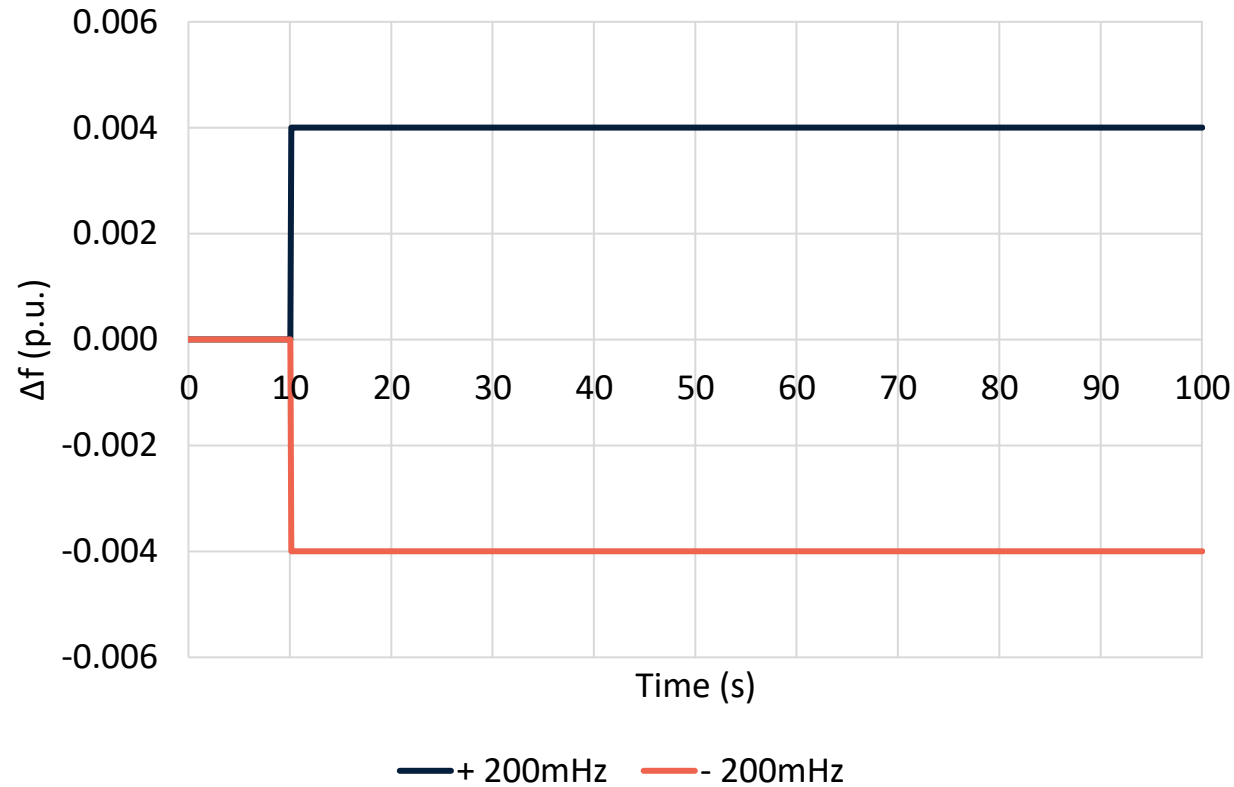
- R_p – permanent droop (p.u.)
- T_{reg} – governor time constant (s)
- K_p – proportional gain (p.u./s)
- K_i – integral gain (p.u./s)
- K_d – derivative gain (p.u.)
- T_a – controller time constant (s)
- T_b – gate servomotor time constant (s)
- A_{tw} – T_w multiplying factor (p.u.)
- D_{turb} – Turbine damping (p.u.)
- $VELM$ – gate velocity limit (p.u./s)
- T_w – water starting time constant (s)
- G_{max} – maximum gate opening (p.u.)
- G_{min} – minimum gate opening (p.u.)
- $P(y)$ – power (p.u.) to gate (p.u.) curve

