University of Idaho
College of Engineering

VIRTUAL SYNCHRONOUS GENERATOR CONTROLLER PERFORMANCE AND EVALUATION

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- Virtual Synchronous Generator Controller Structure
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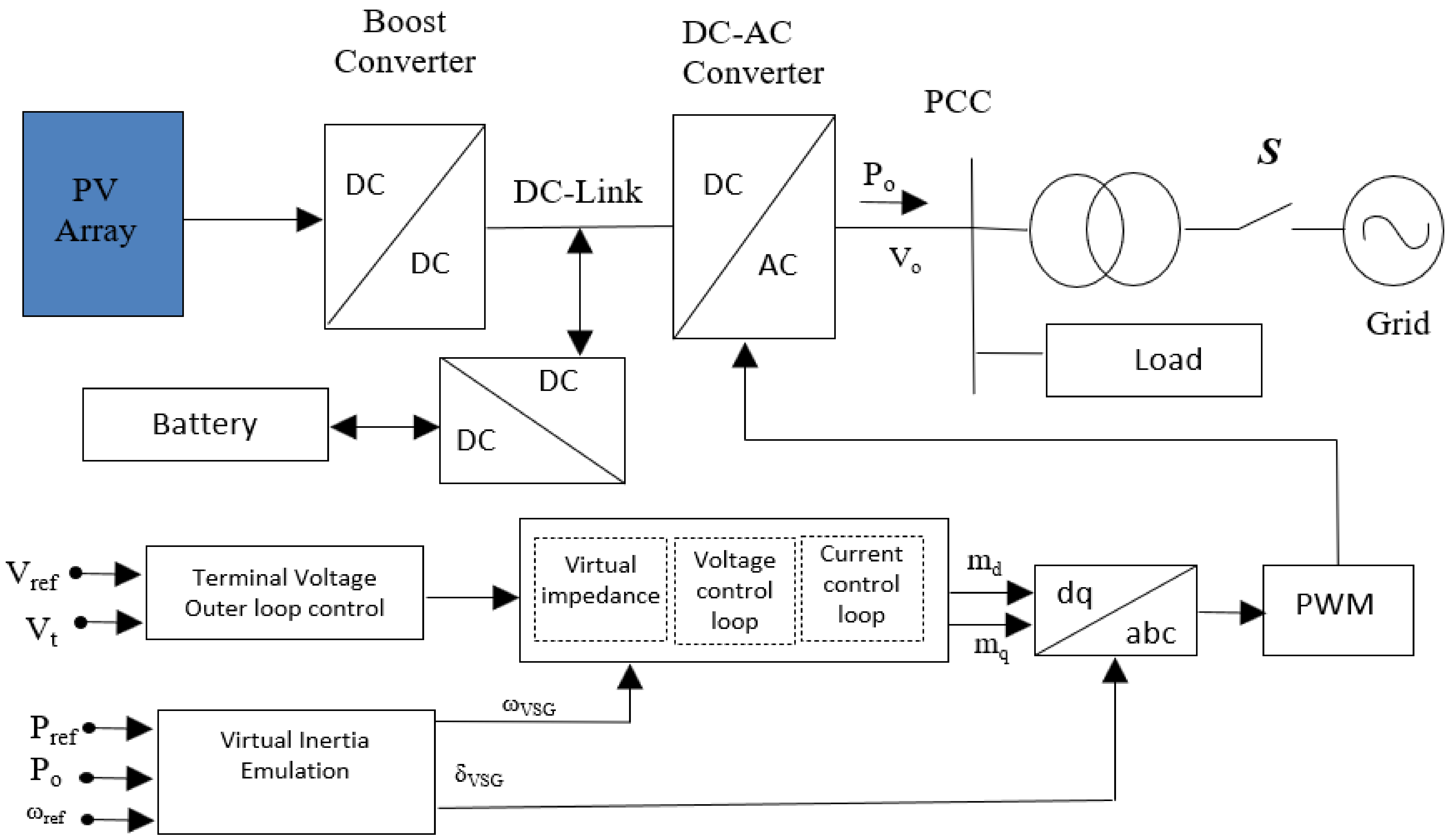
Introduction

- Effect of inertia and damping of SGs on system's stability.
- Effect of inverter-based RERs on system inertia.

