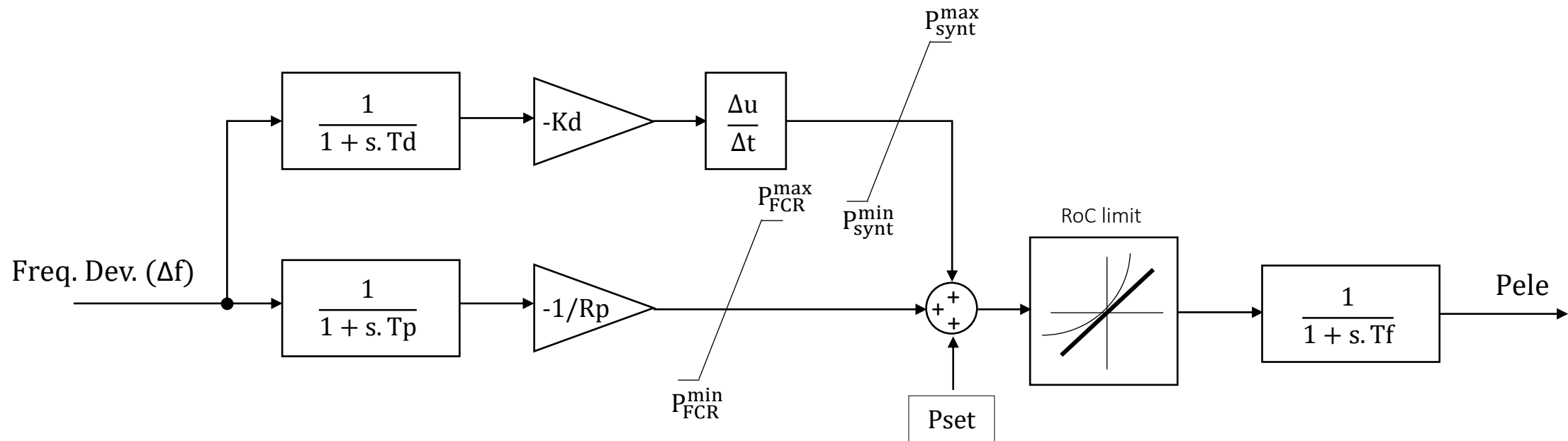


Frades 2 – Variable speed model (with and without SPPS)

Block Diagram for FCR and aFRR provision



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

Model's input signals, output signals and parameters

Input signals:

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

Output signals:

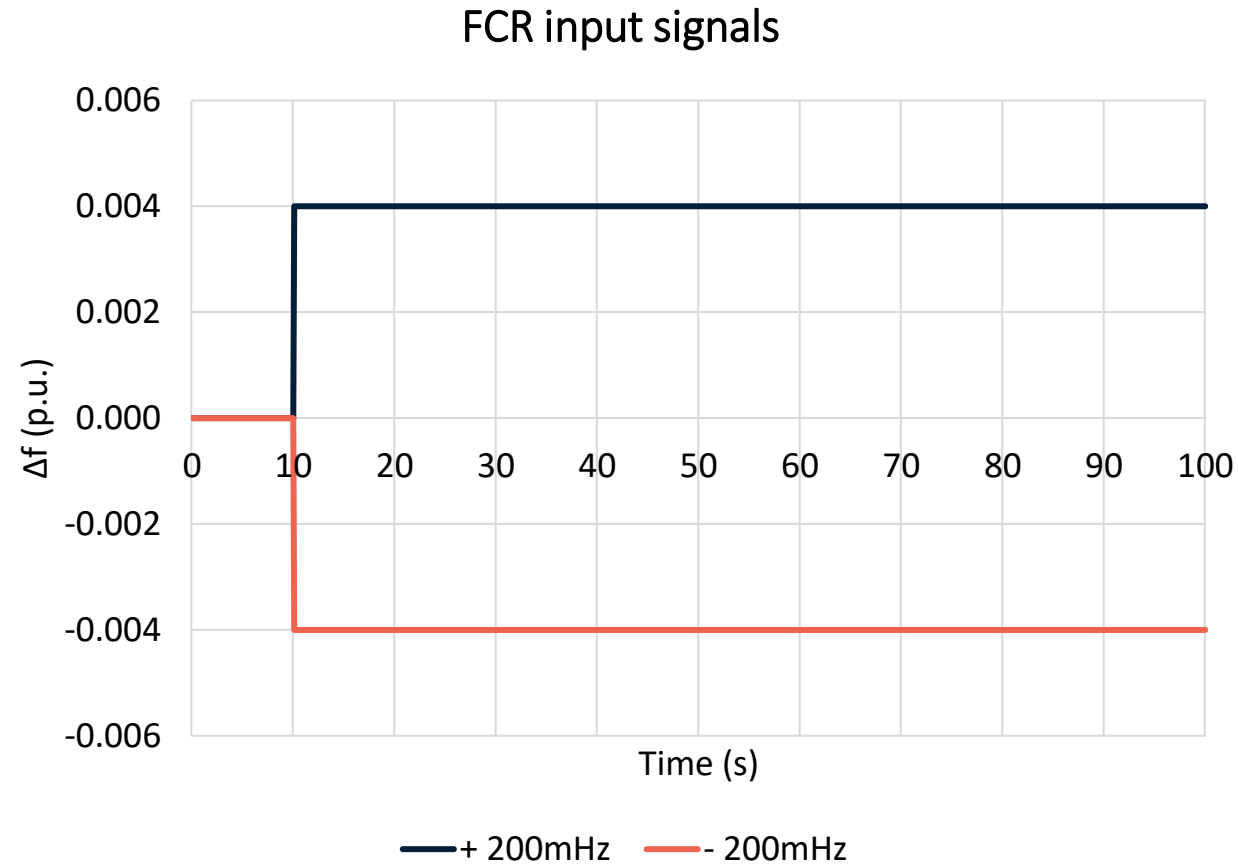
- P_{ele} – electrical active power (p.u.)

