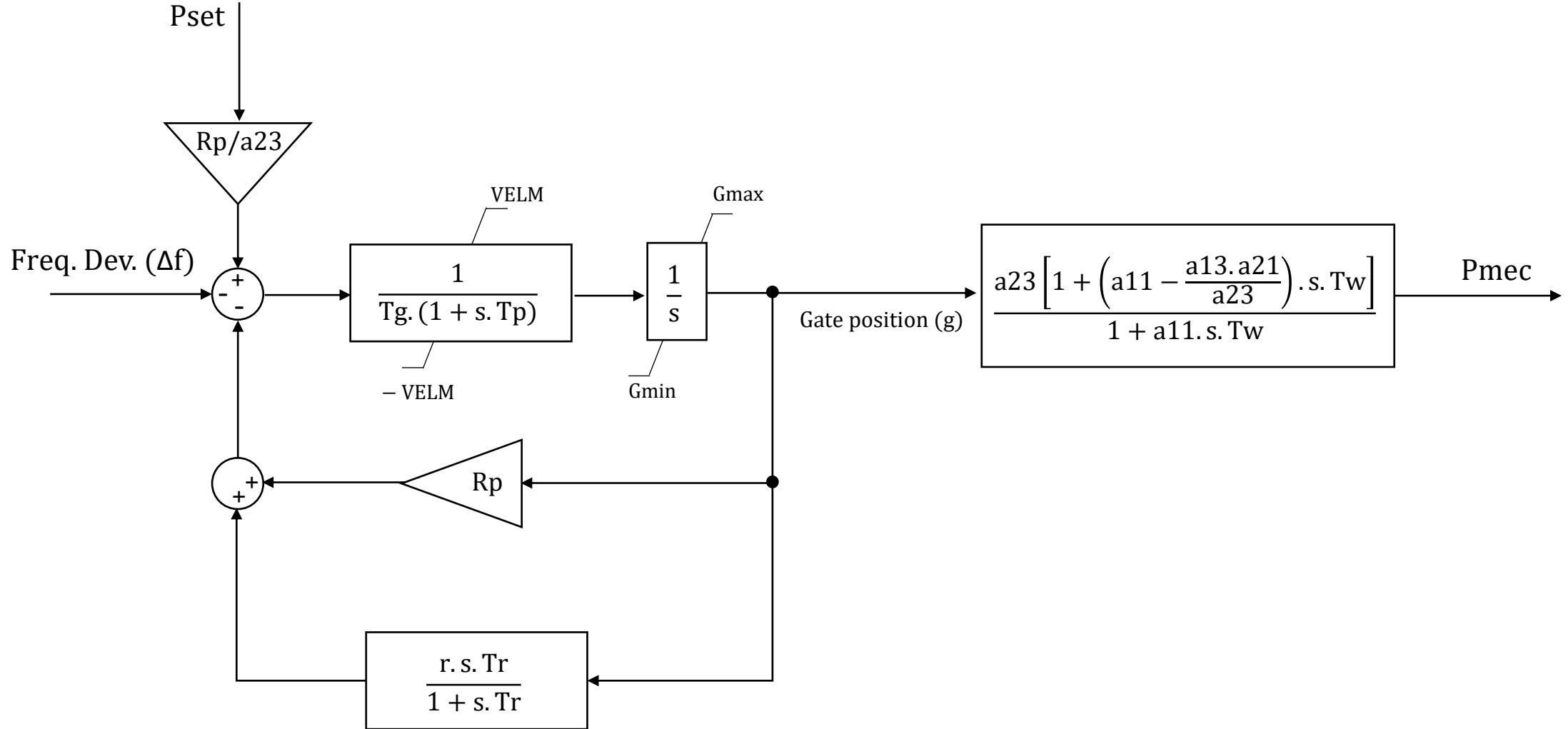


Frades 2 – Fixed speed model (with and without SPPS)

Block Diagram for FCR and aFRR provision (based on IEEEG3 model)



Frades 2 – Fixed speed model (with and without SPPS)

Model's input signals, output signals and parameters (based on IEEEG3)

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:

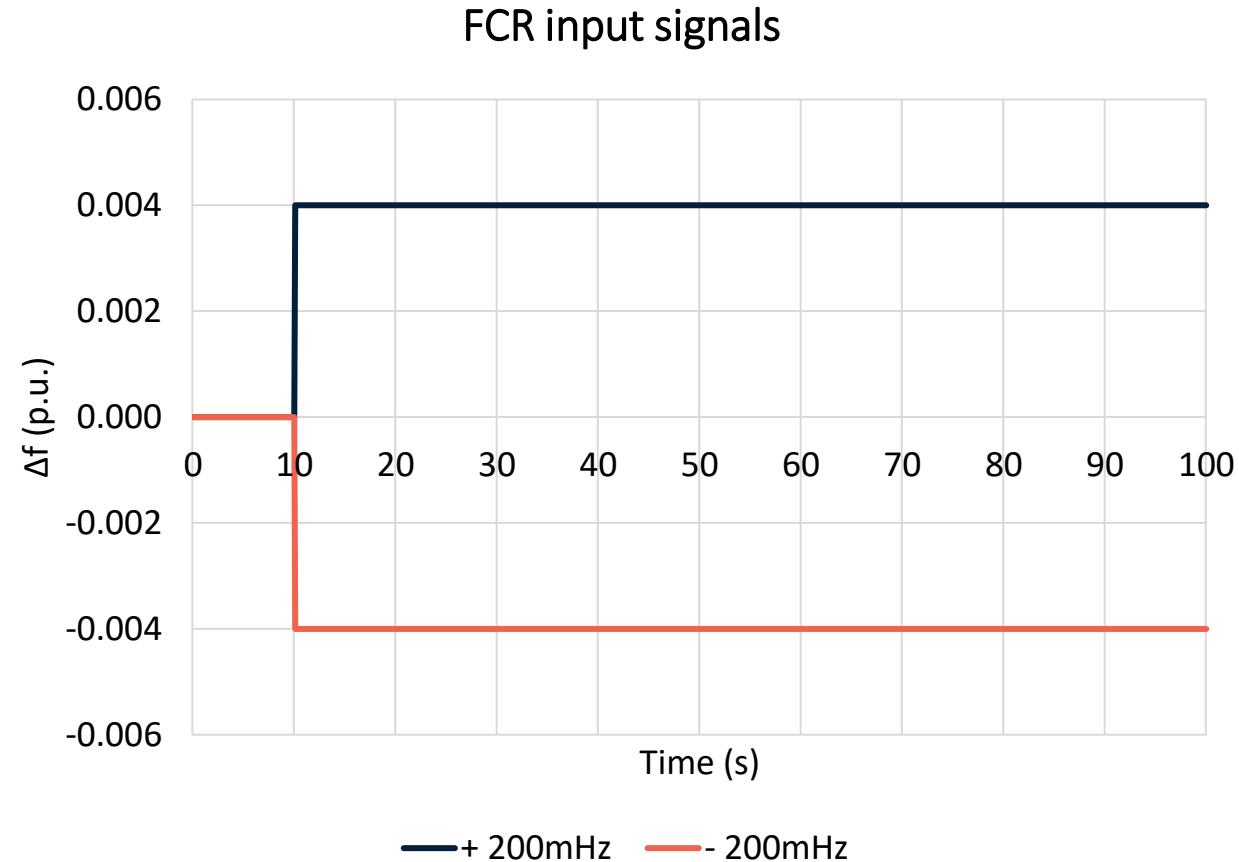
- P_{mec} – mechanical power (p.u.)

Parameters:

- R_p – permanent droop (p.u.)
- r – transient speed droop (p.u.)
- T_r – governor time constant (s)
- T_p – pilot value time constant (s)
- T_g – gate servomotor time constant (s)
- $VELM$ – gate velocity limit (p.u./s)
- T_w – water starting time constant (s)
- a_{11}, a_{13}, a_{21} and a_{23} – penstock coefficients
- G_{max} – maximum gate opening (p.u.)
- G_{min} – minimum gate opening (p.u.)