This paper would describe:

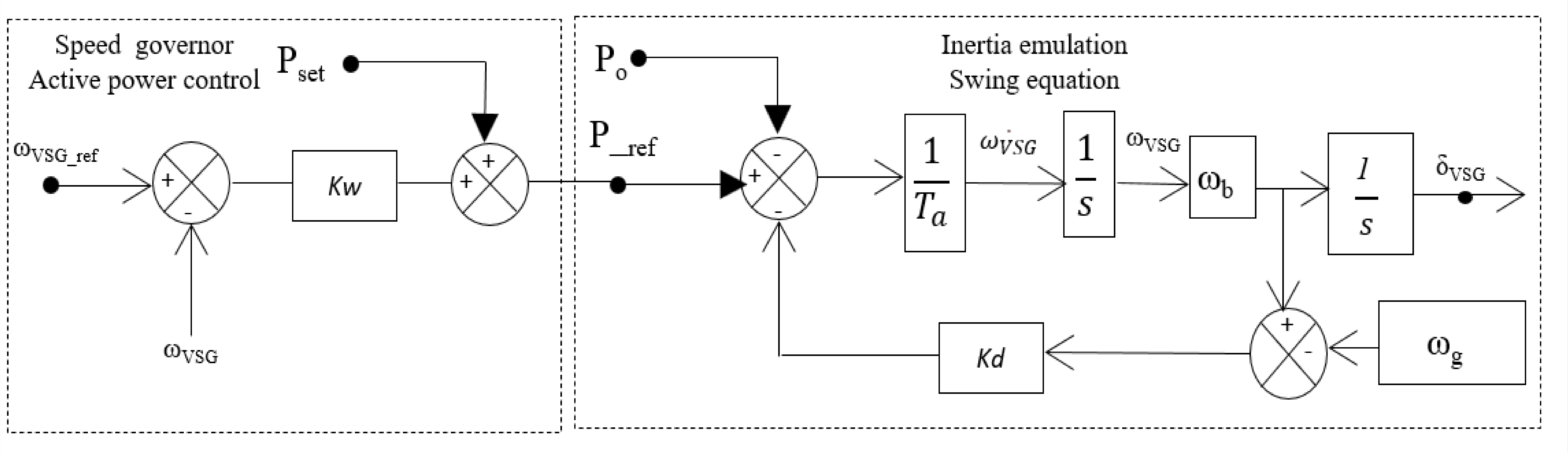
- VSG controller structure
- ESS
- Simulation results for different scenario



