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ADVERSE IMPACTS ON VOLTAGE AND REACTIVE POWER PERFORMANCES DUE TO PSSS

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INTRODUCTION

- **Studying the adverse terminal voltage and reactive power transients induced by the presence of PSSs**

➔ **Comparing the PSSs derived from either rotor speed, terminal power or integral of accelerating power**

➔ **Presenting some of the benefits introduced by the ramp-tracking fourth-order filter, for the $PSS_{\int P_{acel}}$**

Step Response of a Second Order System

- **Second order system with one zero**

$$G(s)=\frac{\omega_n^2(as+1)}{\left(s^2+2\zeta\omega_n s+\omega_n^2\right)}$$	
Zero	$s_z=-\frac{1}{a}$
Poles	$s_{p1},s_{p2}=-\zeta\varpi_n\pm j\omega_n\sqrt{1-\zeta^2}$

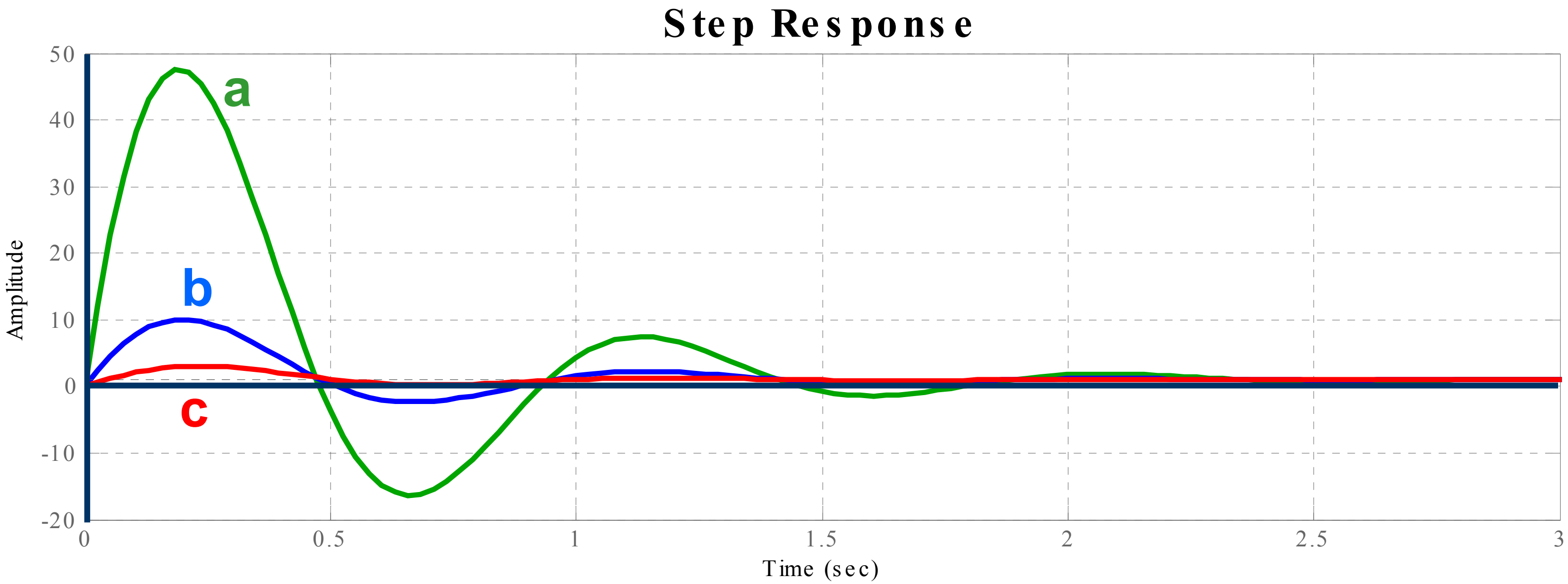
- **The dynamical behavior of *G(s)* will be assessed for different zero locations:**

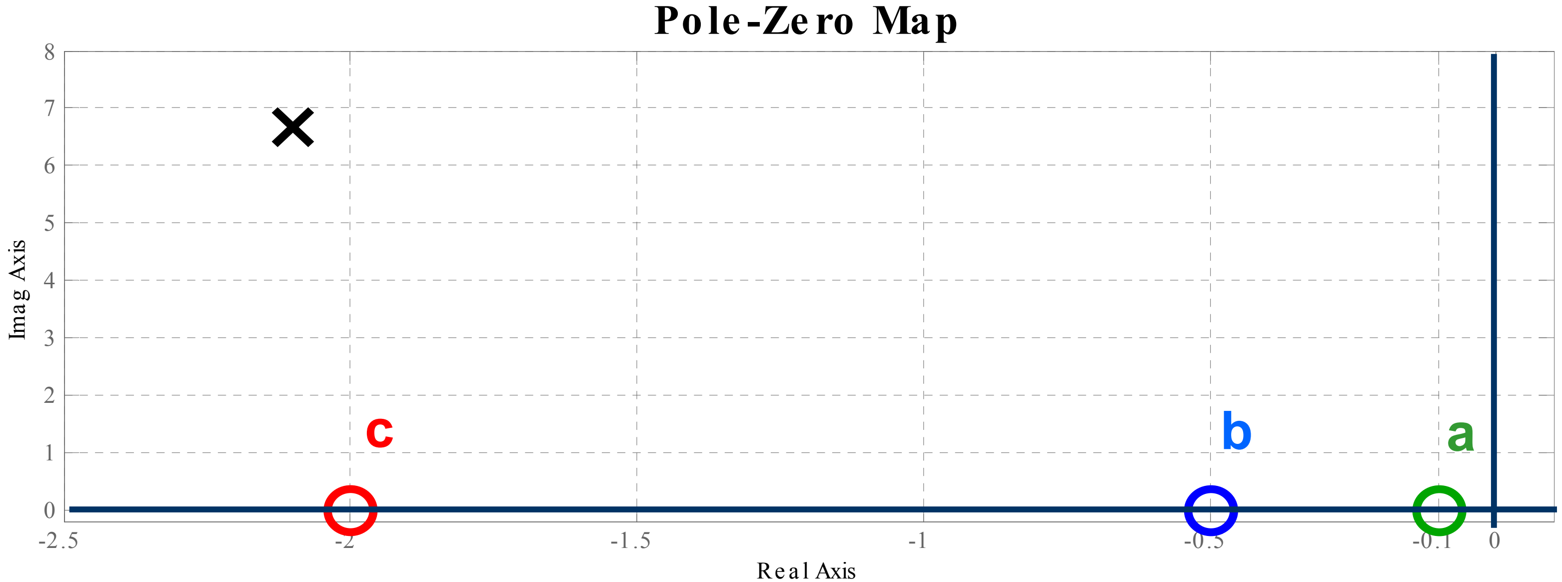
a $\Rightarrow$ s_Z = -0,1 + j0

b $\Rightarrow$ s_Z = -0,5 + j0

c $\Rightarrow$ s_Z = -2,0 + j0

STEP RESPONSE OF A SECOND ORDER SYSTEM





Step Response of a Second Order System

- **Settling time and final value are not affected by the zero location.**

- **Overshoot is greatly affected by the proximity of the zero to the origin.**

- **Knowledge of the zero locations for selected transfer functions may help designing better controllers**

Performance OF A SMIB System Equipped With PSS

- Comparison of generator terminal transients for:
  - ➔Different PSS input signals: PSS_{ω}, PSS_{PT}, $PSS_{\int P_{acel}}$
  - ➔$PSS_{\int P_{acel}}$ with and without ramp tracking filter

- Models and parameters of generator, AVR and PSS are those of the Xingó power plant (a 3000 MW hydro plant owned by CHESF, in Brazil)

PSS DERIVED FROM ROTOR SPEED OR TERMINAL POWER

- The two PSSs were tuned so that the electromechanical mode is the same in both cases