Frades 2 – Fixed speed model (with and without SPPS)

FCR input signals

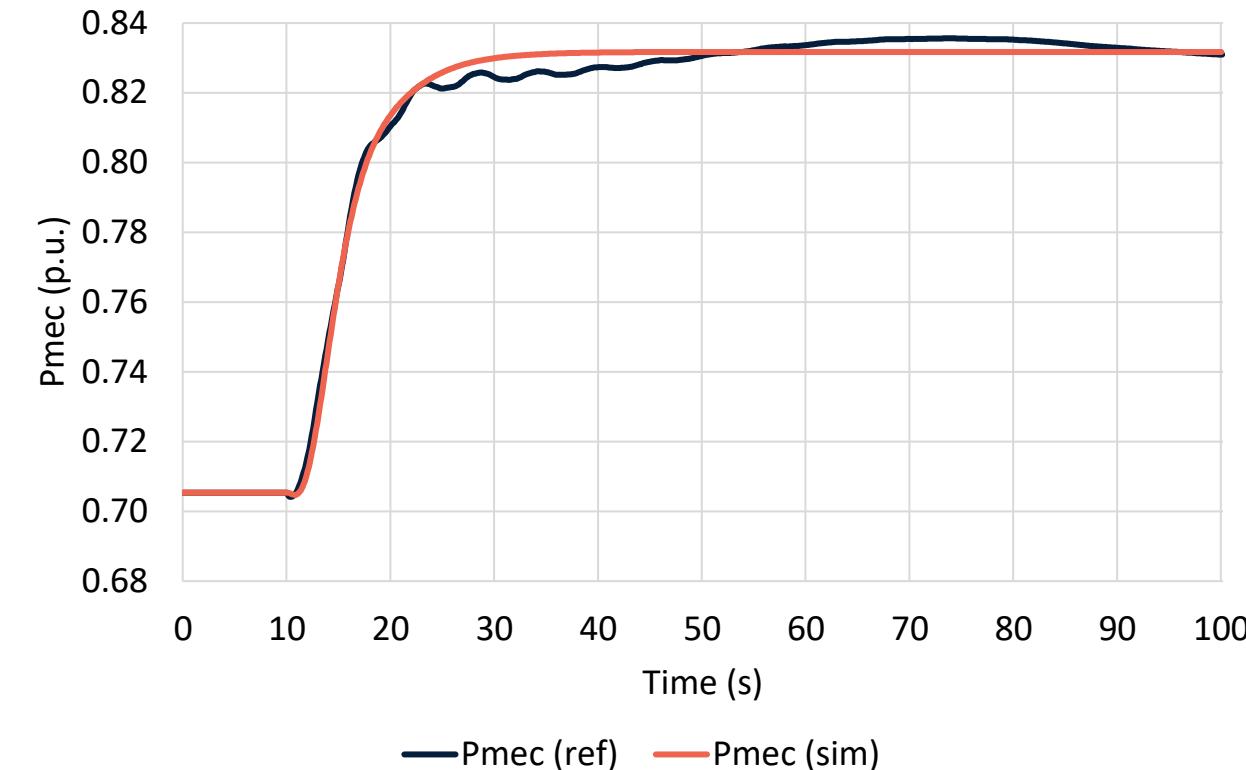


Frades 2 – Fixed speed model (with and without SPPS)

