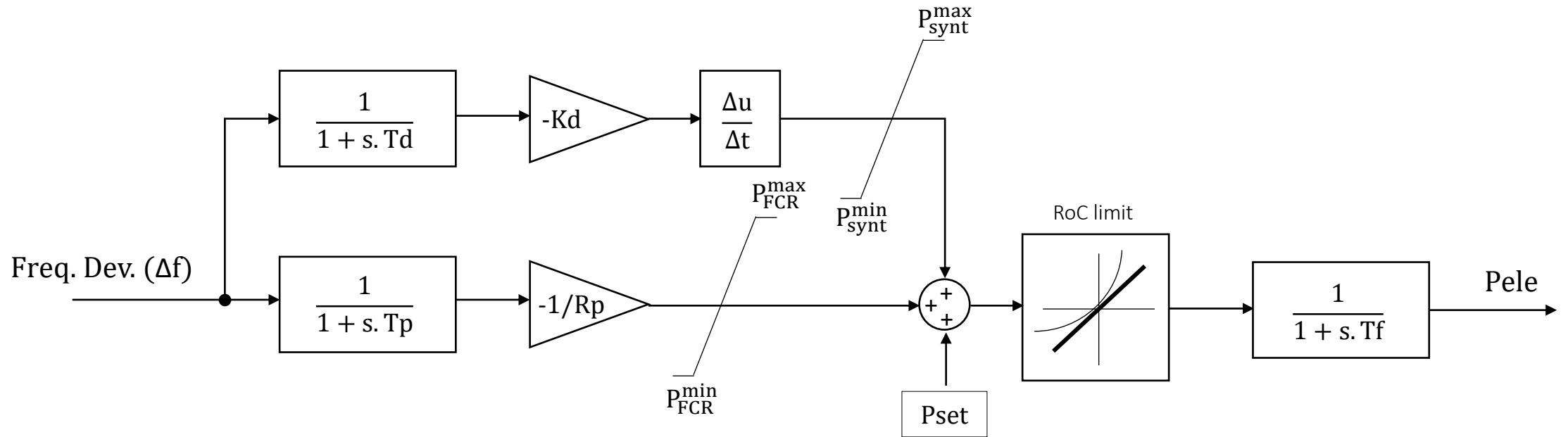


Alto Lindoso – Variable speed model (with and without SPPS)

Block Diagram for FCR and aFRR provision



Reservoir storage hydropower plant (no pump mode available)

Alto Lindoso – 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:

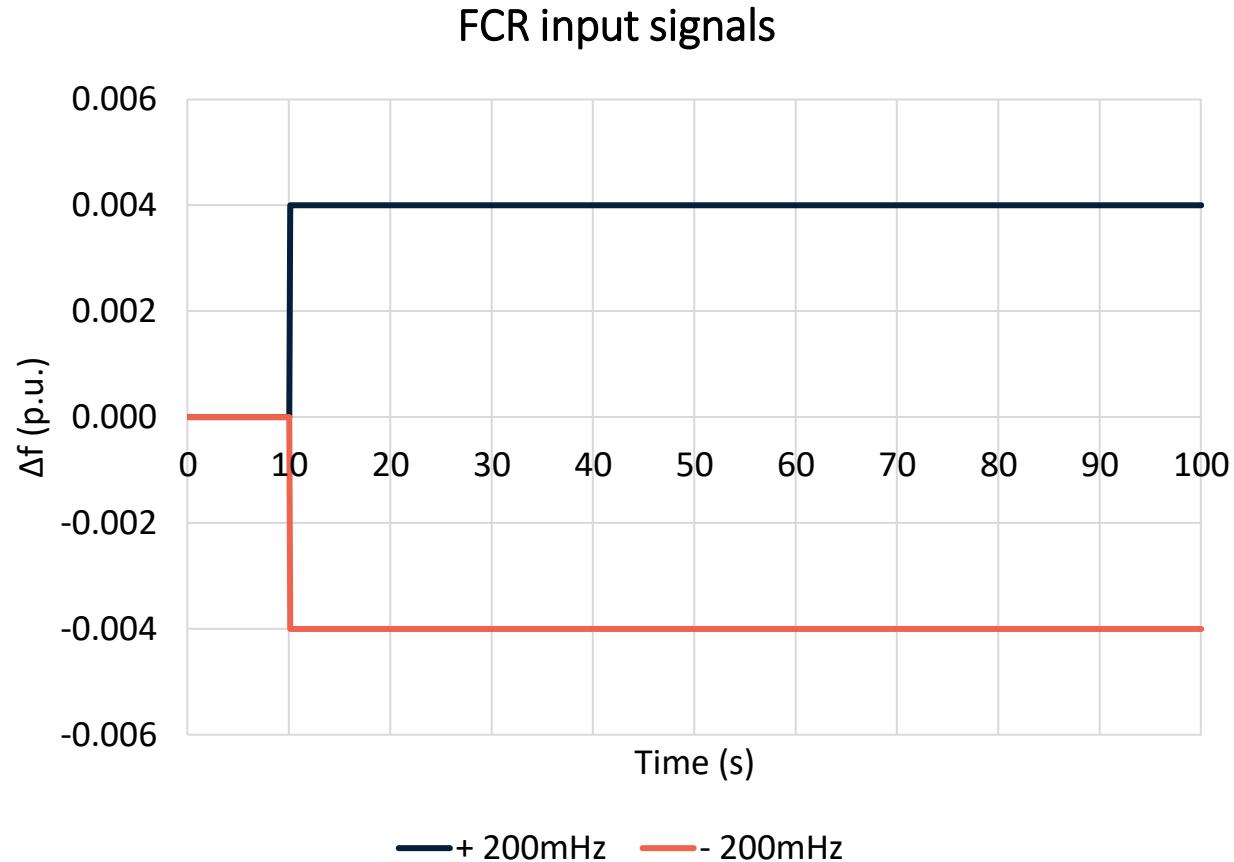
- P_{ele} – electrical active power (p.u.)

Parameters:

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

Alto Lindoso – Variable speed model (with and without SPPS)