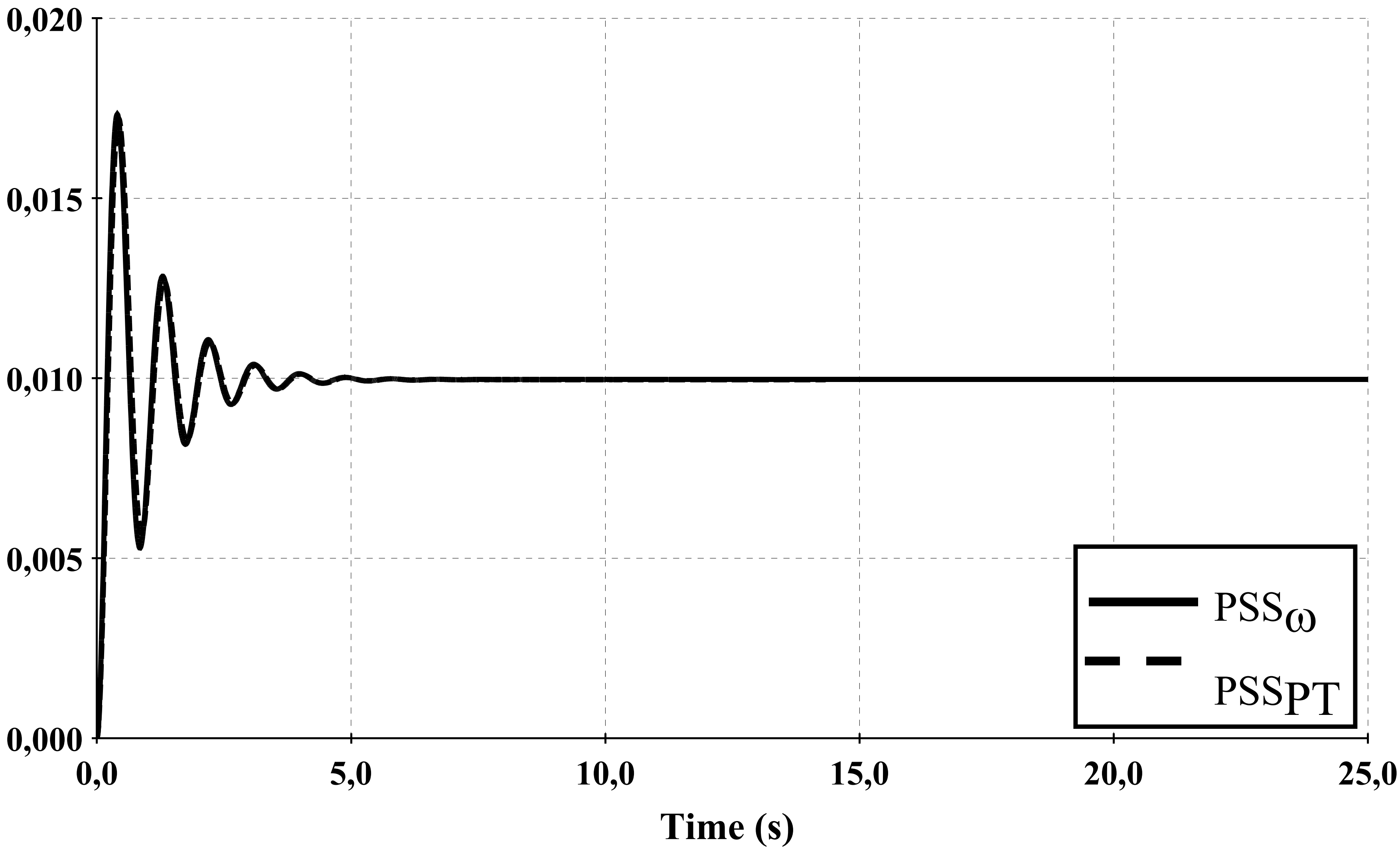
  ➔A fair comparison among PSSs may therefore be made

- The applied disturbance is a 1 % step change in P_{MEC}

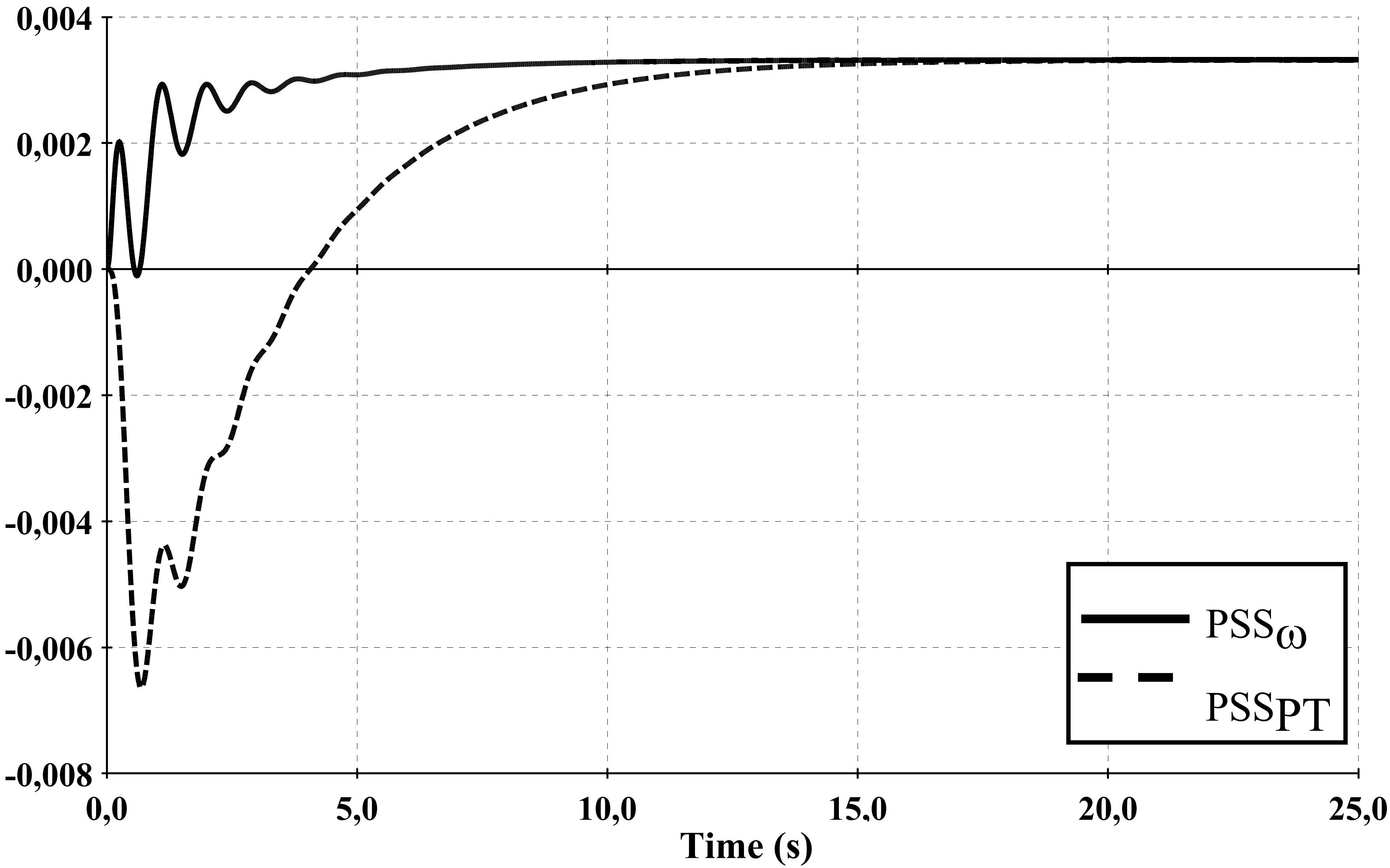
- The monitored system variables are generator terminal voltage, active and reactive power

- Pole-zero maps for $(\Delta P_T/\Delta P_{MEC})$ and $(\Delta Q_T/\Delta P_{MEC})$