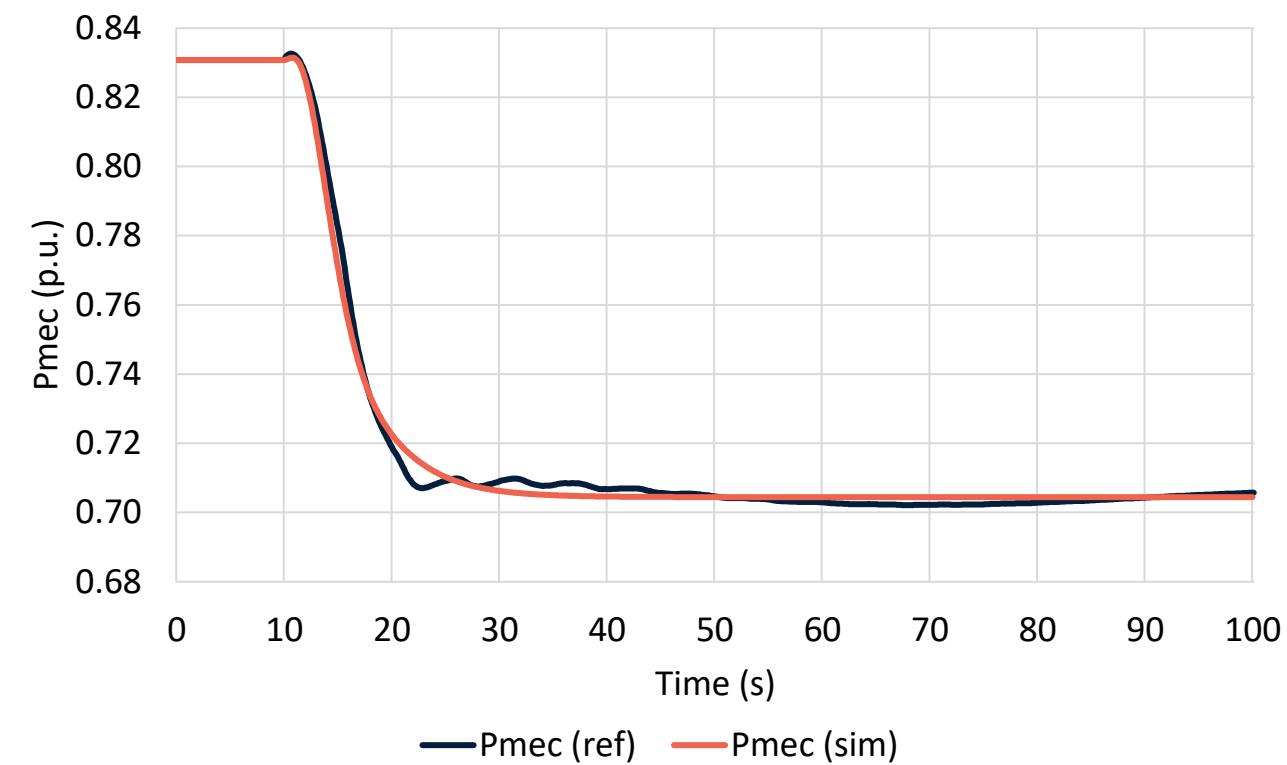
FCR service provision

Turbine mode

Frequency deviation: -200 mHz



Frequency deviation: +200 mHz



Frades 2 – Fixed speed model (with and without SPPS)