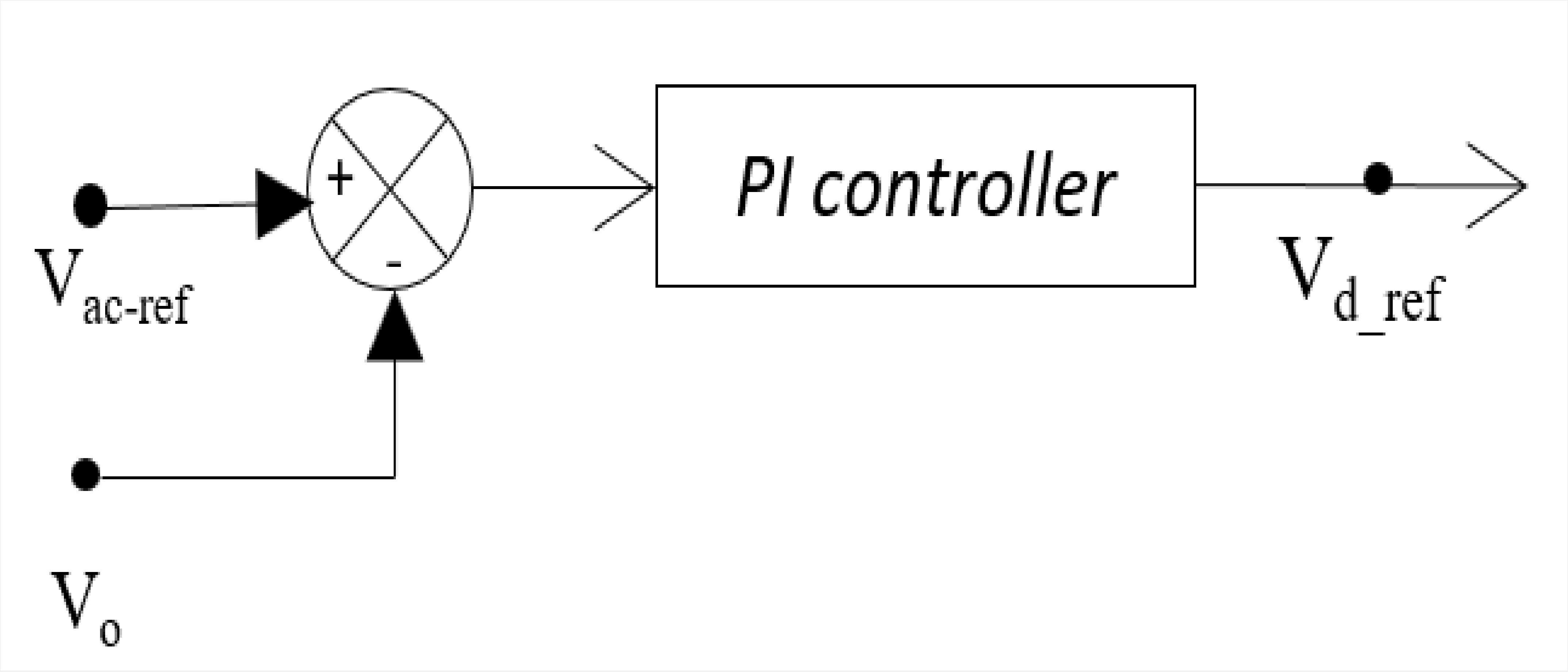
General layout of the proposed system

DC-AC converter controller

Outer loops:
Virtual inertia emulation