FCR input signals



Alto Lindoso – Variable speed model without SPPS

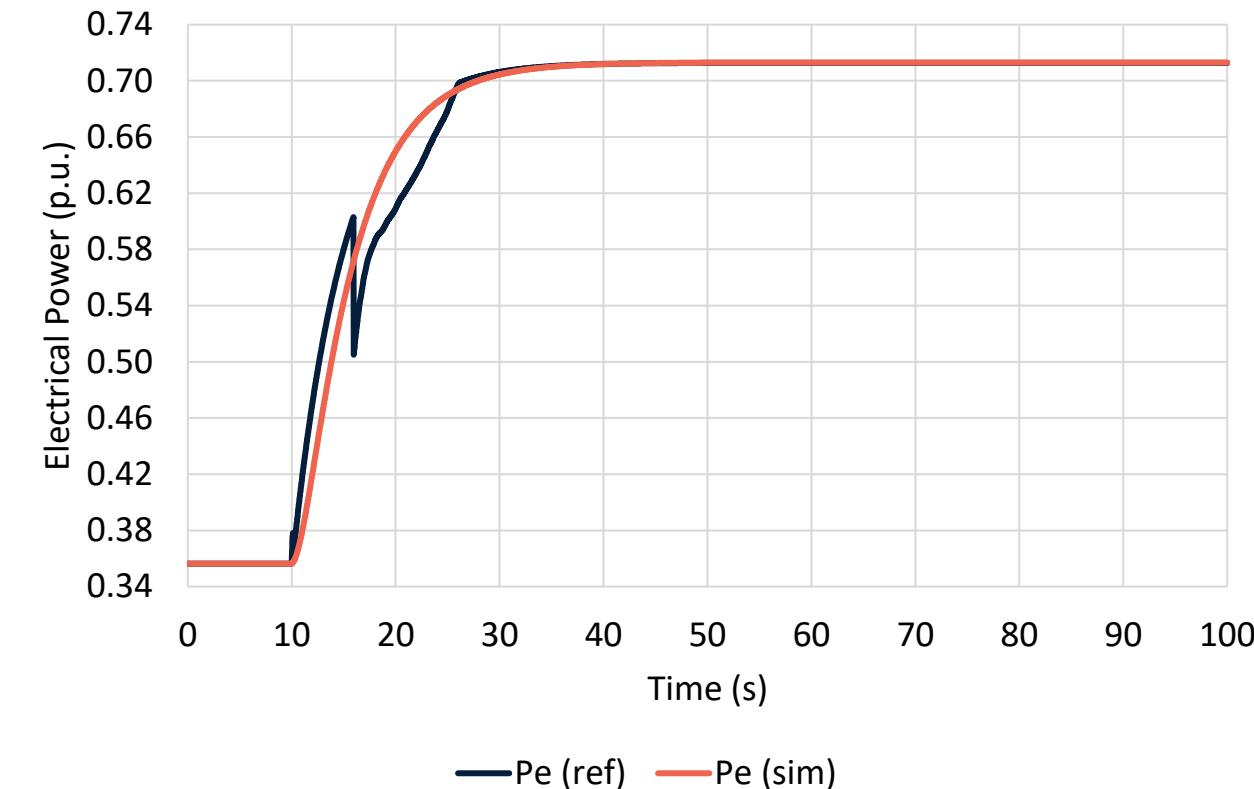
FCR service provision

Operation mode not assessed

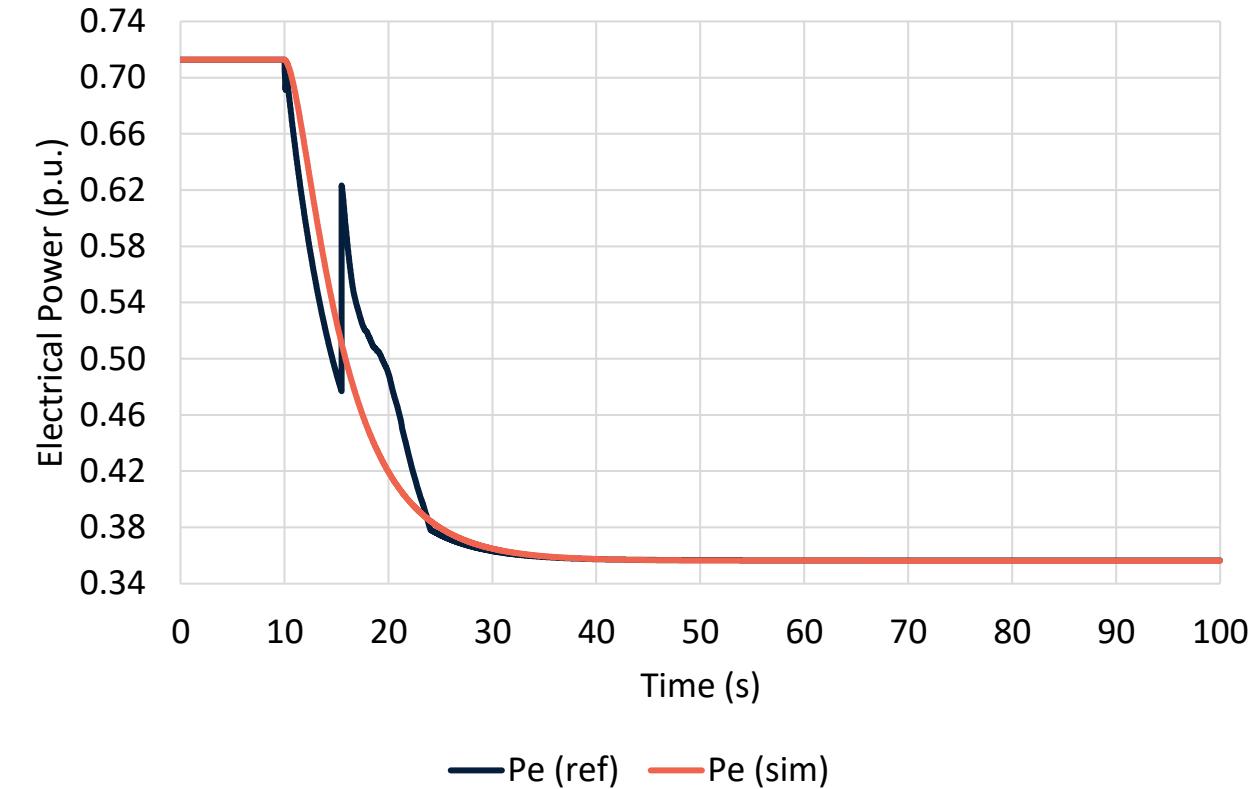
Alto Lindoso – Variable speed model with SPPS