Parameters:

- K_d – derivative gain (p.u.)
- T_d – filter time constant for SI (s)
- $P_{\text{synt}}^{\text{max}}$ – SI maximum limit (p.u.)
- $P_{\text{synt}}^{\text{min}}$ – SI minimum limit (p.u.)
- R_p – permanent droop (p.u.)
- T_p – filter time constant for FCR (s)
- $P_{\text{FCR}}^{\text{max}}$ – FCR maximum limit (p.u.)
- $P_{\text{FCR}}^{\text{min}}$ – FCR minimum limit (p.u.)
- RoC limit – Rate of Change limit (p.u./s)
- T_f – converters delay time constant (s)

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

FCR input signals

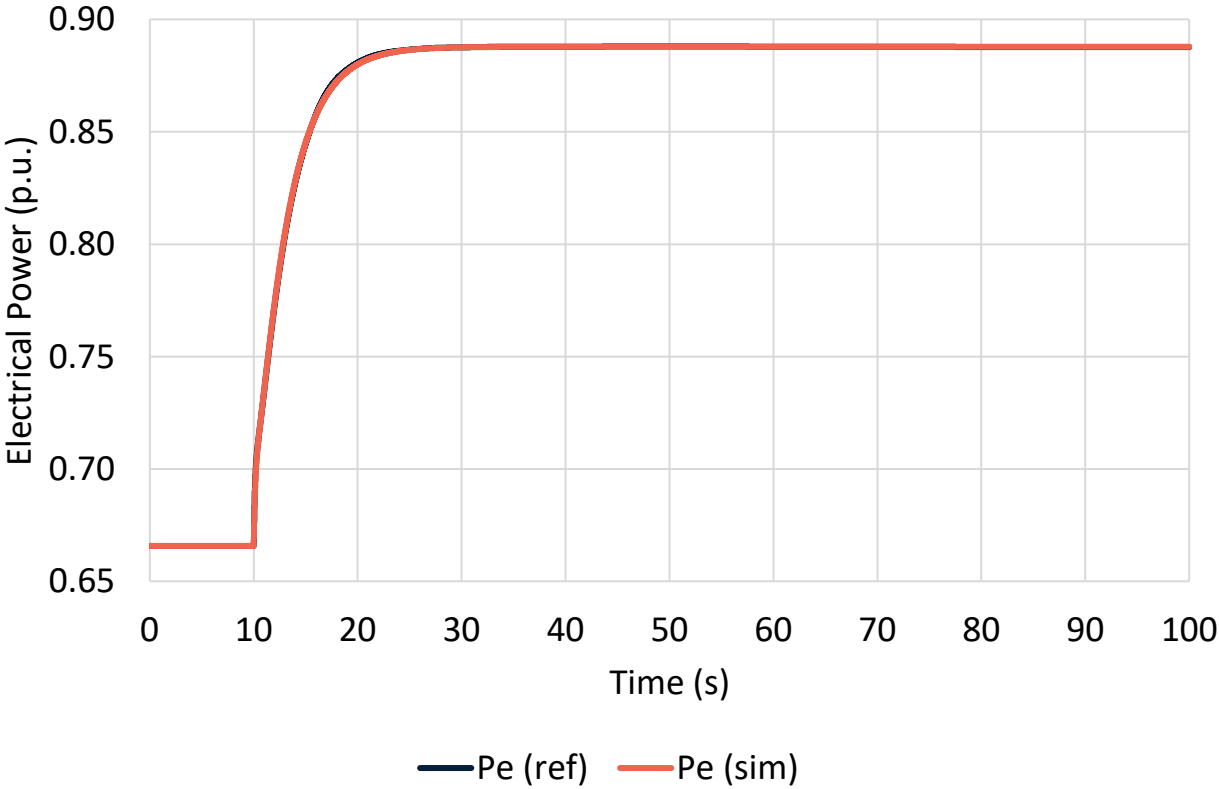


Frades 2 – Variable speed model without SPPS

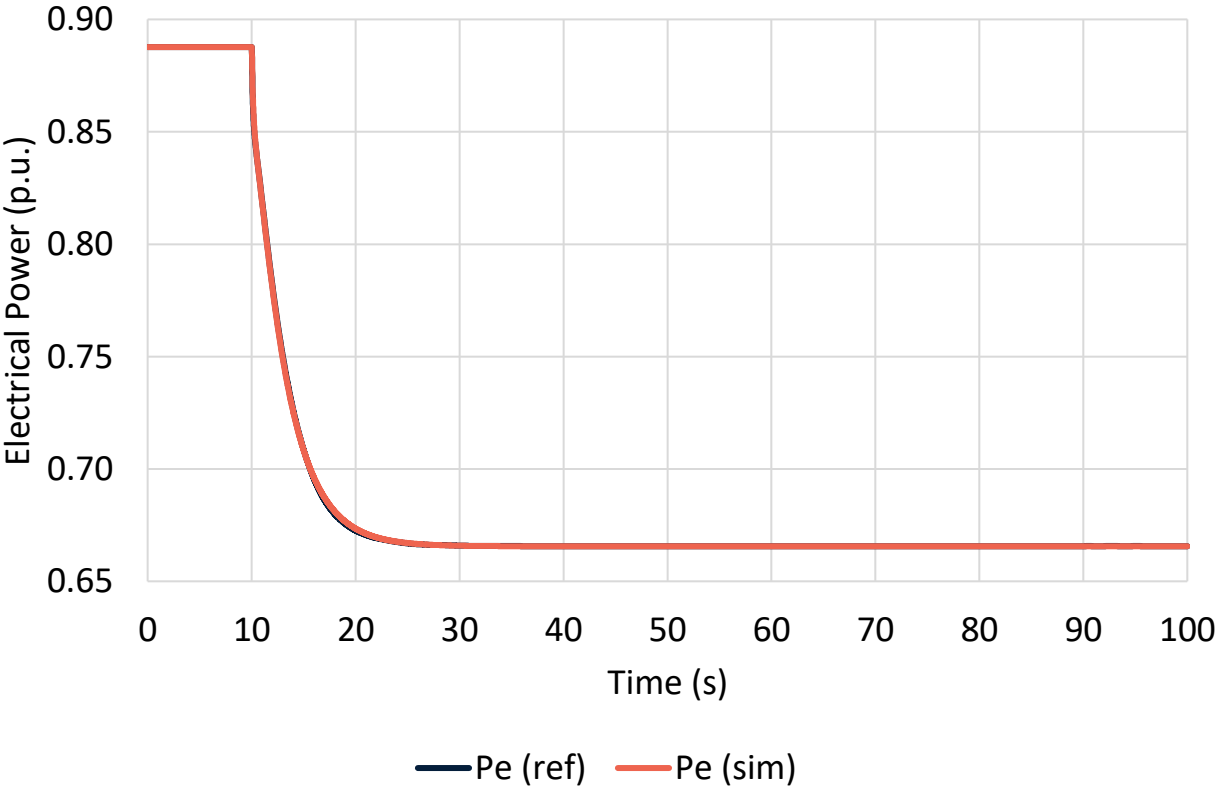
FCR service provision

Turbine mode

Frequency deviation: -200 mHz



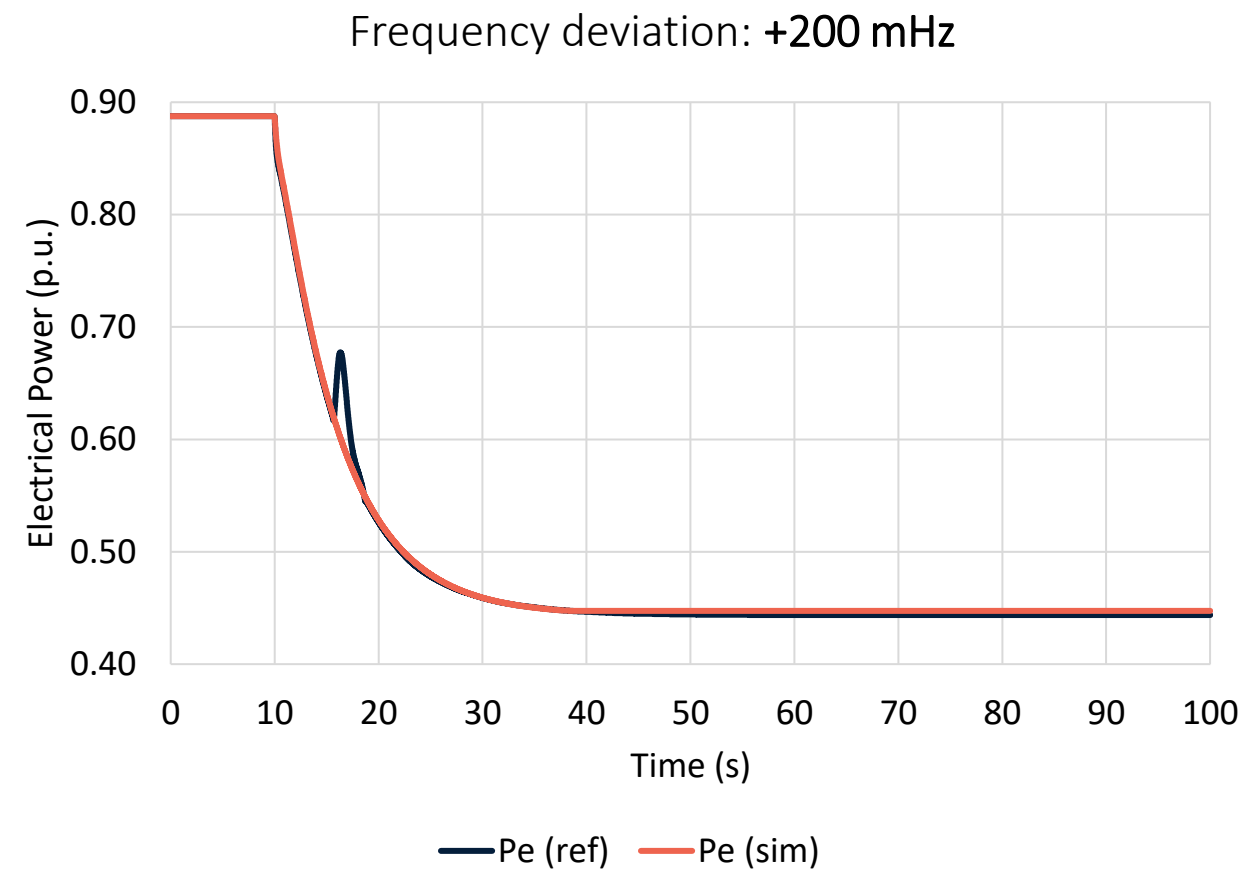
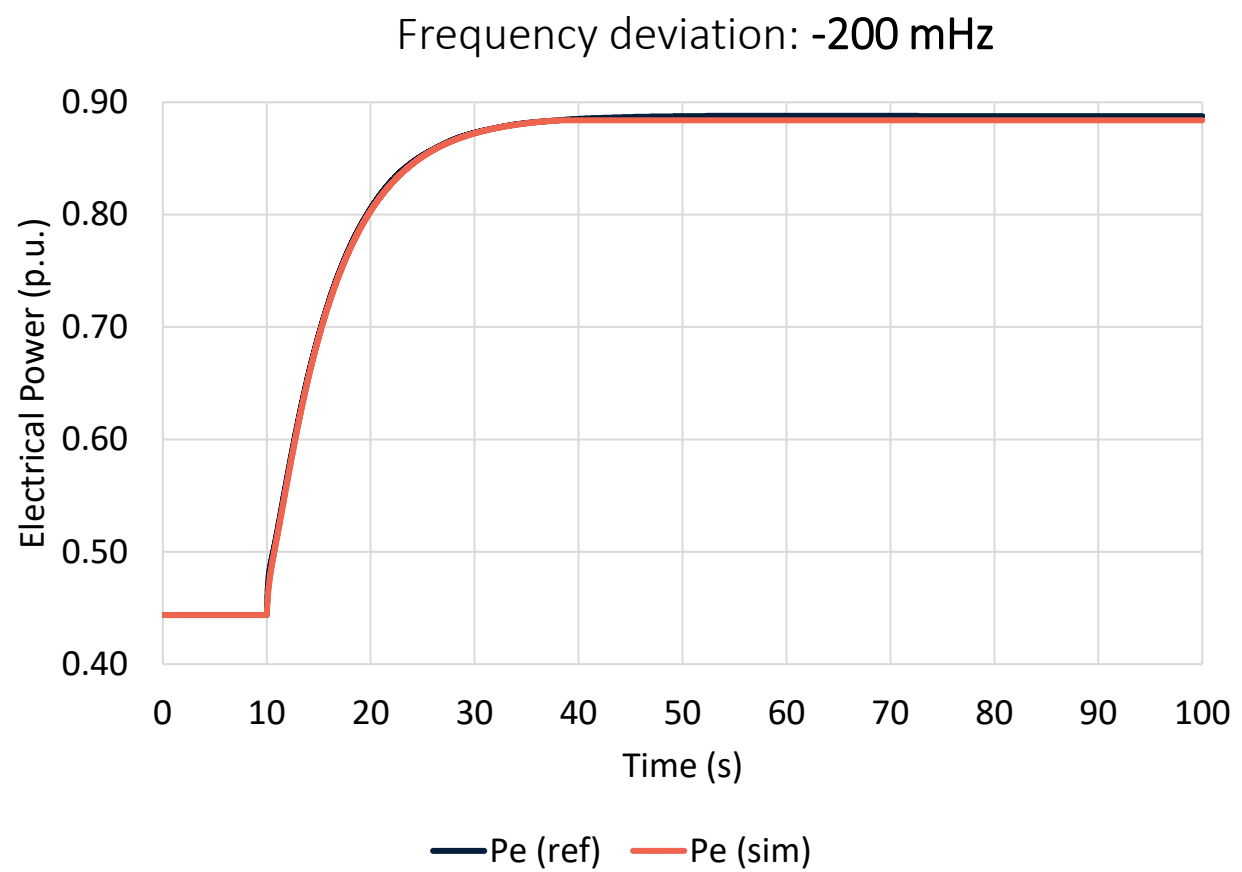
Frequency deviation: +200 mHz