ACTIVE POWER CHANGES FOLLOWING ΔPMEC IN SMIB

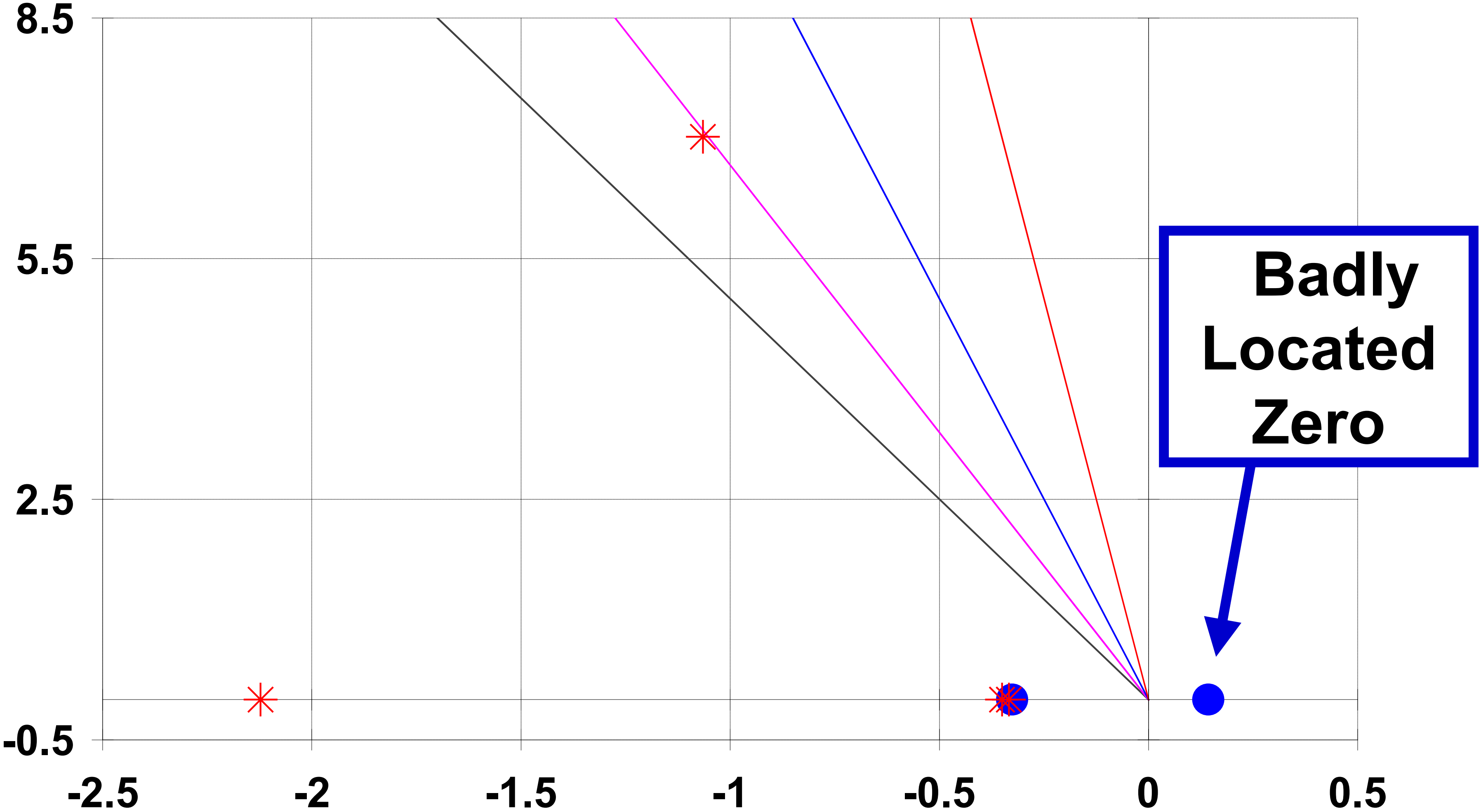


REACTIVE POWER CHANGES FOLLOWING ΔPMEC IN SMIB

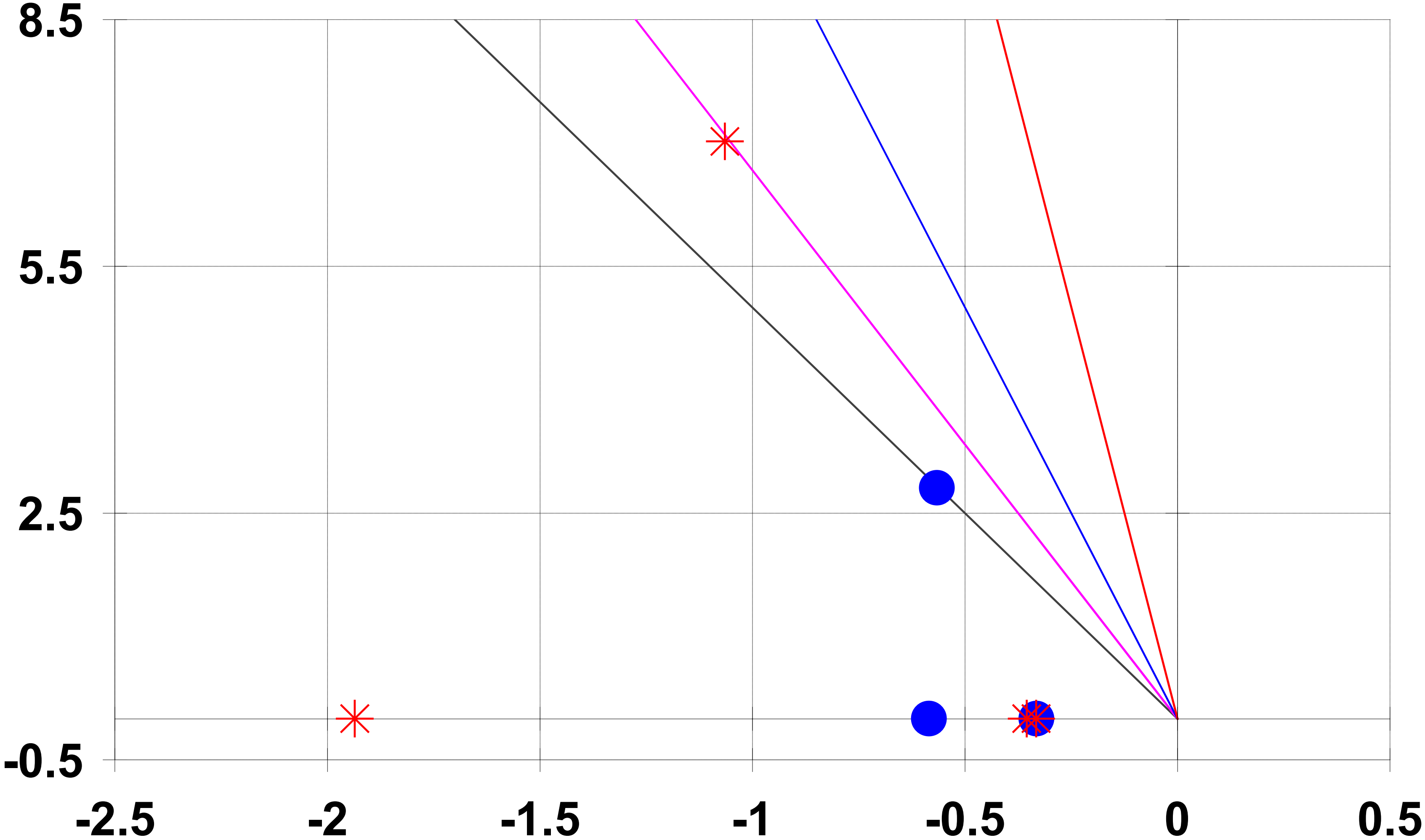


Pole-Zero Map for $\Delta Q_T / \Delta P_{MEC}$ (PSS$_{PT}$)

- Zero near the origin causes bigger overshoot in the step response



Pole-Zero Map for $\Delta Q_T / \Delta P_{mec}$ (PSSω)

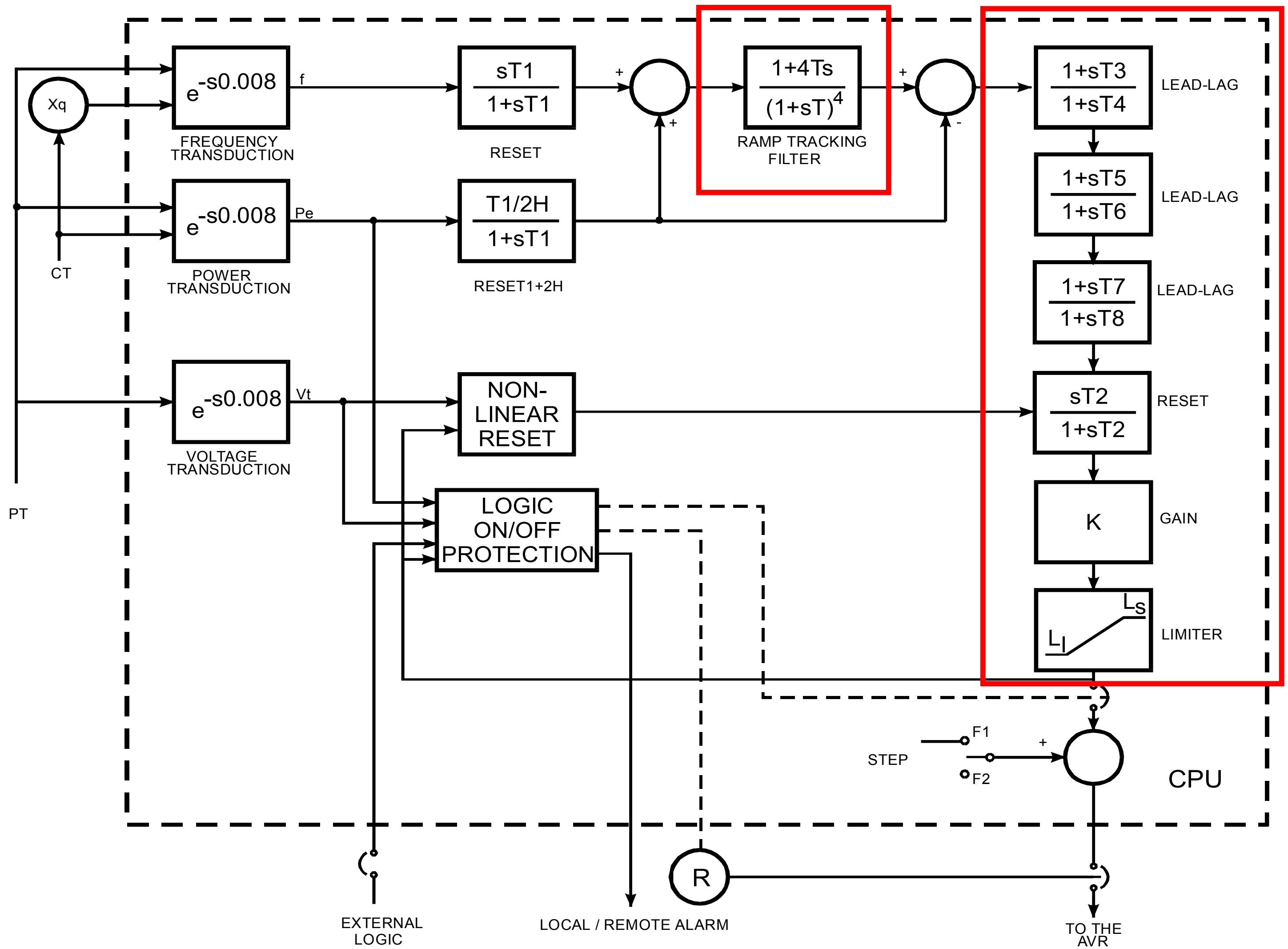


PSS DERIVED FROM INTEGRAL OF ACCELERATING POWER

- Preferred PSS structure in Brazil and abroad
  - ➔ Embedded fourth order ramp tracking filter
  - ➔ Effective input signal is close to filtered rotor speed
  - ➔ The PSSs installed at Xingó are of this type