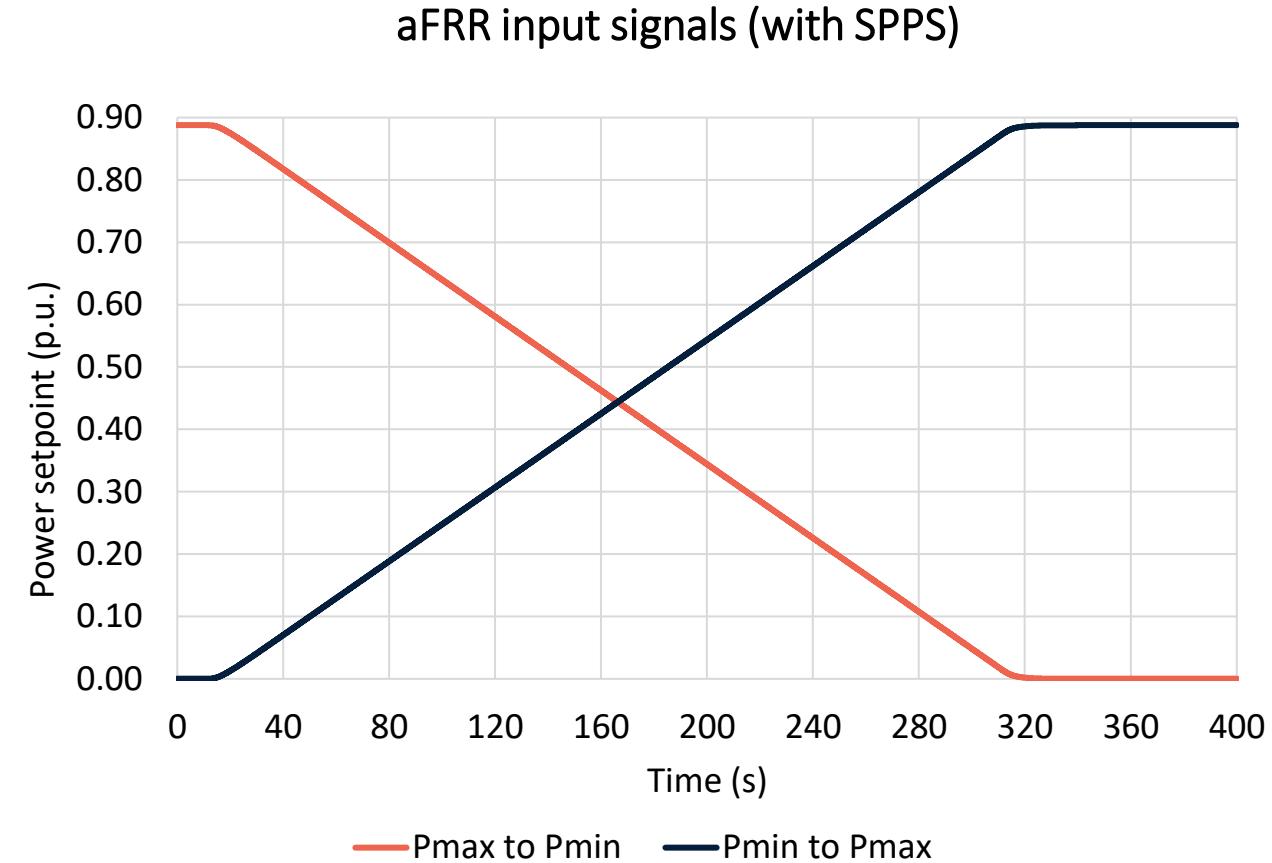
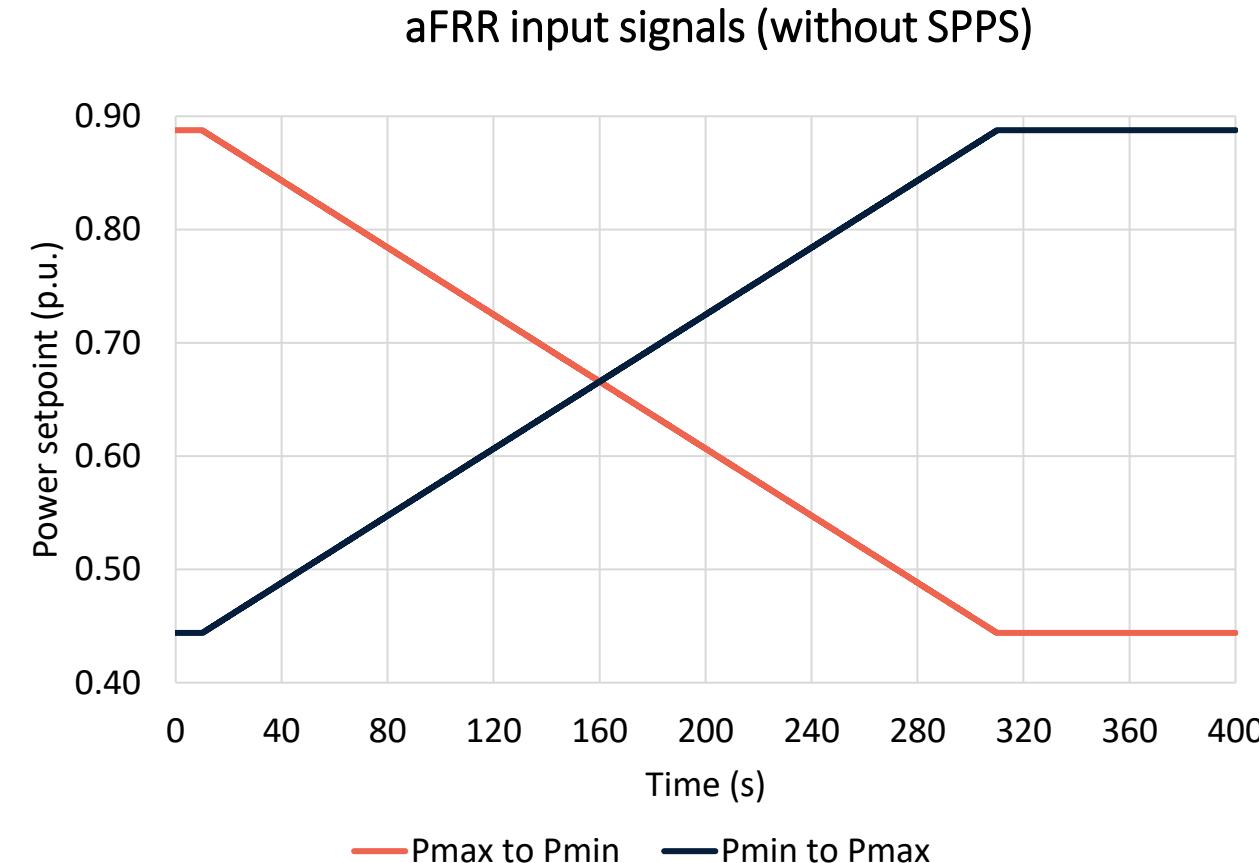
FCR service provision