Frades 2 – Variable speed model with SPPS

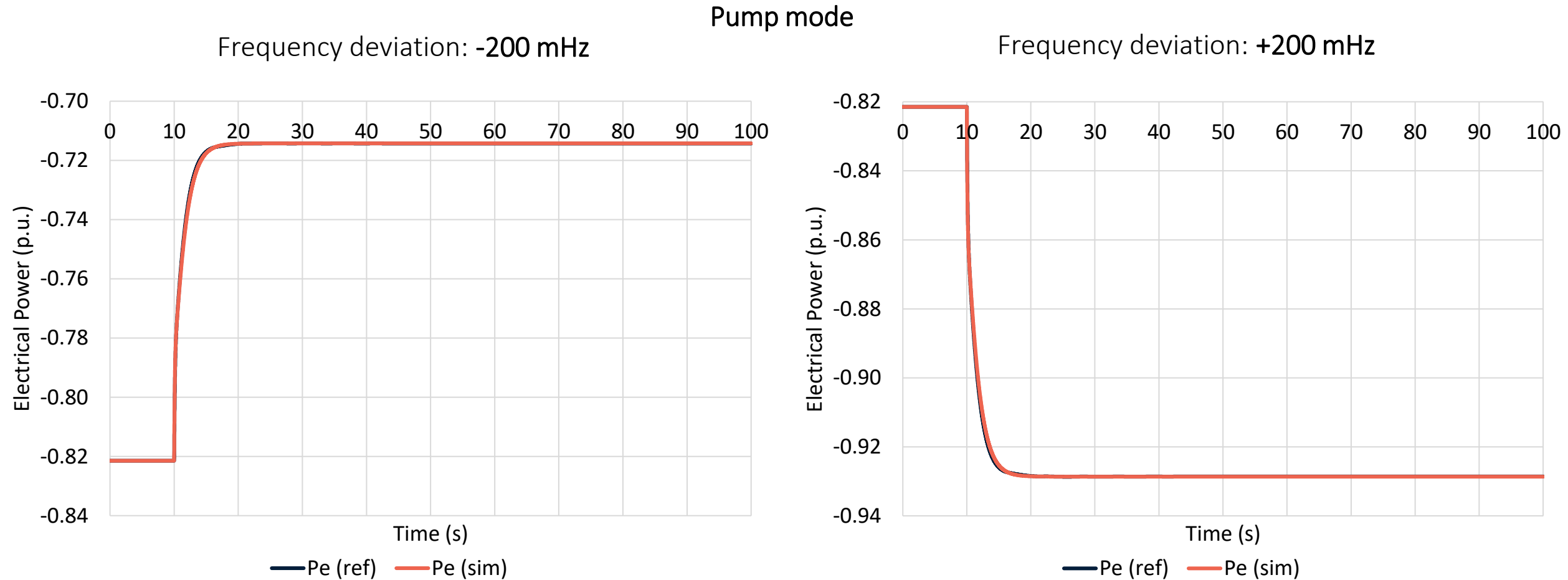
FCR service provision

Turbine mode



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

FCR service provision

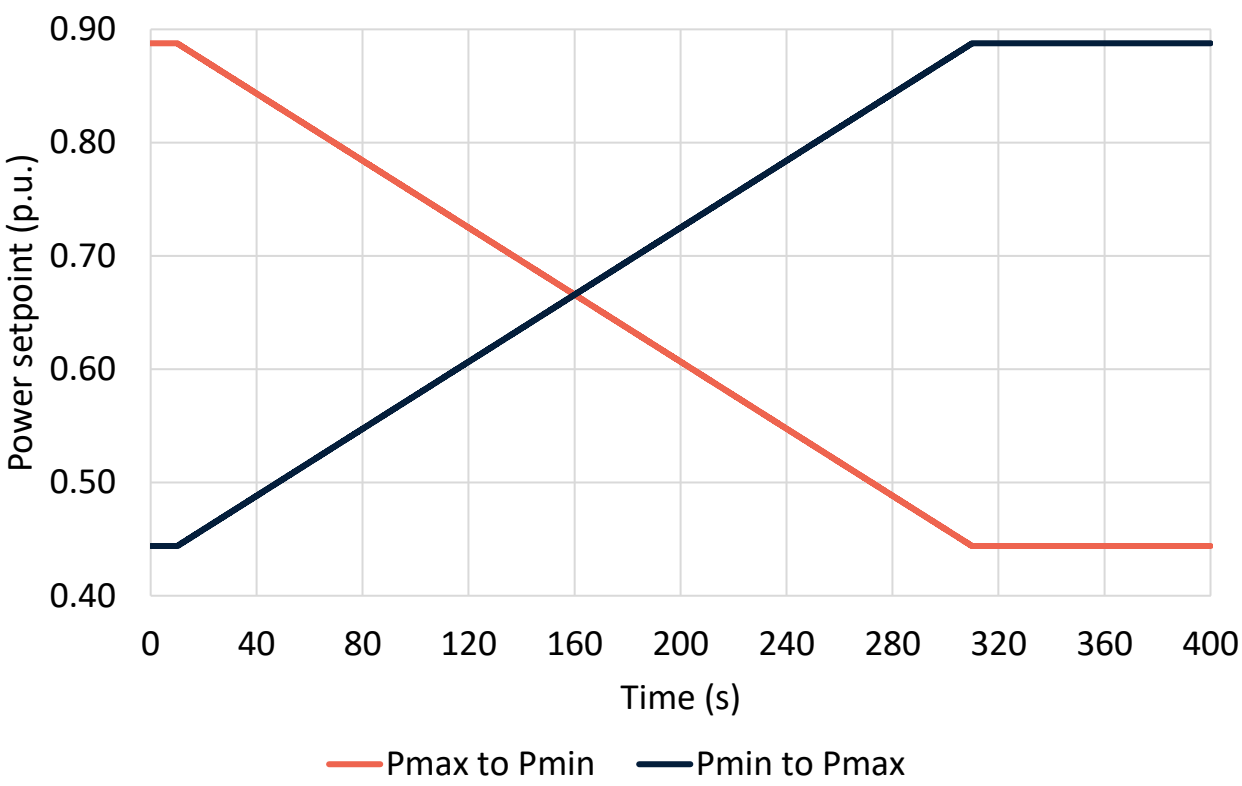


Frades 2 – Variable speed model (with and without SPPS)

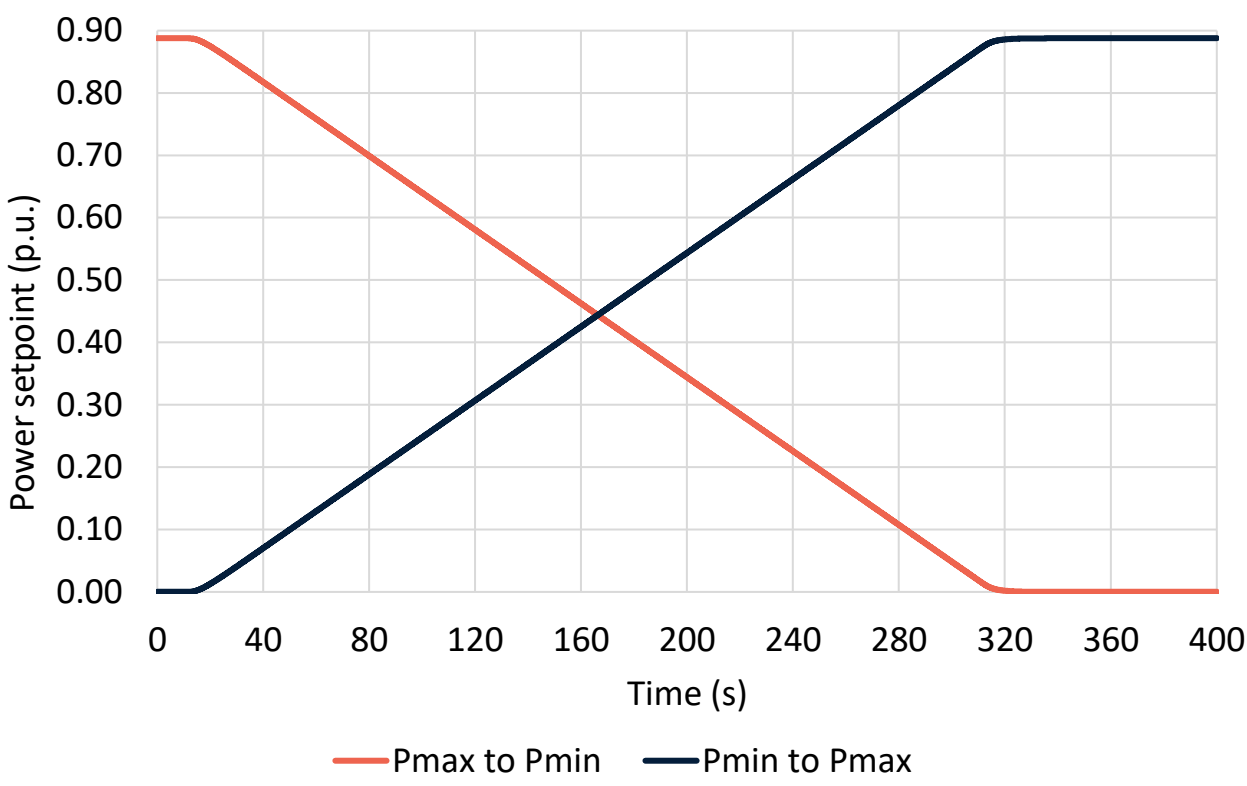
aFRR input signals

Turbine mode

aFRR input signals (without SPPS)



aFRR input signals (with SPPS)