PSS Derived from Integral of Accelerating Power

Power System Stabilizer – REIVAX PWX 500



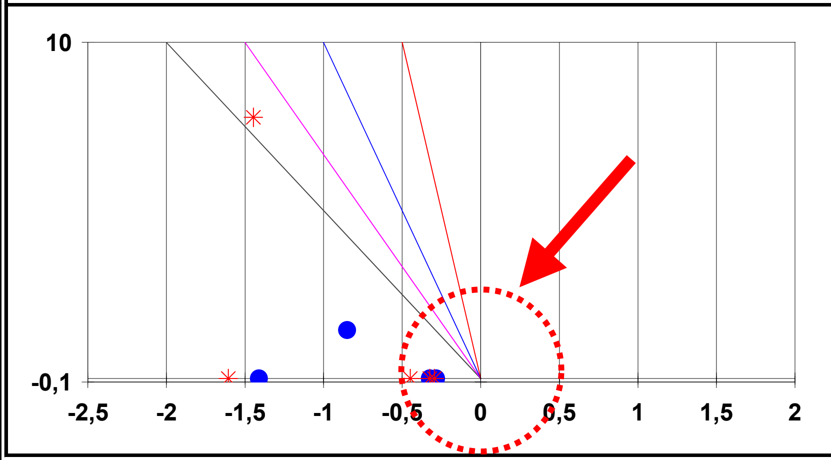
PSS DERIVED FROM INTEGRAL OF ACCELERATING POWER

- Analysis of the pole-zero map for $(\Delta Q_T/\Delta P_{MEC})$
- Time response to a 1 % step change in P_{MEC}
- Assessment of PSS performance
    - ➔ With or without fourth-order ramp tracking filter
    - ➔ Different filter configurations
        - Filter with ramp tracking (different time constants)
        - Filter without ramp tracking

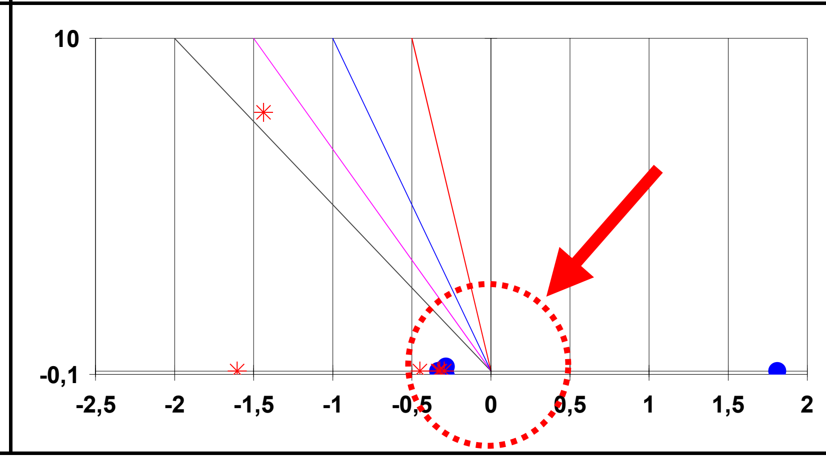
PSS Derived from Integral of Accelerating Power

Pole-Zero Map for ($\Delta Q_T/\Delta P_{MEC}$)