FCR service provision

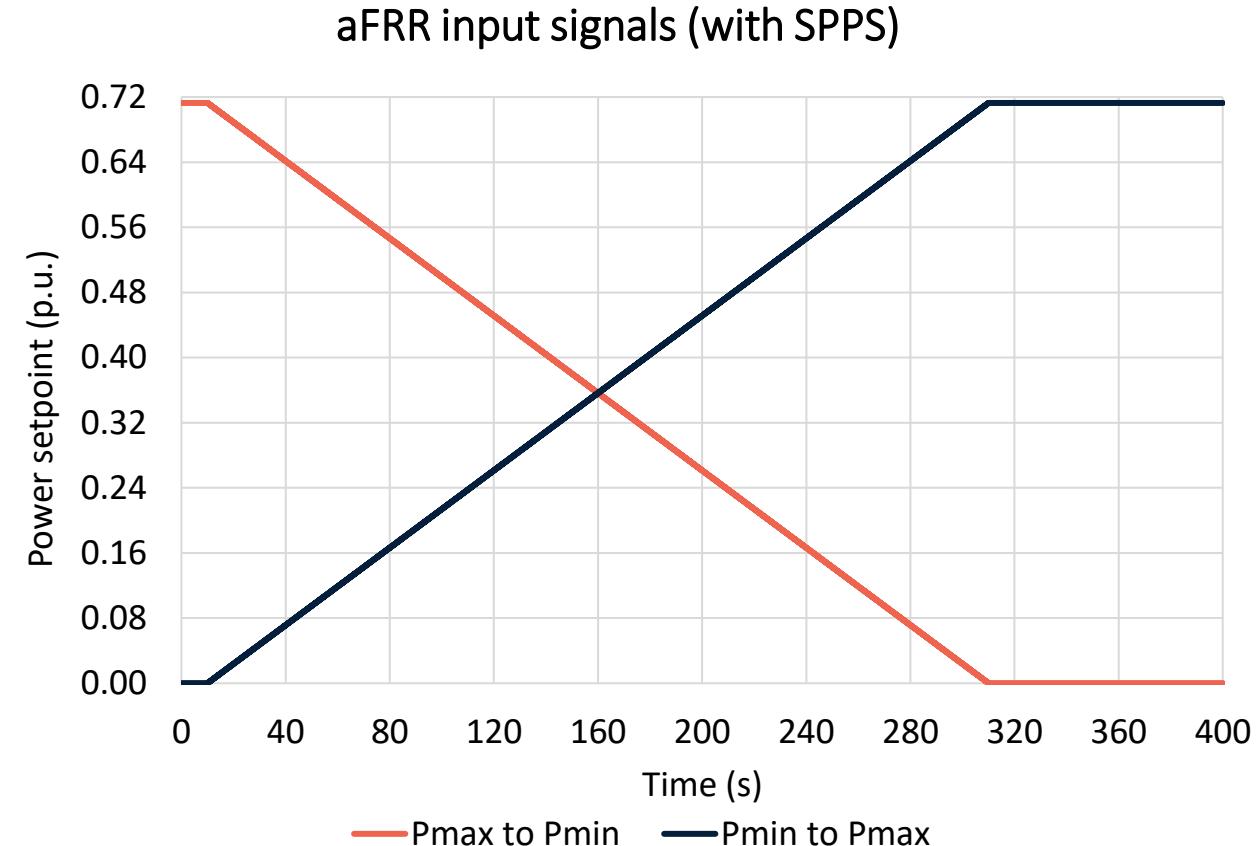