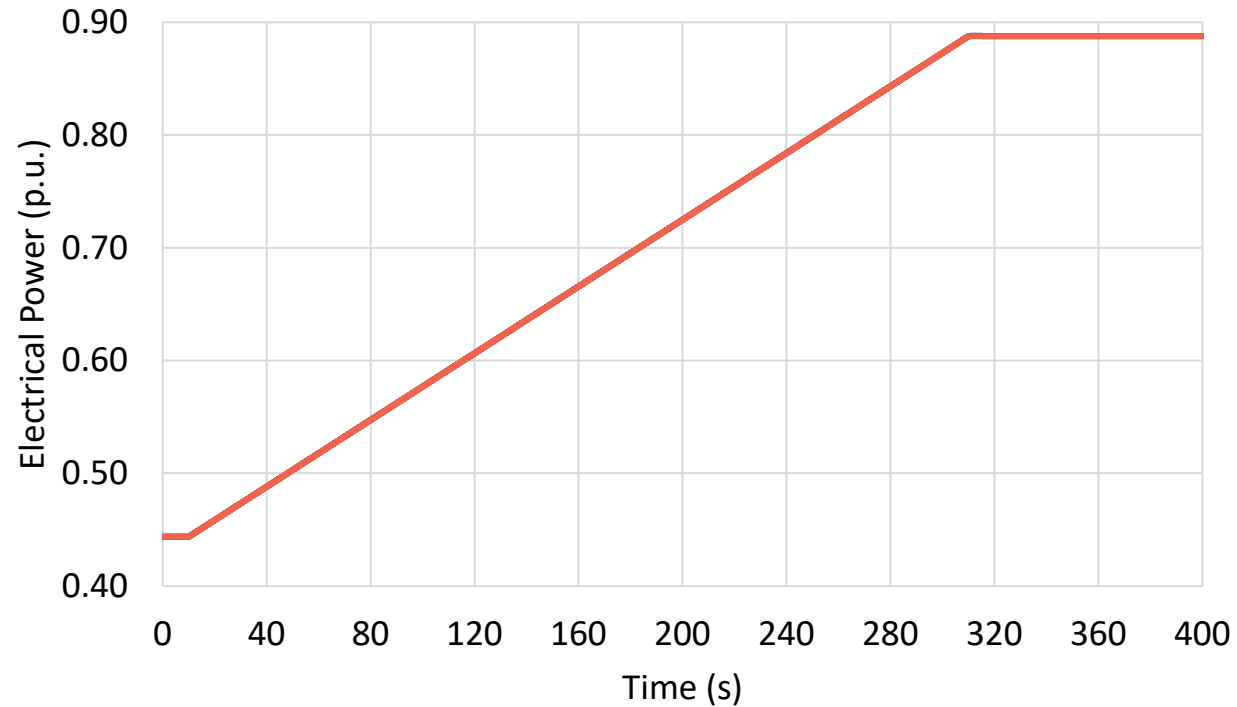


Frades 2 – Variable speed model without SPPS

aFRR service provision

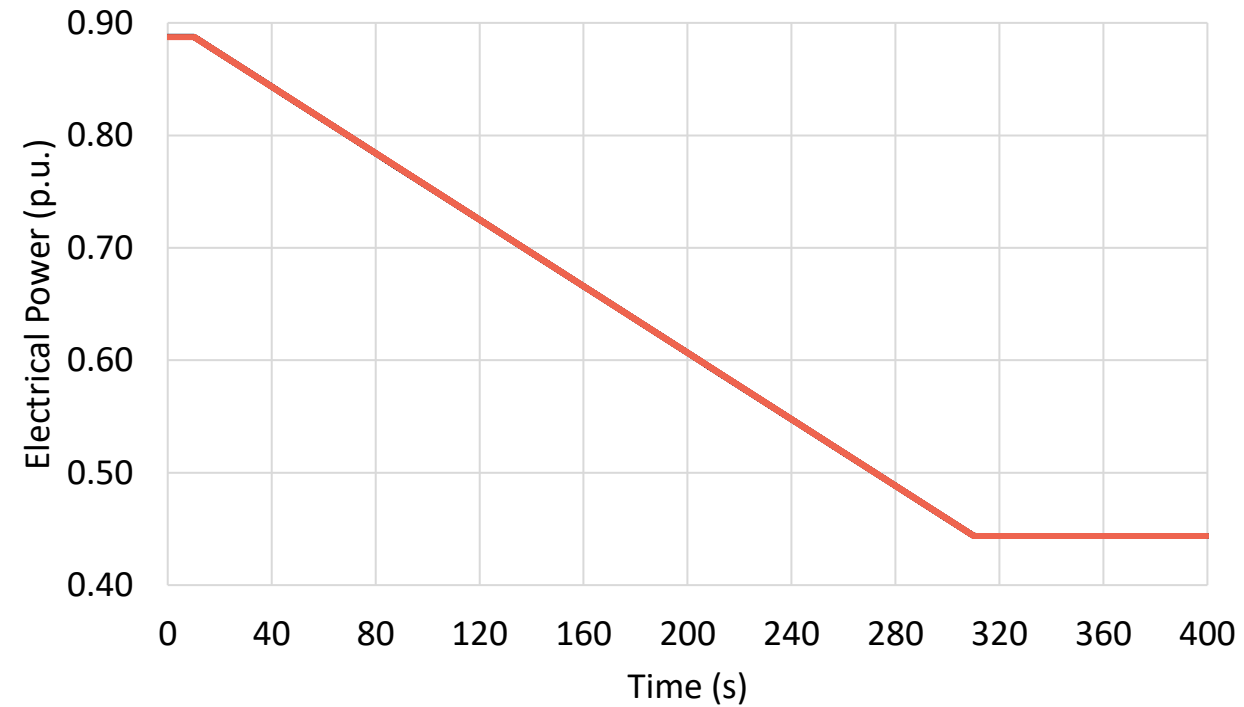
Turbine mode

Pmin to Pmax



— Pe (ref) — Pe (sim)