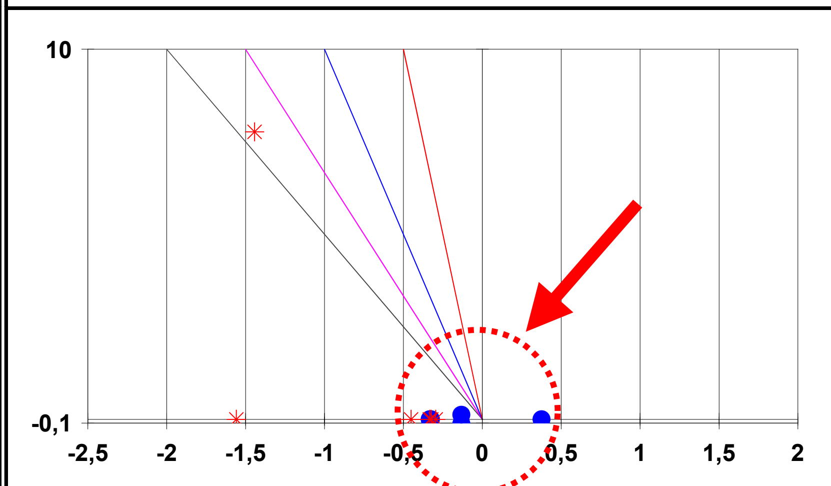
Without Filter



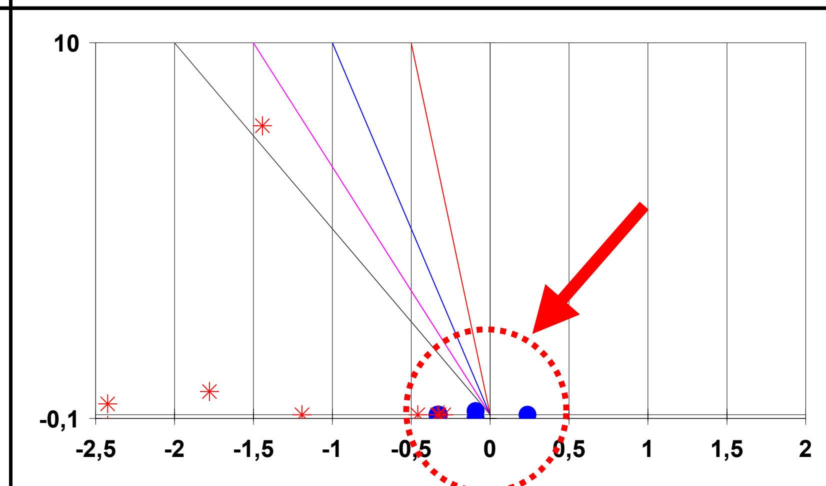
Filter with T=0.1s



Filter with T=0.3s

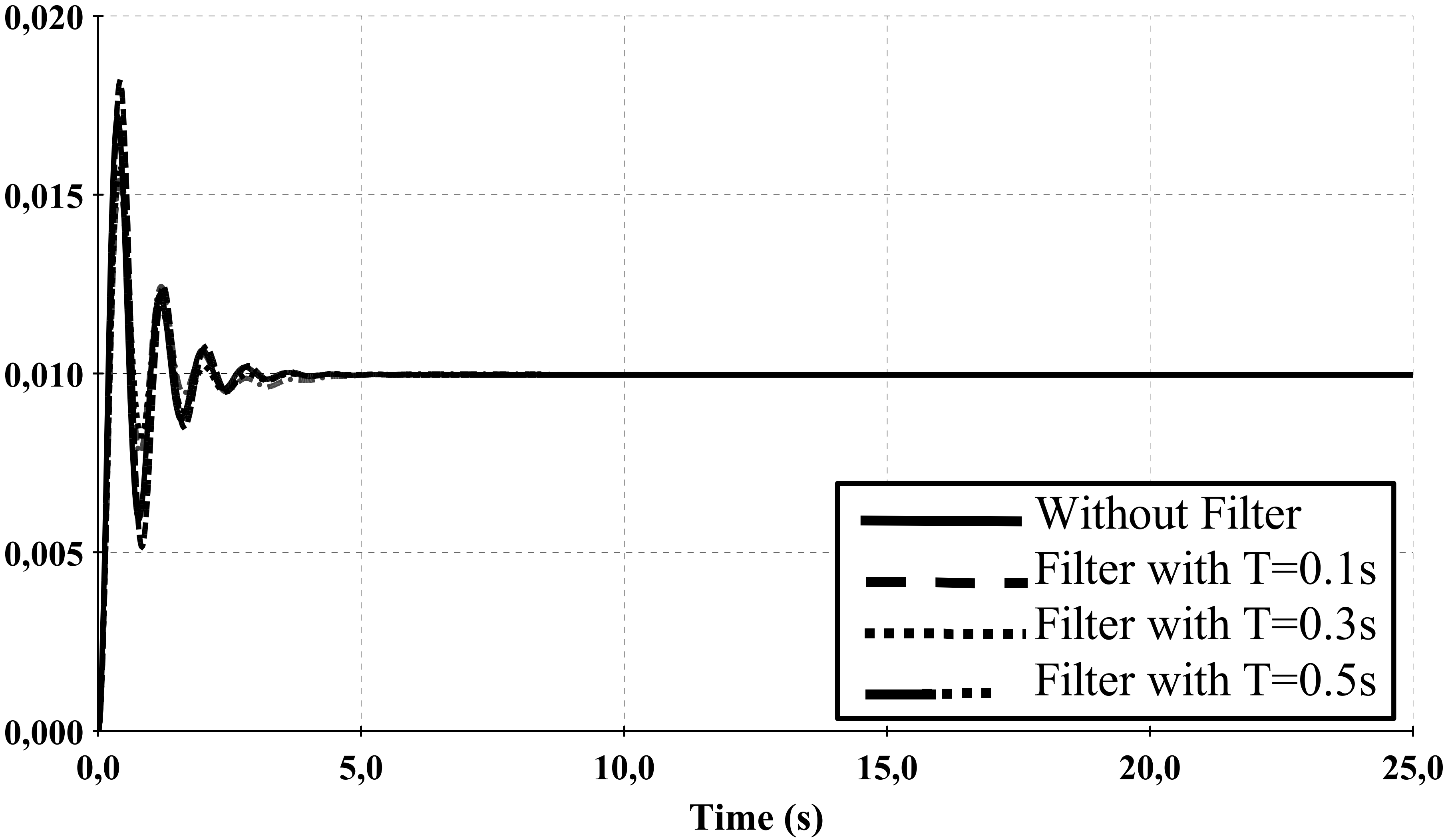


Filter with T=0.5s



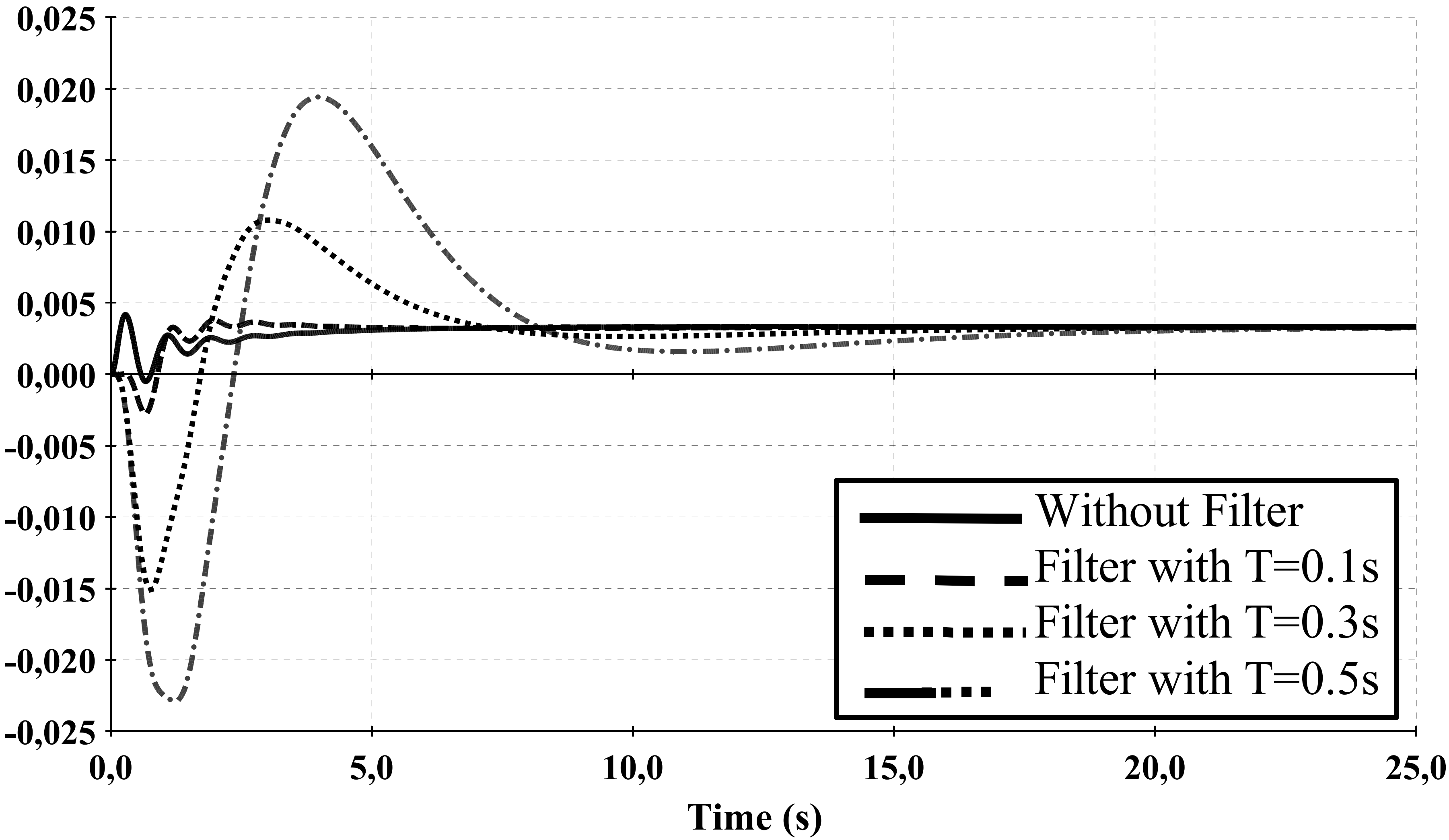
ACTIVE POWER CHANGES FOLLOWING ΔPMEC IN SMIB

➢ **PSS DERIVED FROM INTEGRAL OF ACCELERATING POWER**



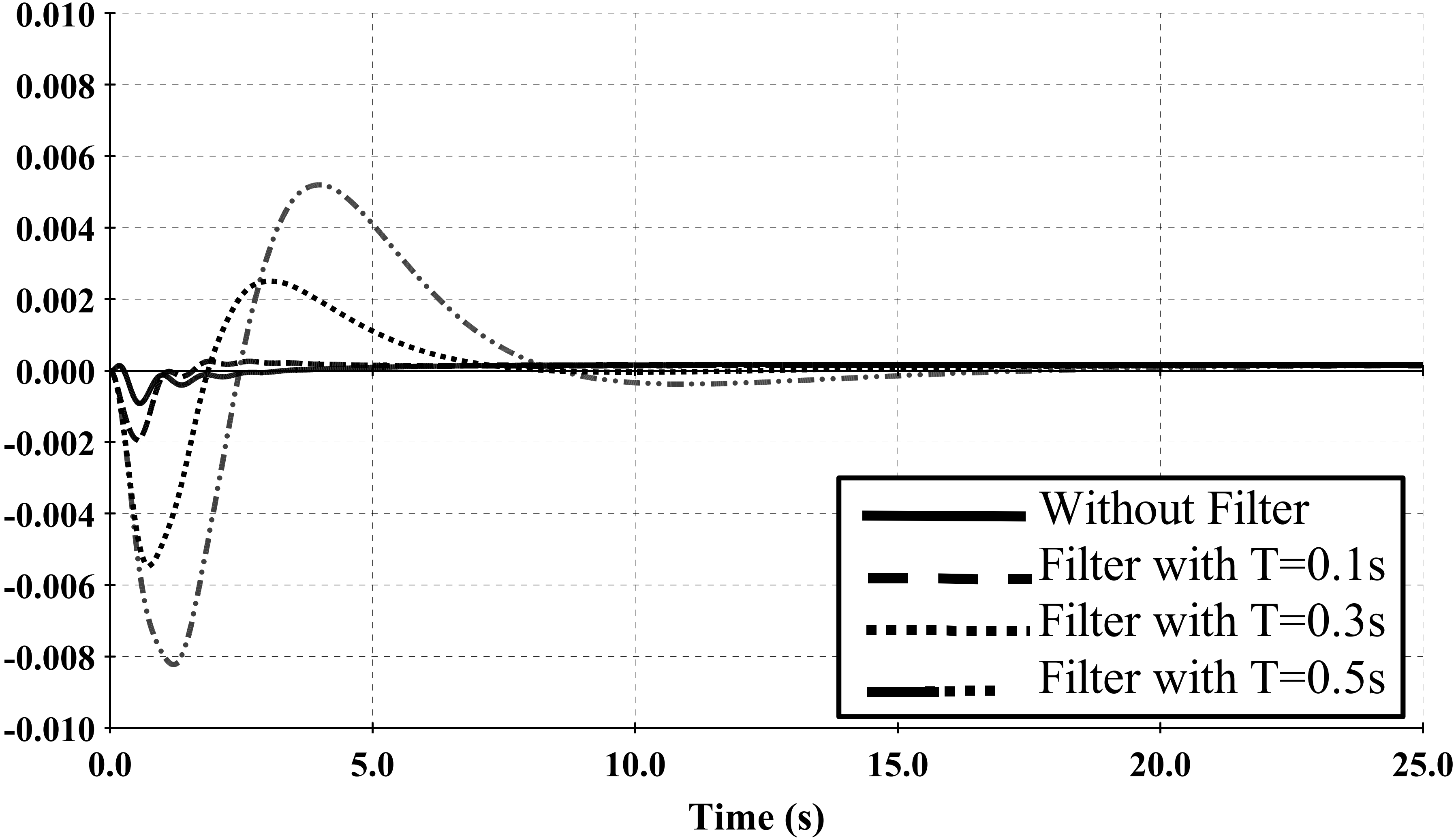
Reactive Power Changes Following ΔPmec in SMIB