Pump mode

No capability to comply with service requirements

Frades 2 – Fixed speed model (with and without SPPS) aFRR input signals

Turbine mode



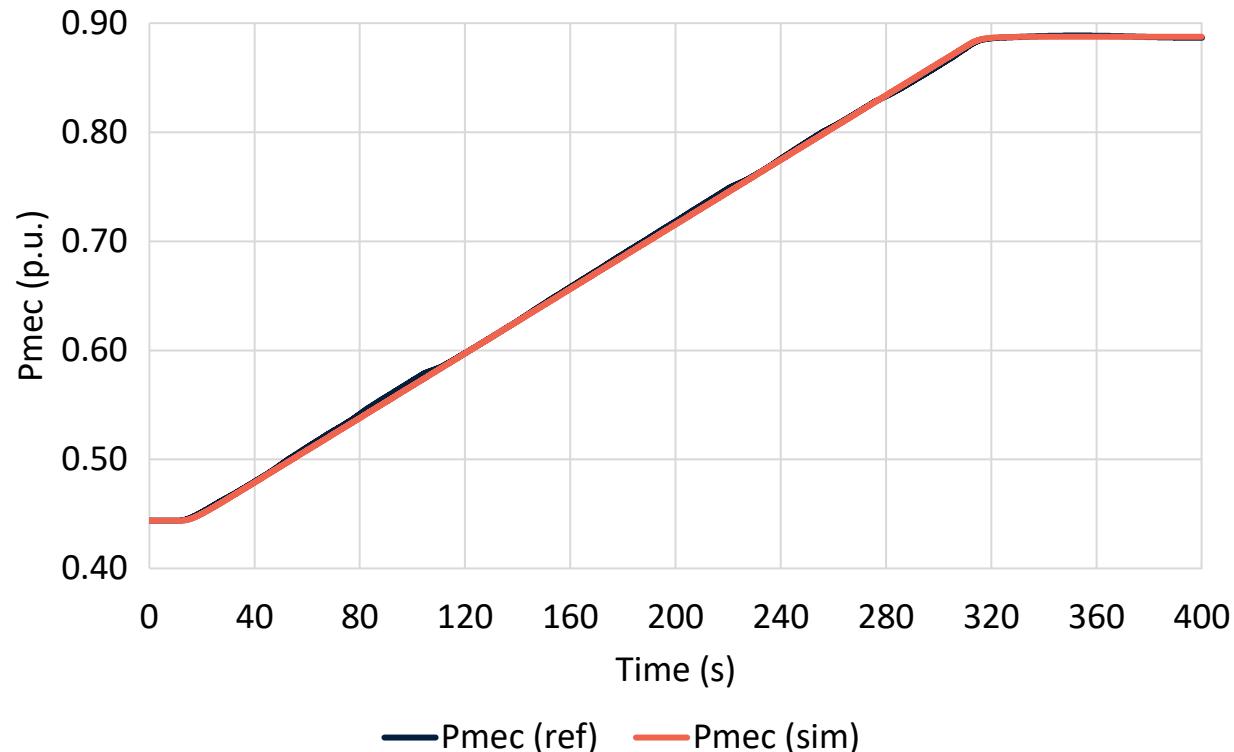
Pump mode: No capability to comply with service requirements