Pmax to Pmin



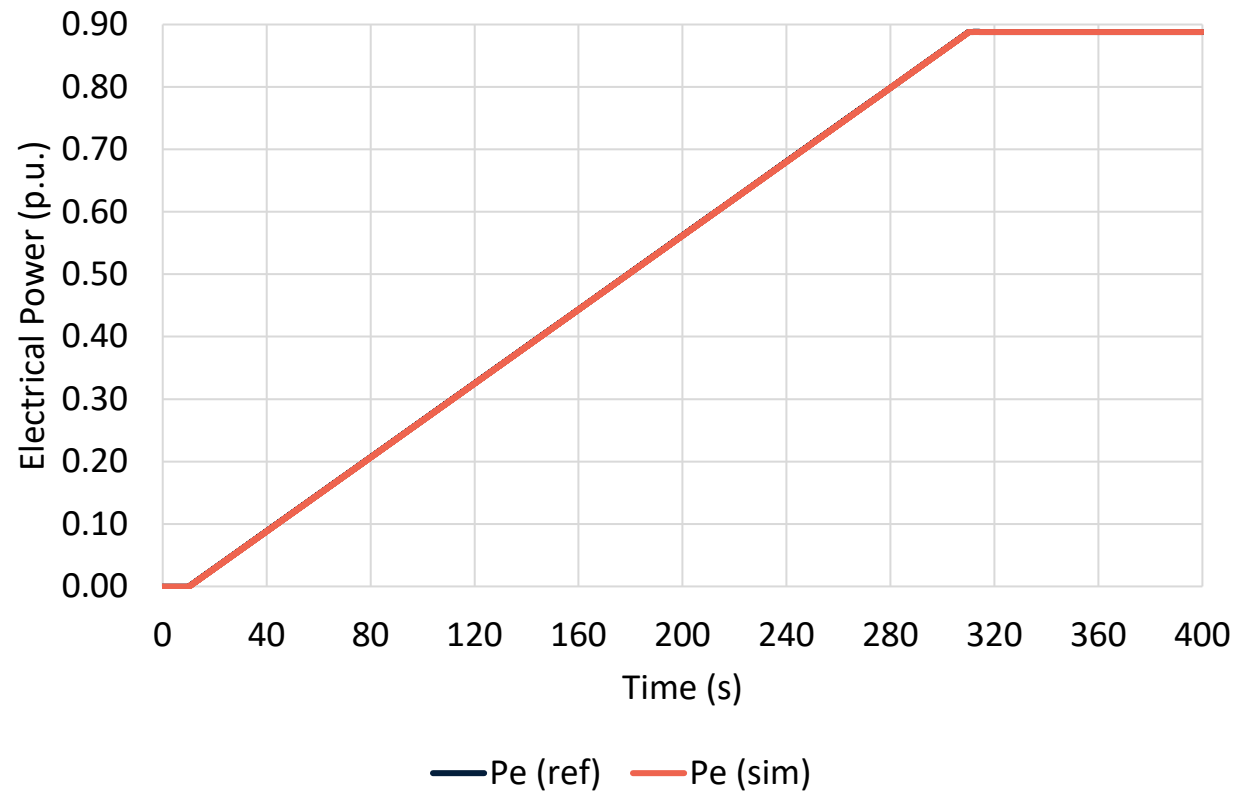
— Pe (ref) — Pe (sim)