Z'Mutt – Fixed speed model without SPPS

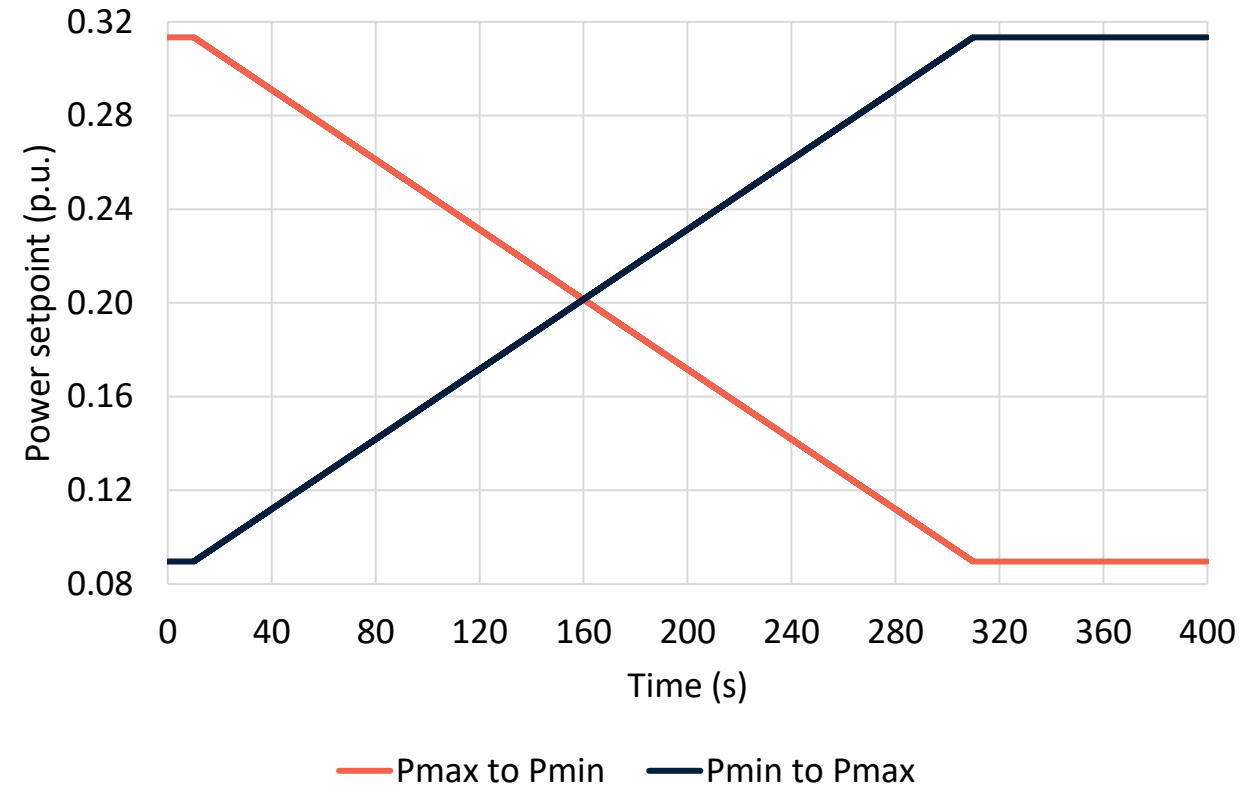
FCR and aFRR input signals

Turbine mode

FCR input signals



aFRR input signals



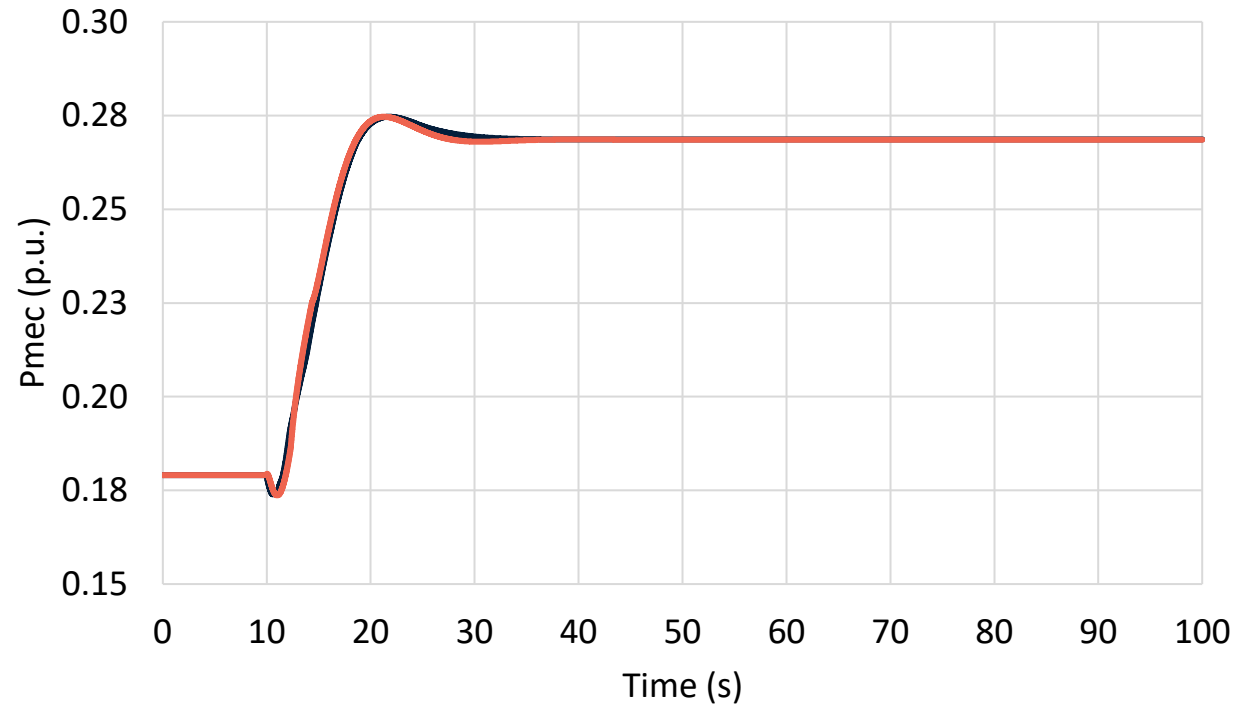
Pump mode: No capability to comply with service requirements