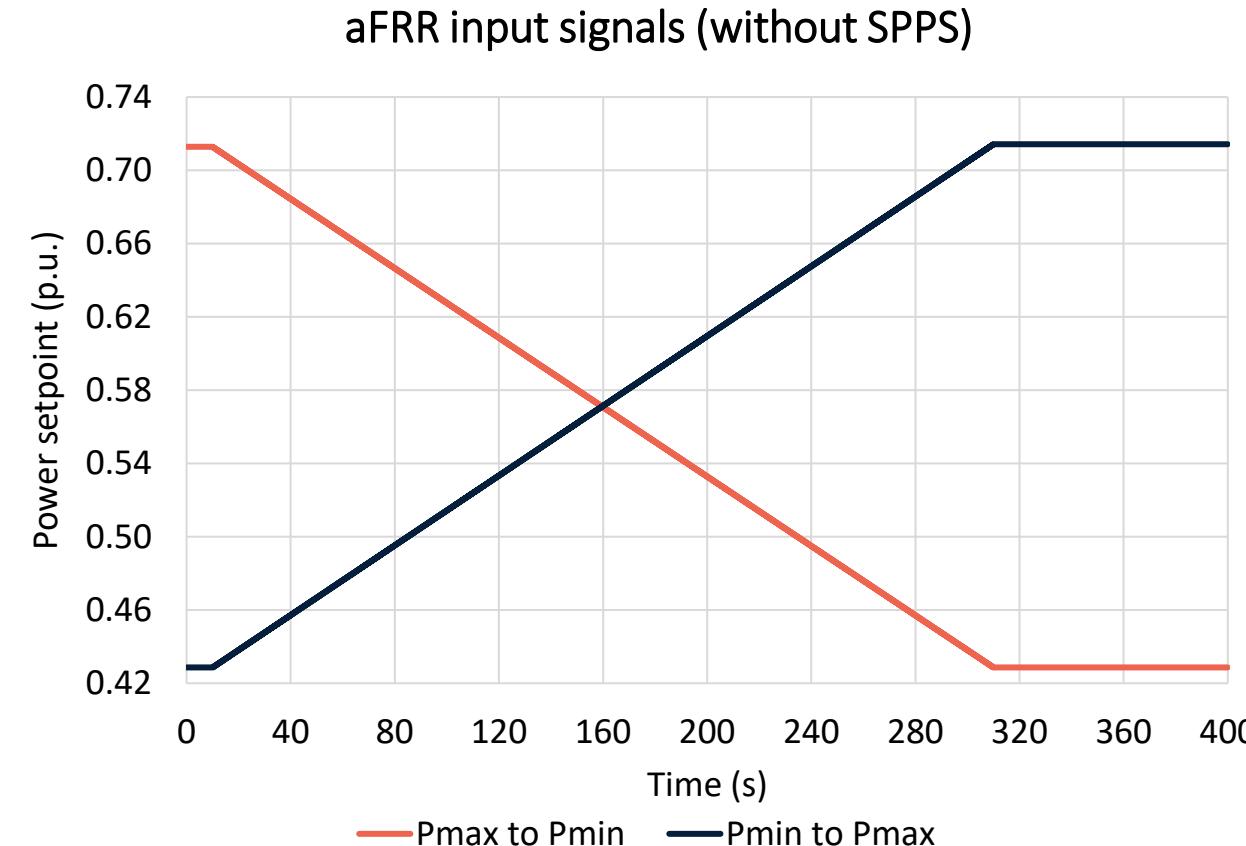
Frequency deviation: -200 mHz