➢ **PSS Derived from Integral of Accelerating Power**



Terminal Voltage Changes Following ΔPmec in SMIB

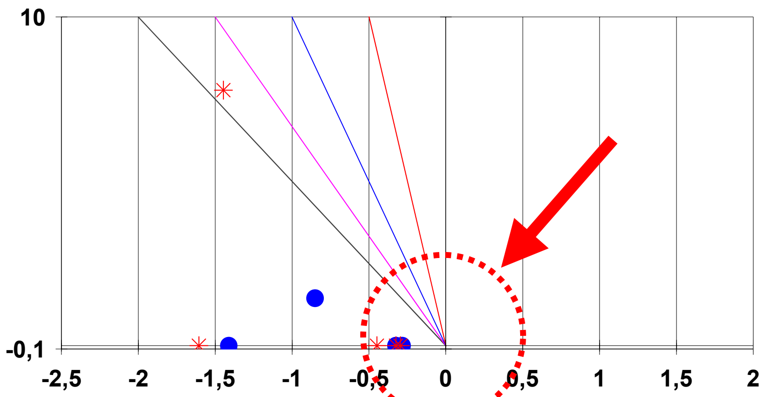
➢ **PSS Derived from Integral of Accelerating Power**



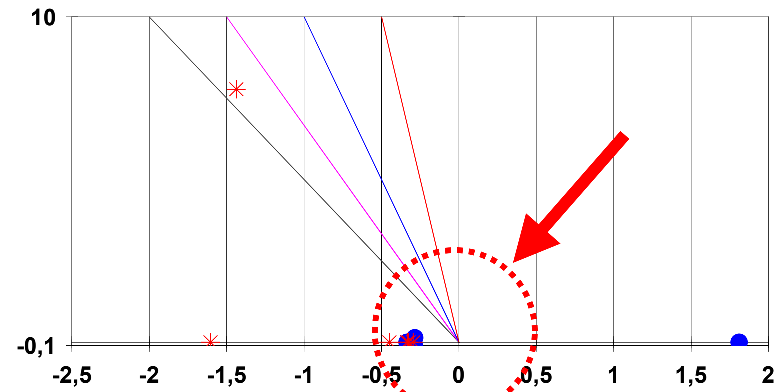
PSS Derived from Integral of Accelerating Power

Pole-Zero Map for ($\Delta Q_T / \Delta P_{MEC}$)