Z'Mutt – Fixed speed model without SPPS

FCR service provision

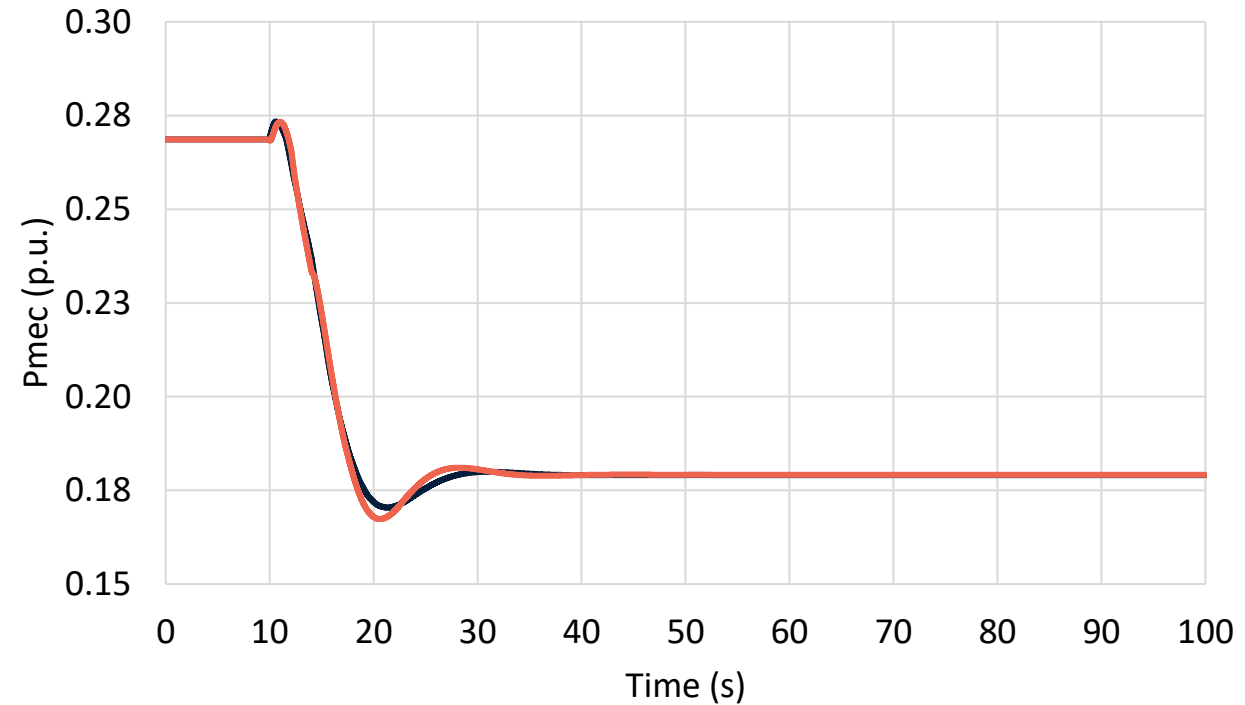
Turbine mode

Frequency deviation: -200 mHz



— P_{mec} (ref) — P_{mec} (sim)

Frequency deviation: +200 mHz