Frades 2 – Variable speed model with SPPS

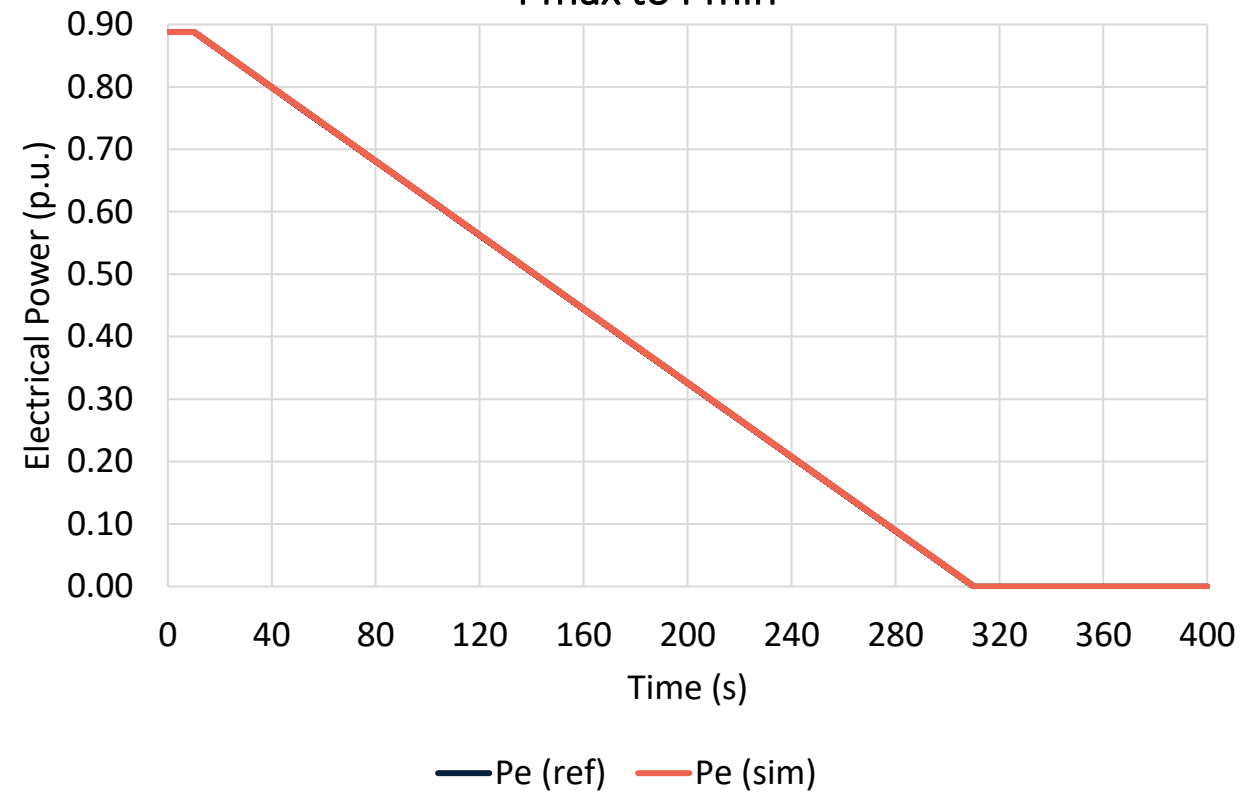
aFRR service provision

Turbine mode

Pmin to Pmax

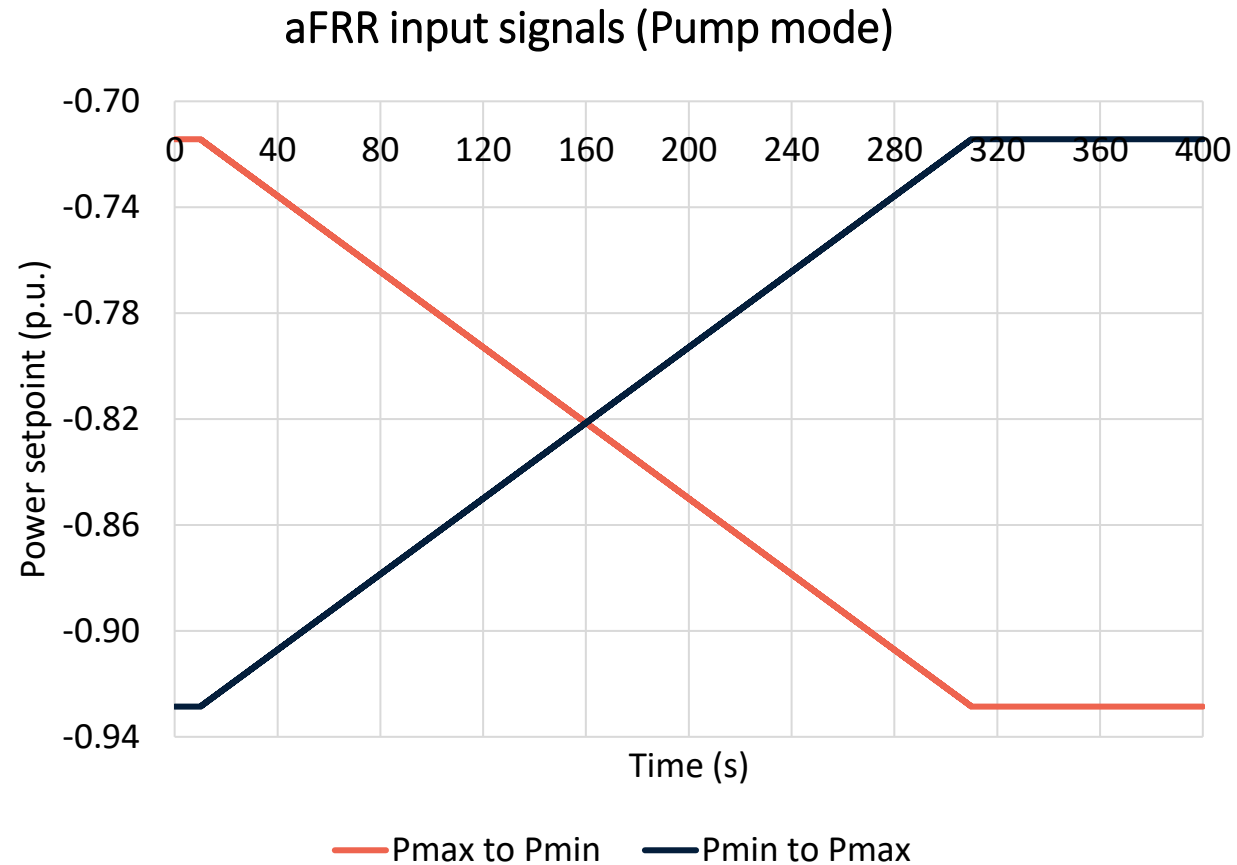


Pmax to Pmin