Frades 2 – Fixed speed model without SPPS

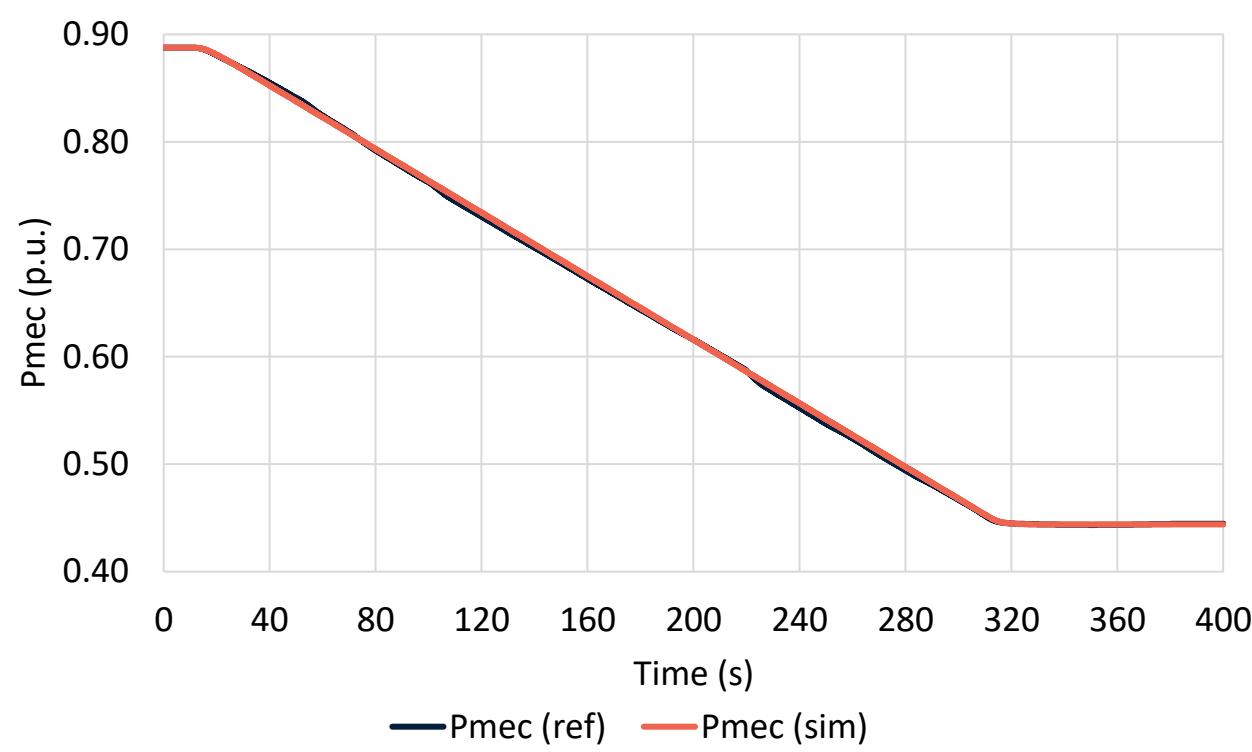
aFRR service provision

Turbine mode

Pmin to Pmax



Pmax to Pmin

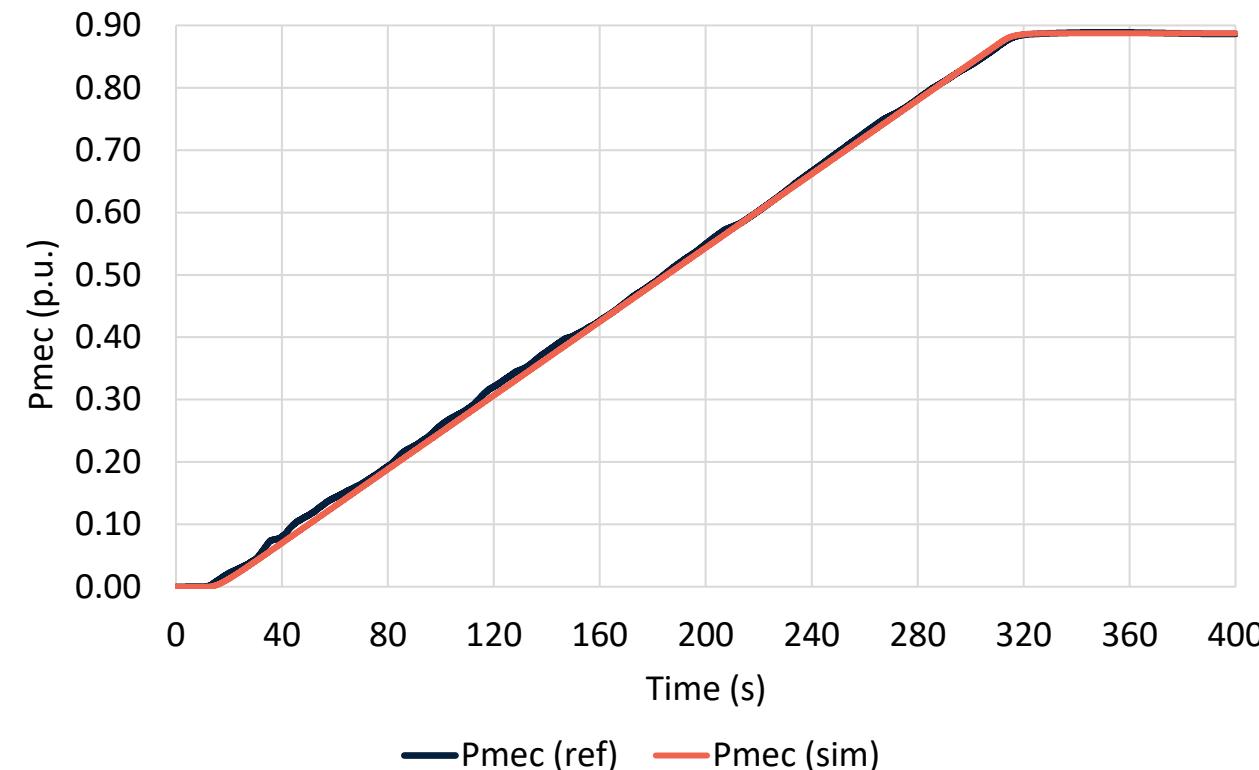


Frades 2 – Fixed speed model with SPPS