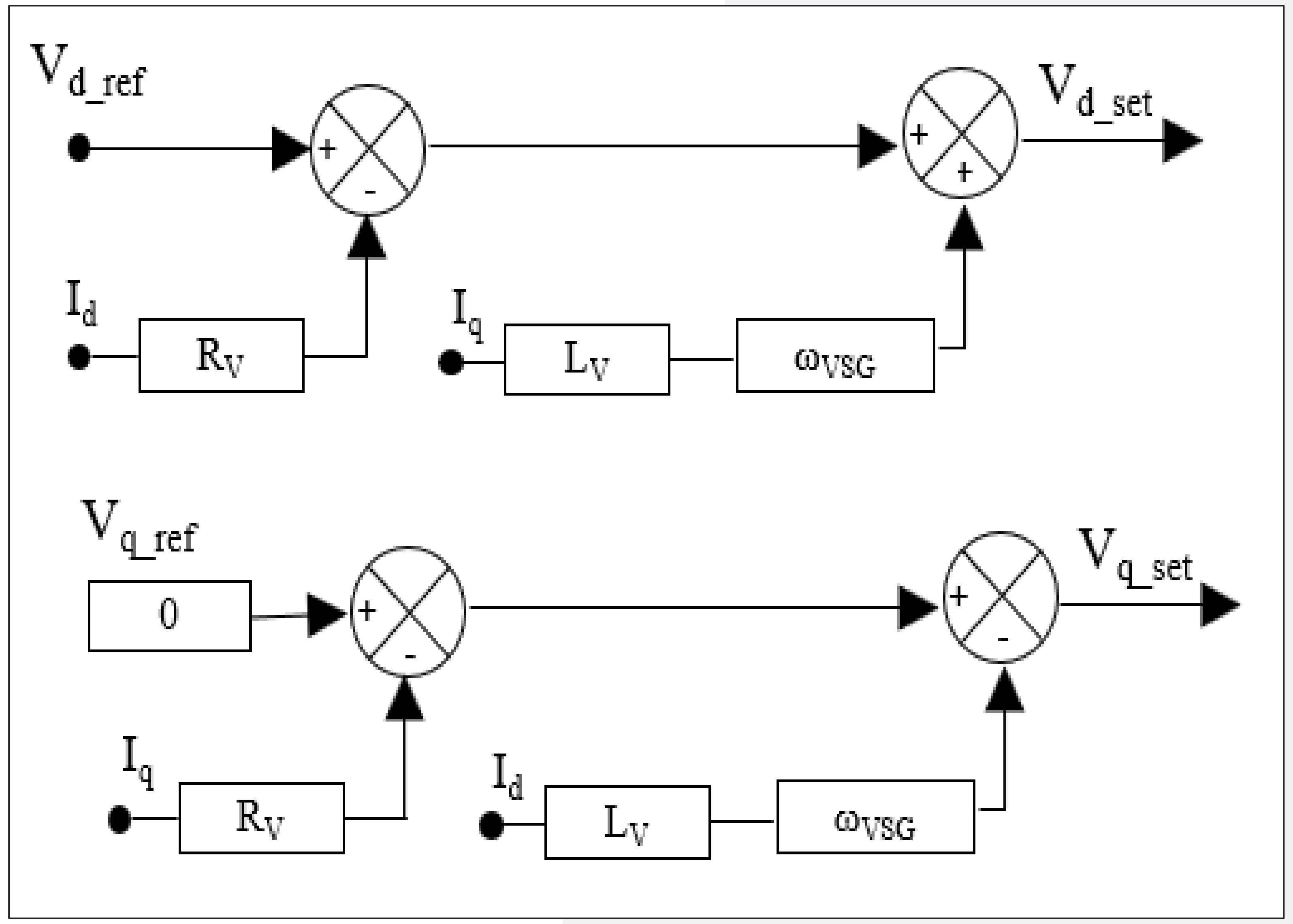
Ta ….Inertia time constant
Kd ….Damping constant
Kw….Frequency droop constant