Frequency deviation: +200 mHz

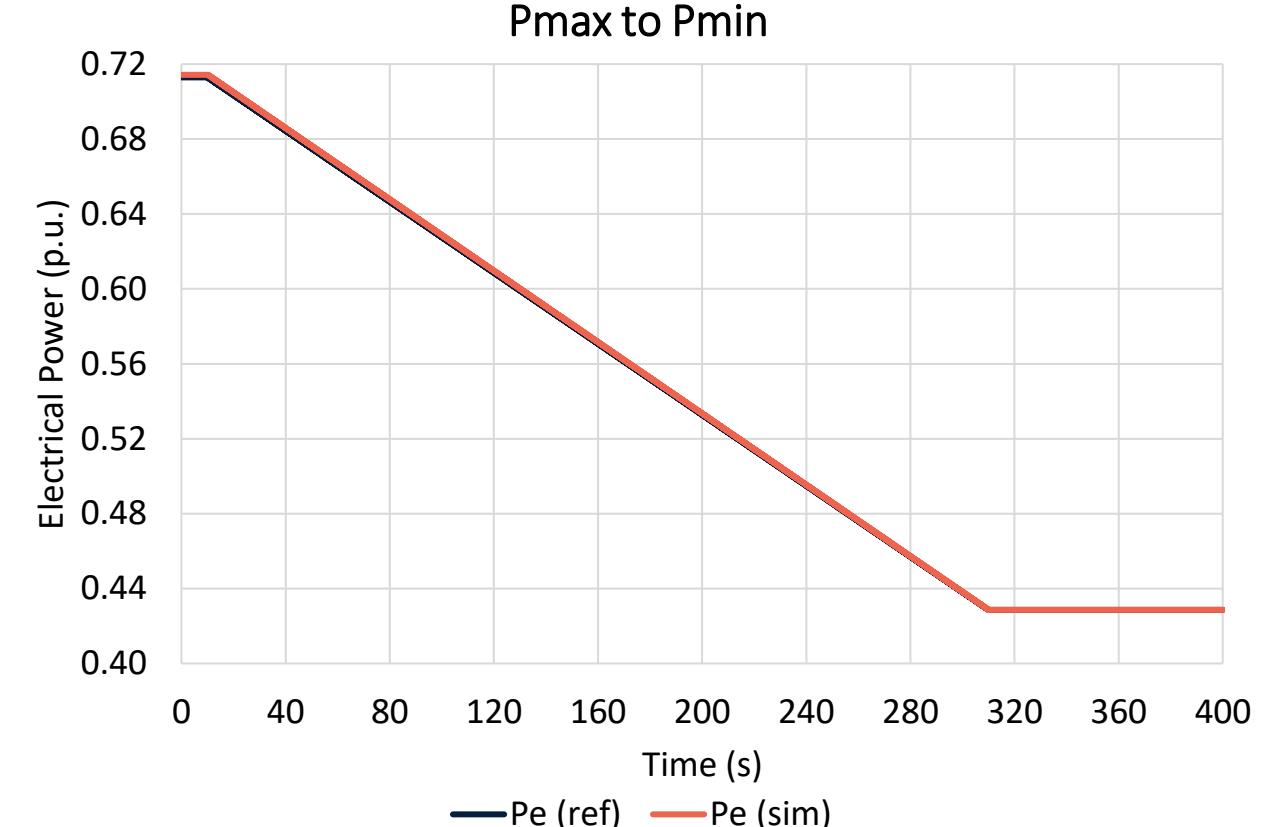
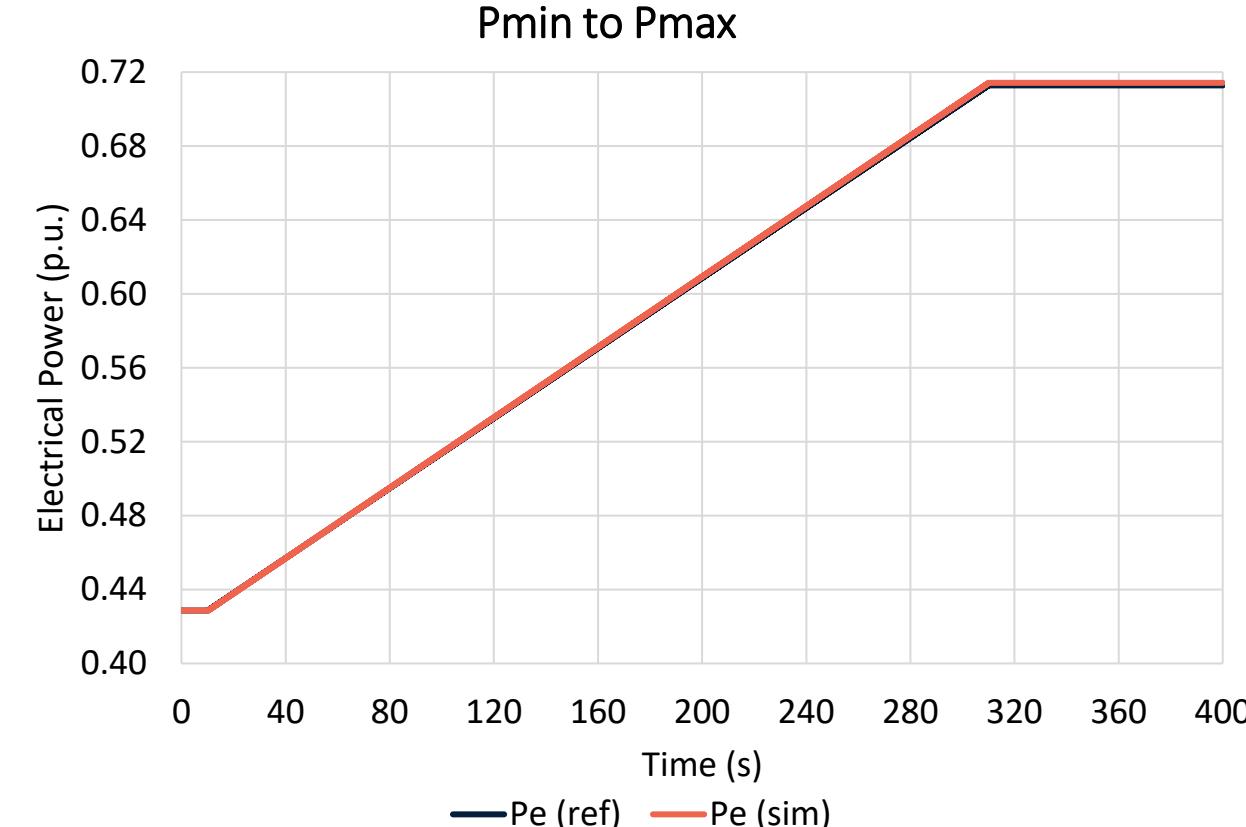


Alto Lindoso – Variable speed model (with and without SPPS) aFRR input signals



Alto Lindos – Variable speed model without SPPS

aFRR service provision



Alto Lindoso – Variable speed model with SPPS

aFRR service provision