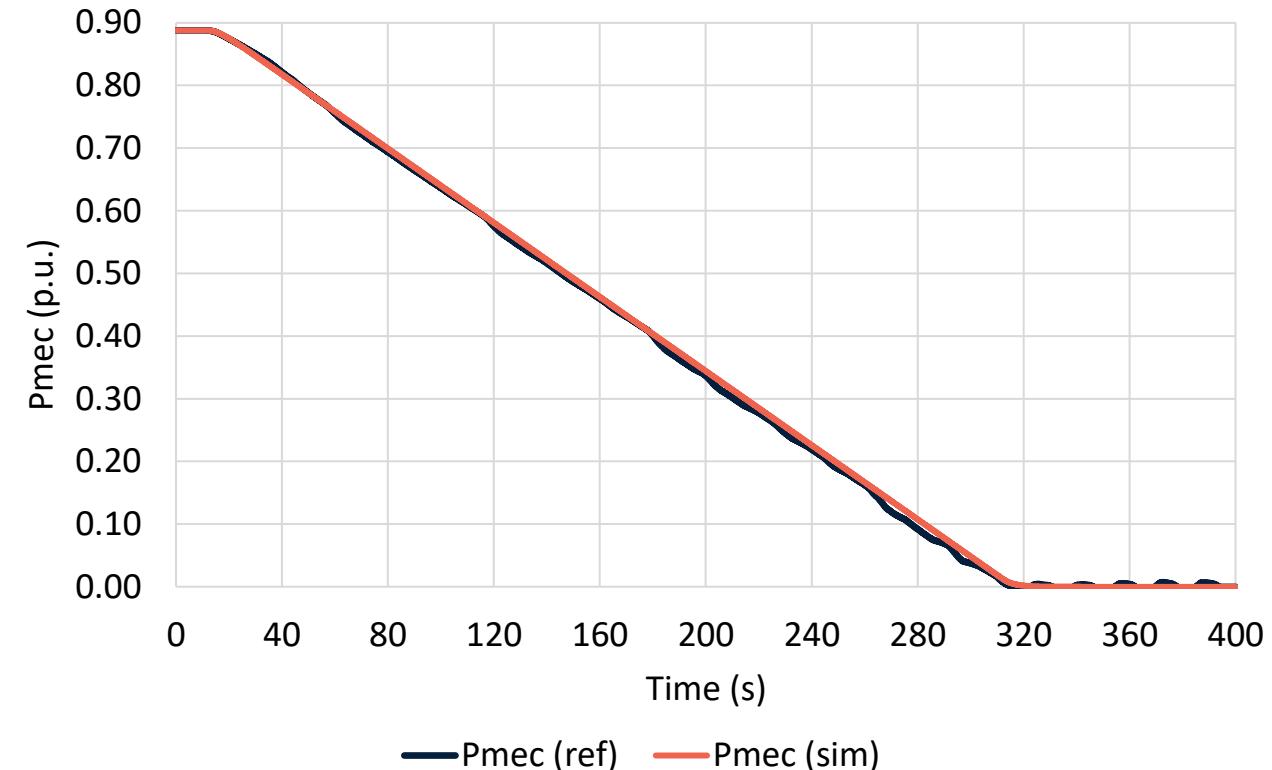
aFRR service provision

Turbine mode

Pmin to Pmax



Pmax to Pmin



Frades 2 – Fixed speed model (with and without SPPS) aFRR service provision

Pump mode

No capability to comply with service requirements