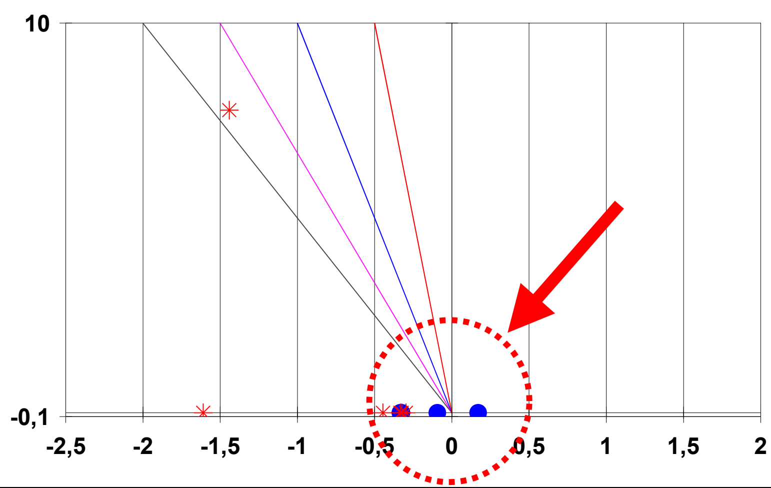
Without Filter



Filter with T=0.1s

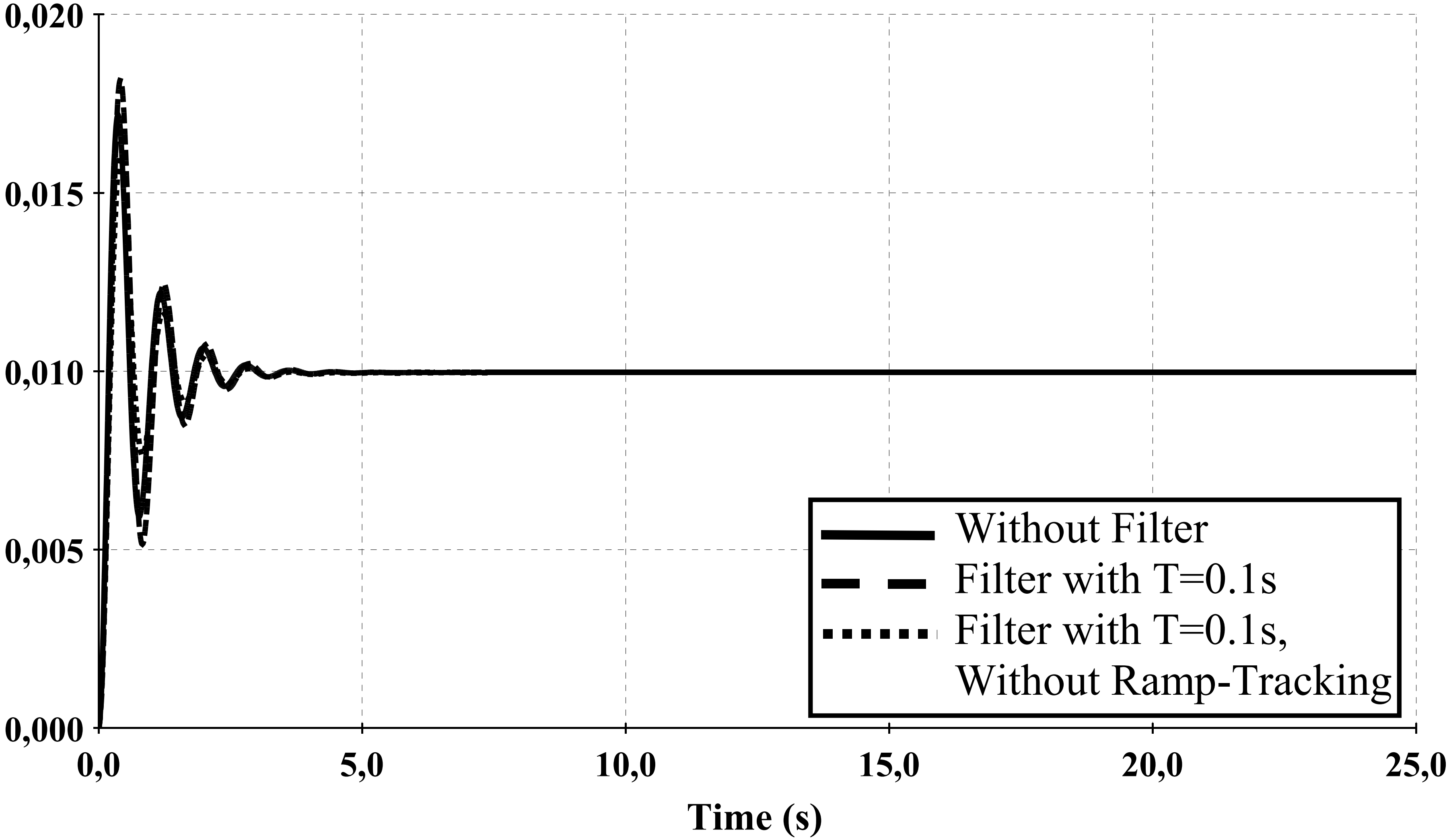


Filter with T=0.1s, without Ramp Tracking



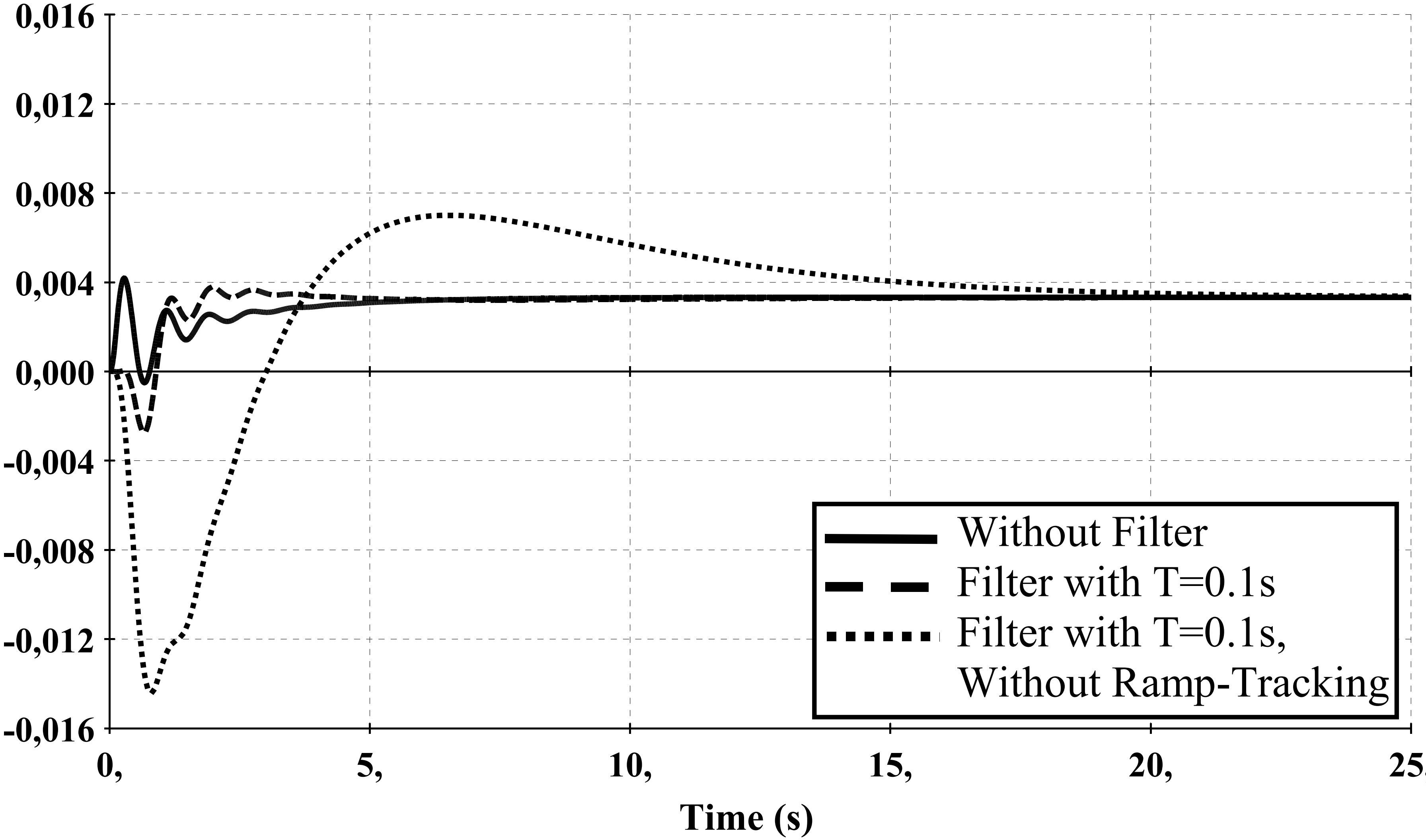
ACTIVE POWER CHANGES FOLLOWING ΔPMEC IN SMIB

➢PSS DERIVED FROM INTEGRAL OF ACCELERATING POWER



REACTIVE POWER CHANGES FOLLOWING ΔPMEC IN SMIB

➢PSS DERIVED FROM INTEGRAL OF ACCELERATING POWER



CONCLUSIONS

- TF zeros proved to be a valuable in the study of adverse transients on terminal voltage and reactive power

- Different PSSs compared for a 1 % step change in P_{MEC}

  - ➔Active power response ⇒ identical behavior

  - ➔Voltage and reactive power response ⇒ very different transient response, showing large overshoots in some cases

- The studies confirmed the practical benefits of using the fourth-order ramp tracking filter in PSSs derived from integral of accelerating power

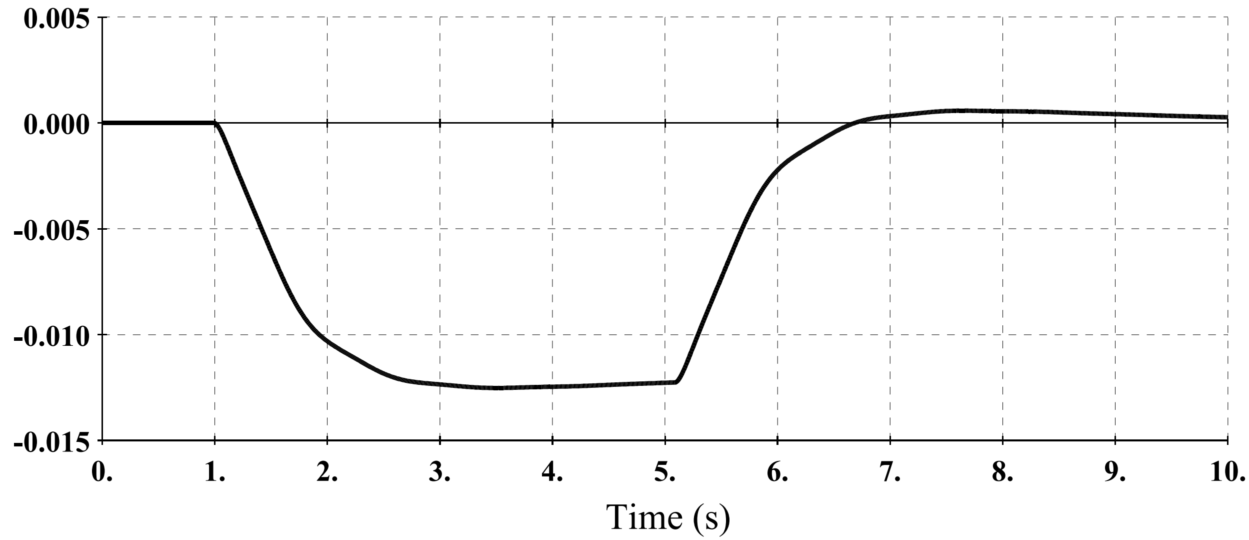
APPENDIX: COMPARING FIELD TESTS WITH SIMULATIONS

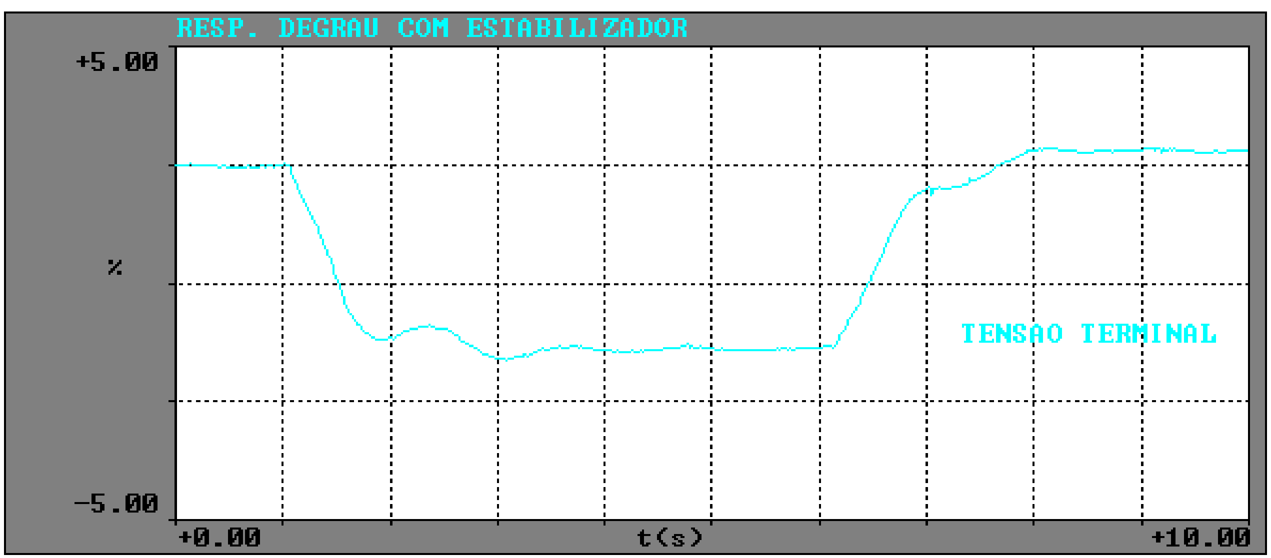
- **Tests carried out during the commissioning of the PSSs at the Xingó power plant**