— P_{mec} (ref) — P_{mec} (sim)

Z'Mutt – Fixed speed model (with and without SPPS)

FCR service provision

Pump mode

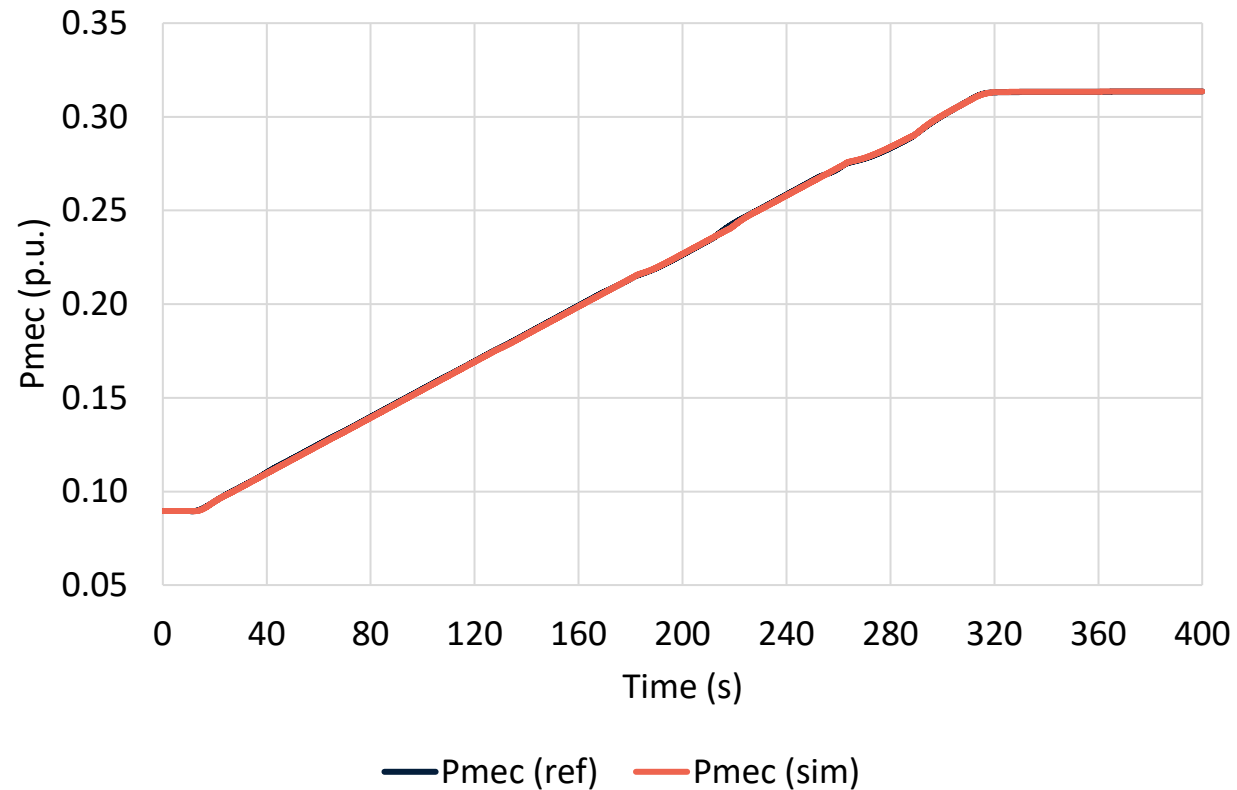
No capability to comply with service requirements