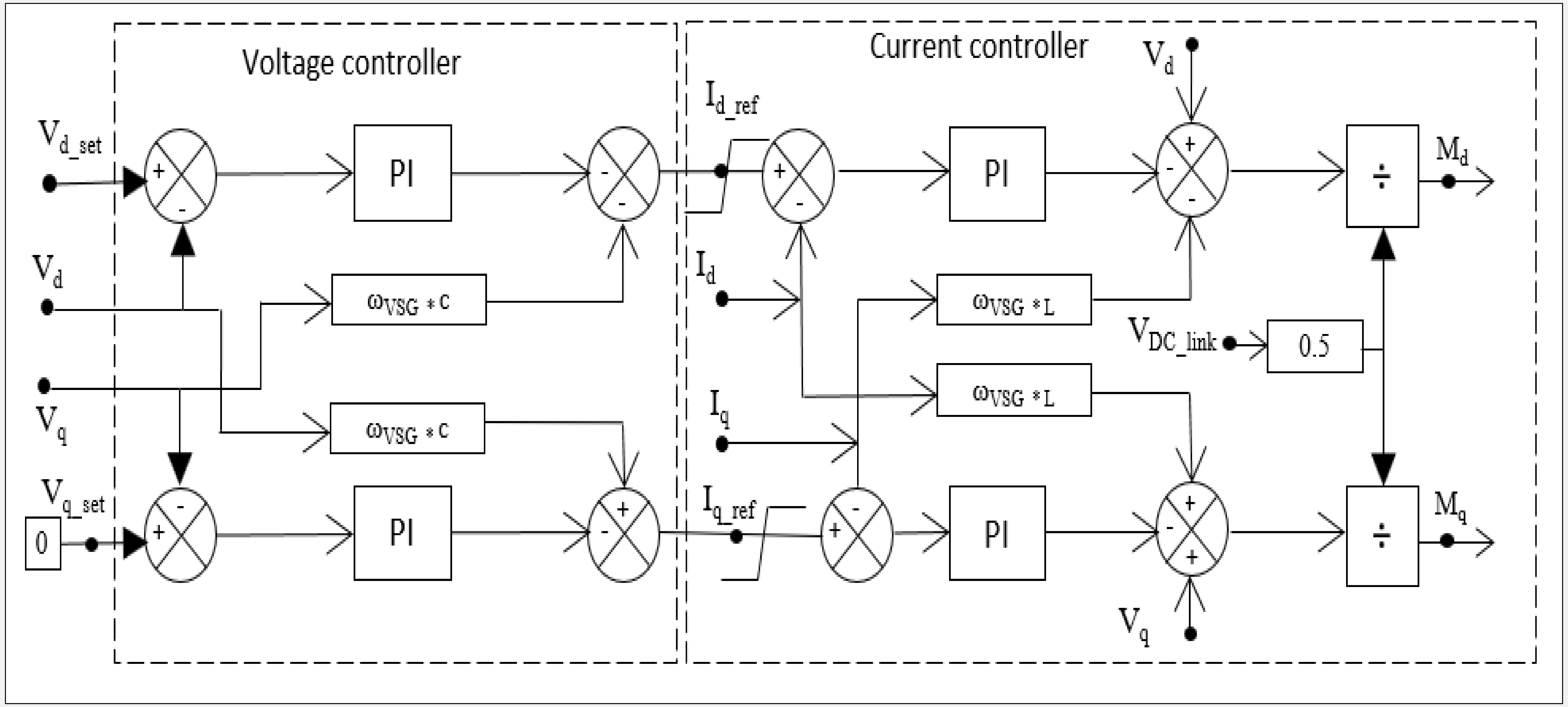
Outer loop:
Terminal voltage Controller

DC-AC converter controller

Inner loops



Virtual impedance



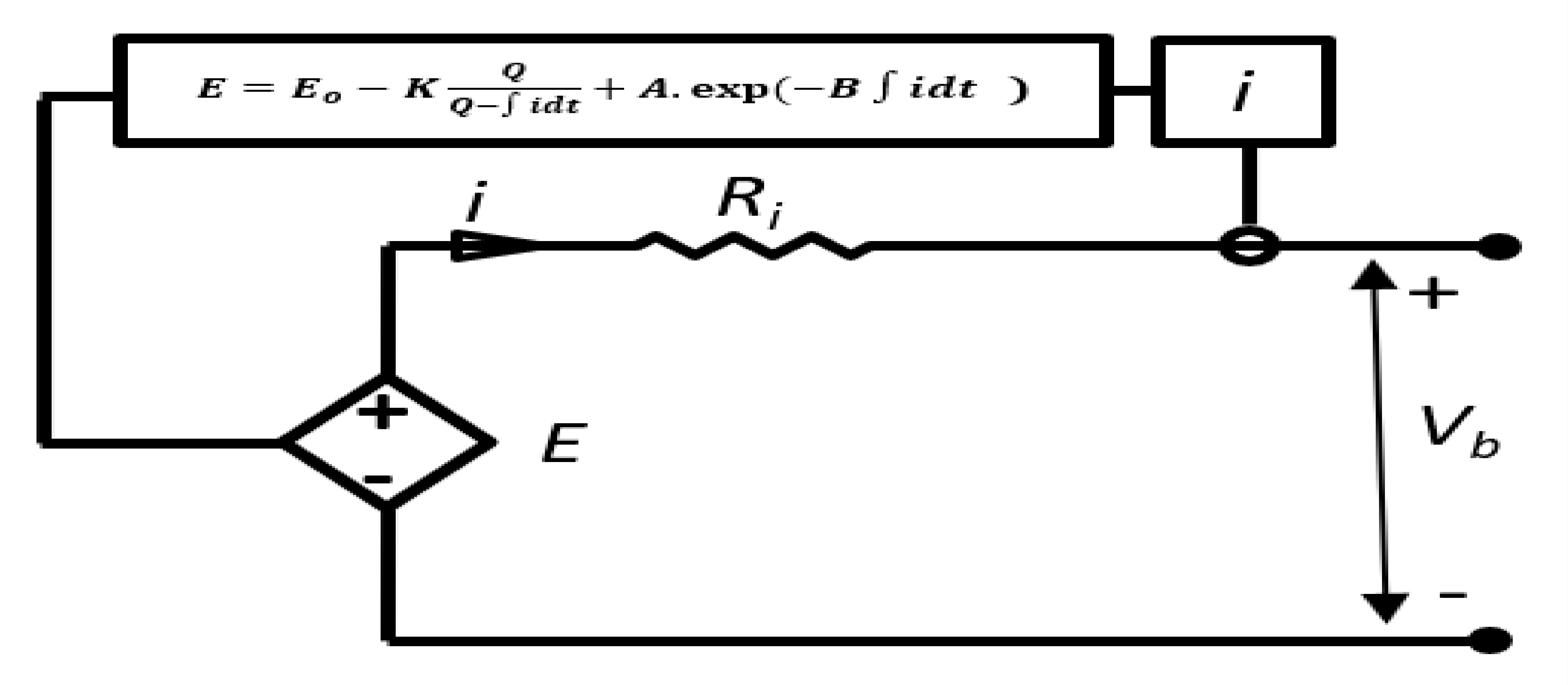
Cascaded voltage and current control loops