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

aFRR input signals

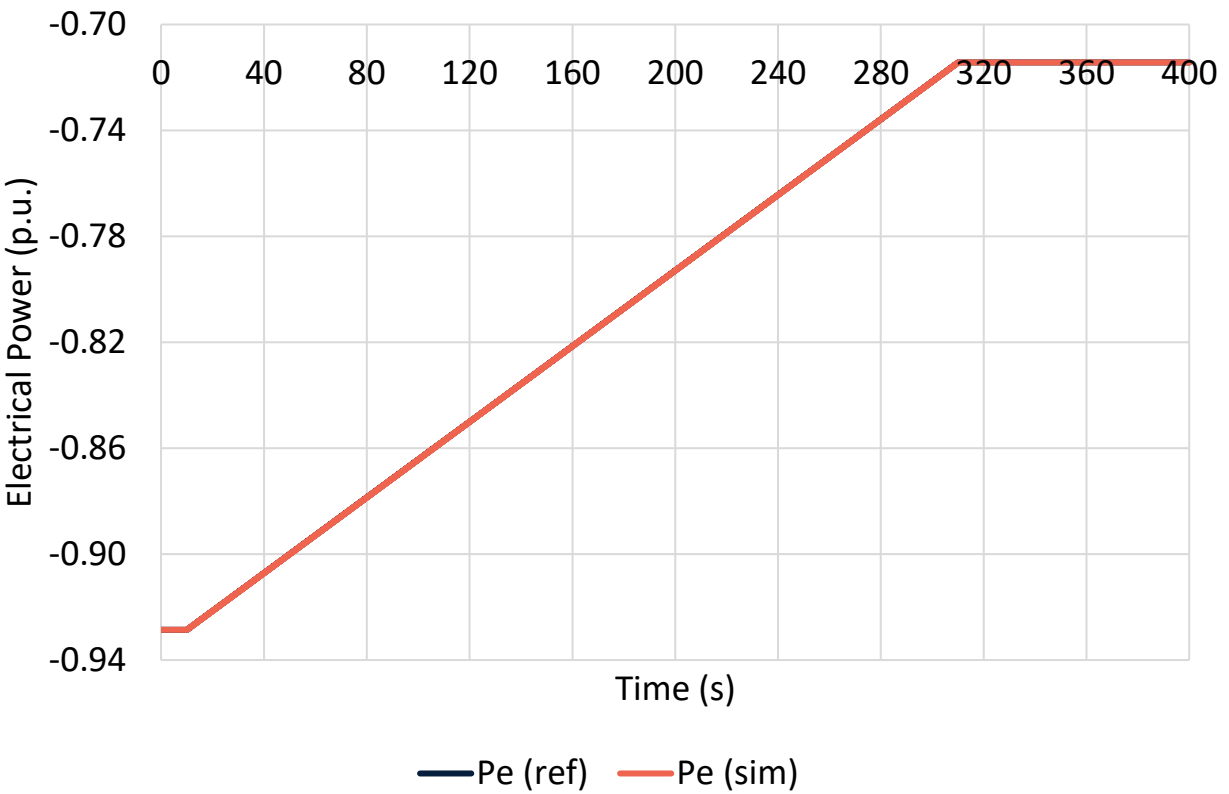


Frades 2 – Variable speed model (with and without SPPS)

aFRR service provision

Pump mode

Pmin to Pmax



Pmax to Pmin