Z'Mutt – Fixed speed model without SPPS

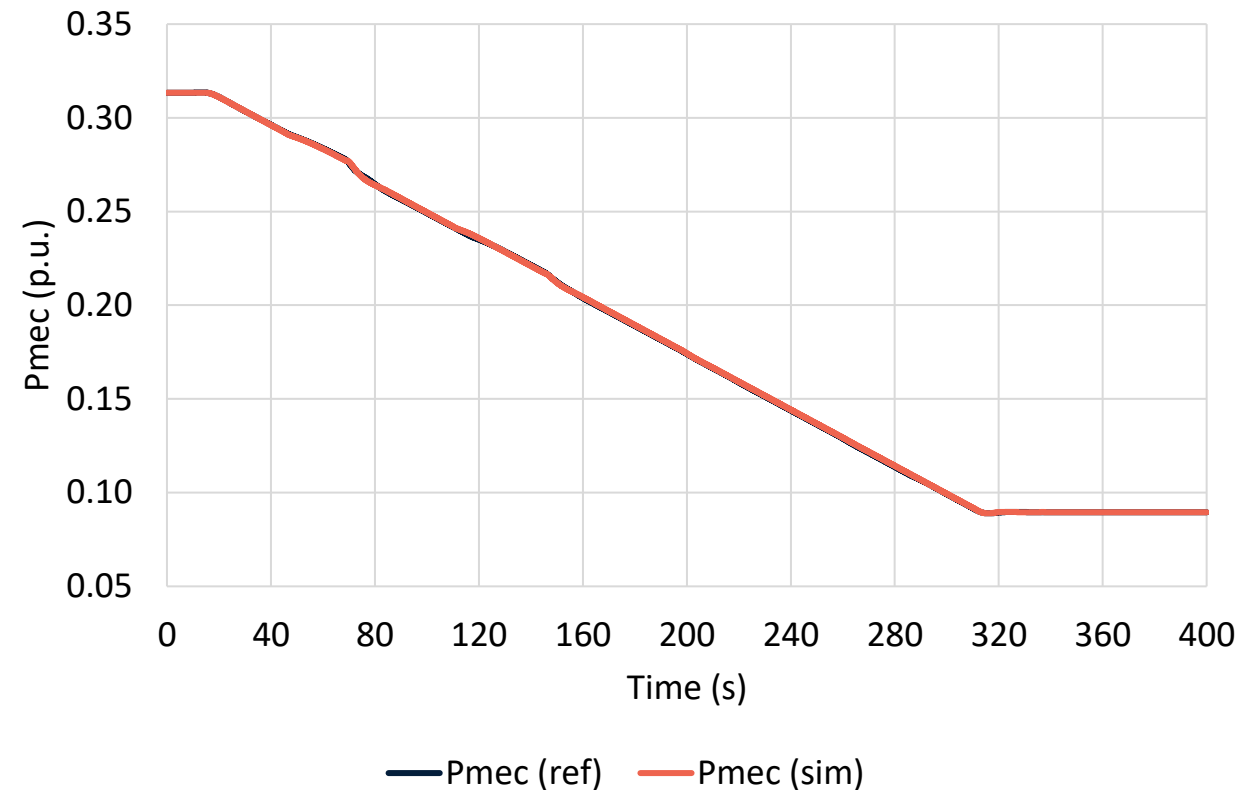
aFRR service provision

Turbine mode

Pmin to Pmax



Pmax to Pmin



Z'Mutt – Fixed speed model (with and without SPPS)

aFRR service provision

Pump mode

No capability to comply with service requirements