- **Negative step at voltage reference during 4 s**

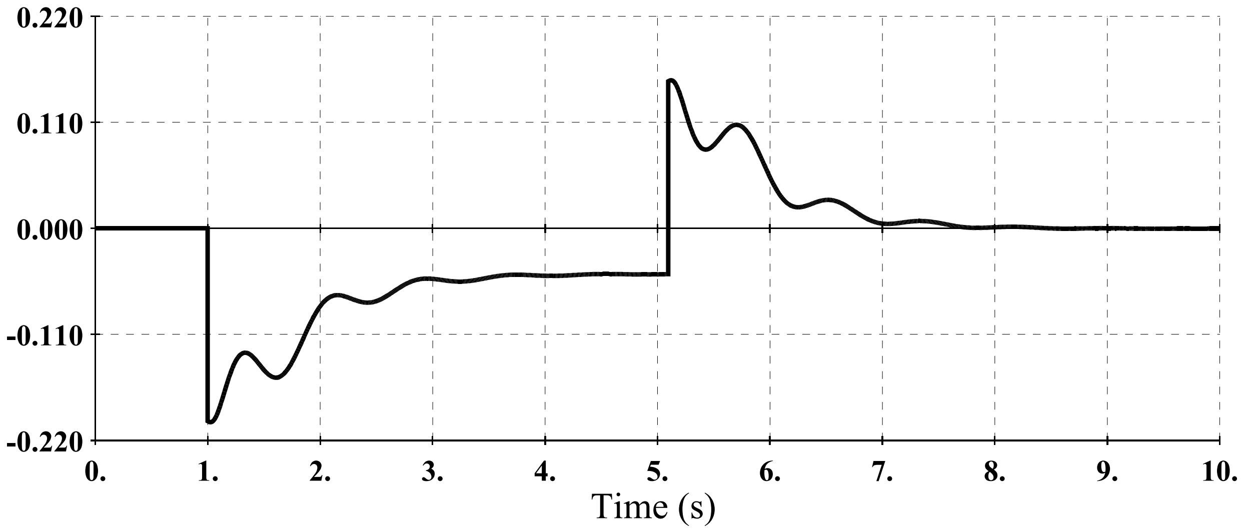
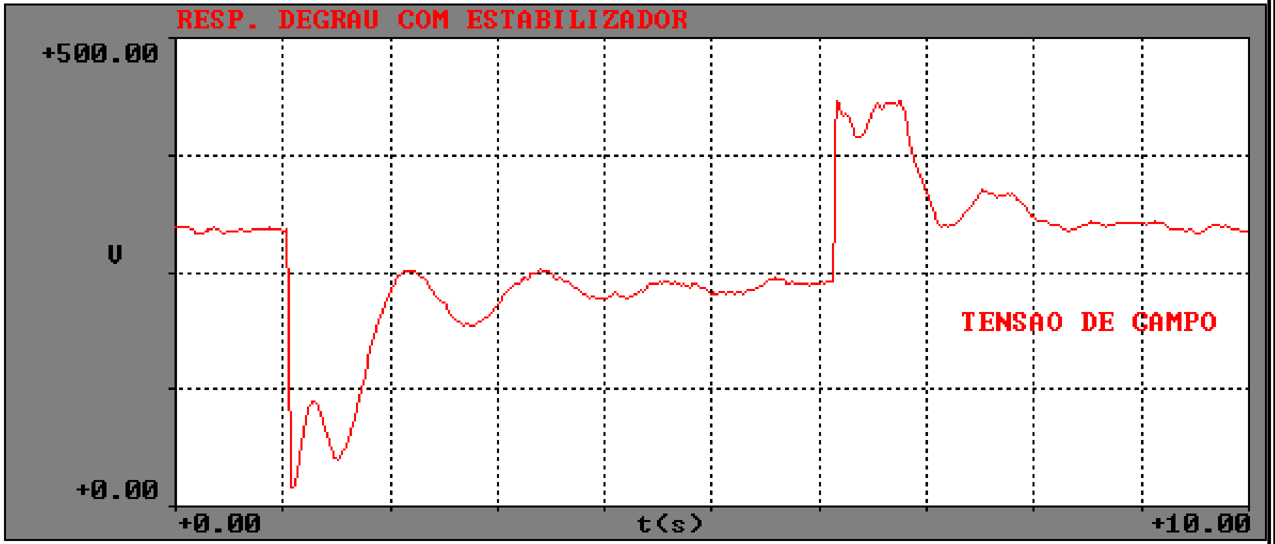
APPENDIX: COMPARING FIELD TESTS WITH SIMULATIONS

Terminal Voltage



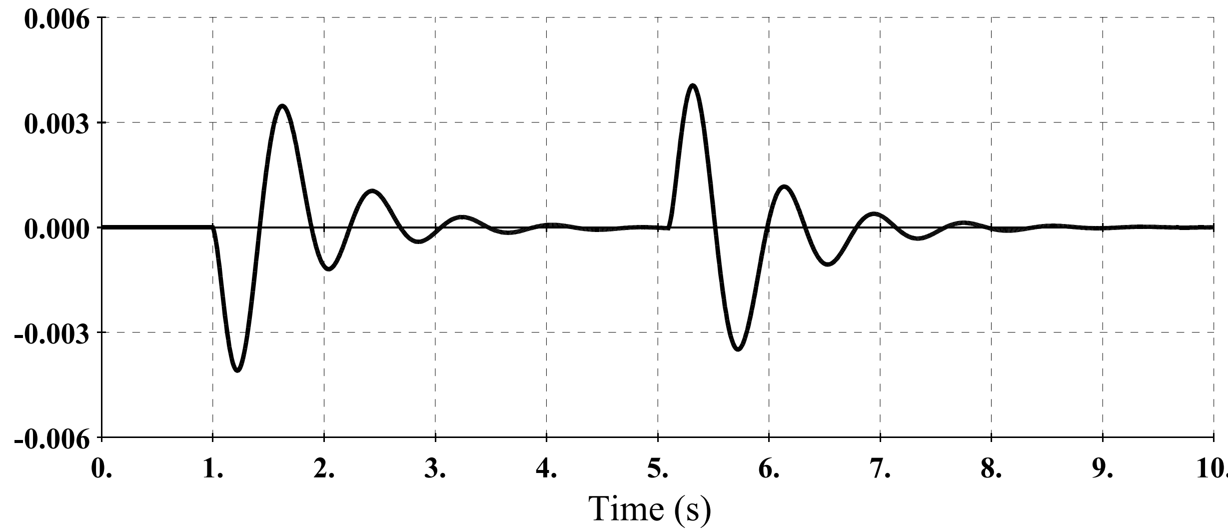


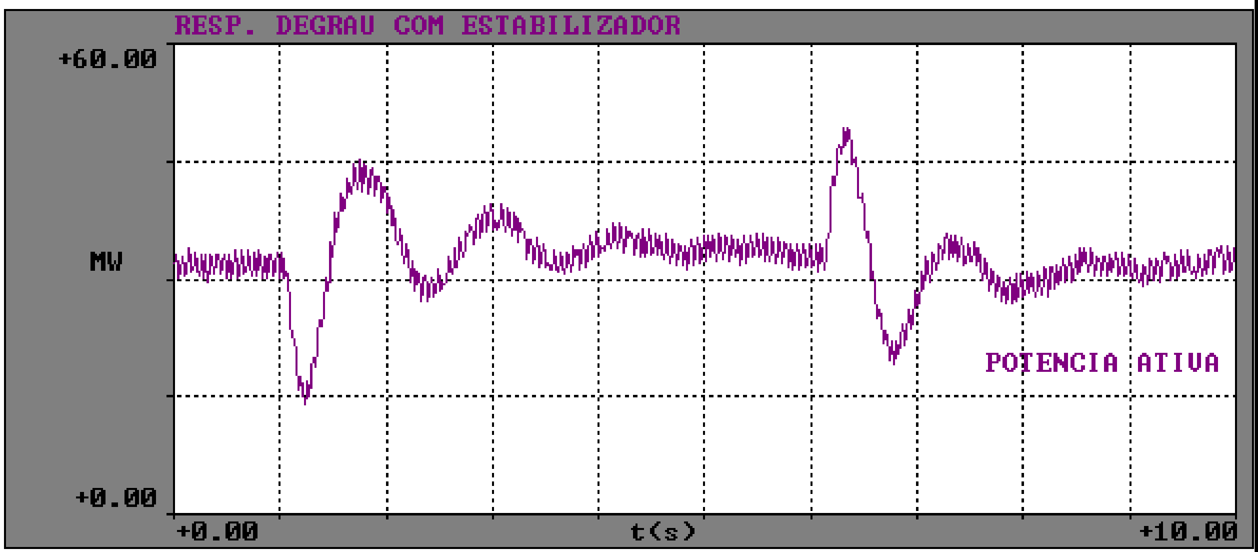
APPENDIX: COMPARING FIELD TESTS WITH SIMULATIONS

Field Voltage	

APPENDIX: COMPARING FIELD TESTS WITH SIMULATIONS

Terminal Active Power





APPENDIX: COMPARING FIELD TESTS WITH SIMULATIONS

Terminal Reactive Power