Battery storage system and dc-dc converter

The equivalent electric circuit model is based on a non-linear equation and the battery is modeled using a controlled voltage source connected with a series resistance.

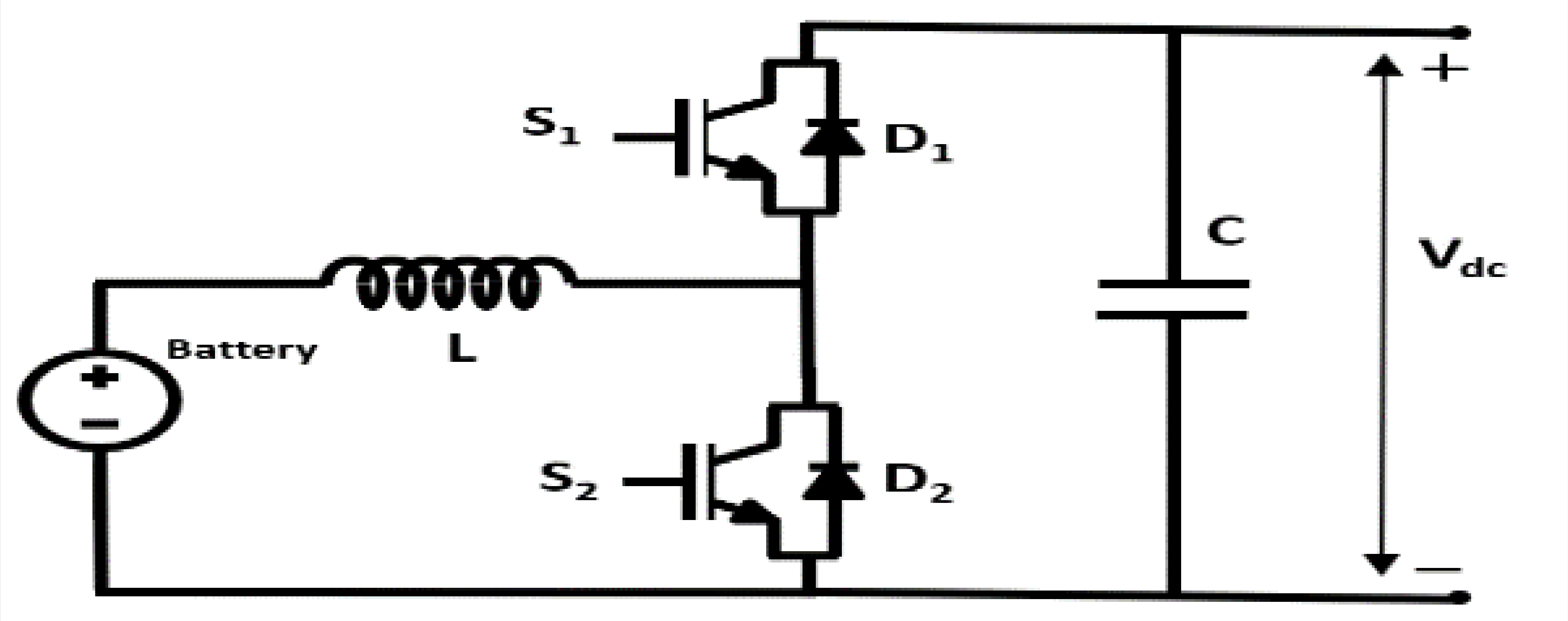
$$E = E_0 - K\left(\frac{Q}{Q - it}\right) + A * e^{-B \int idt}$$

$$V_b = E - R_i * i$$



Battery equivalent electric circuit model

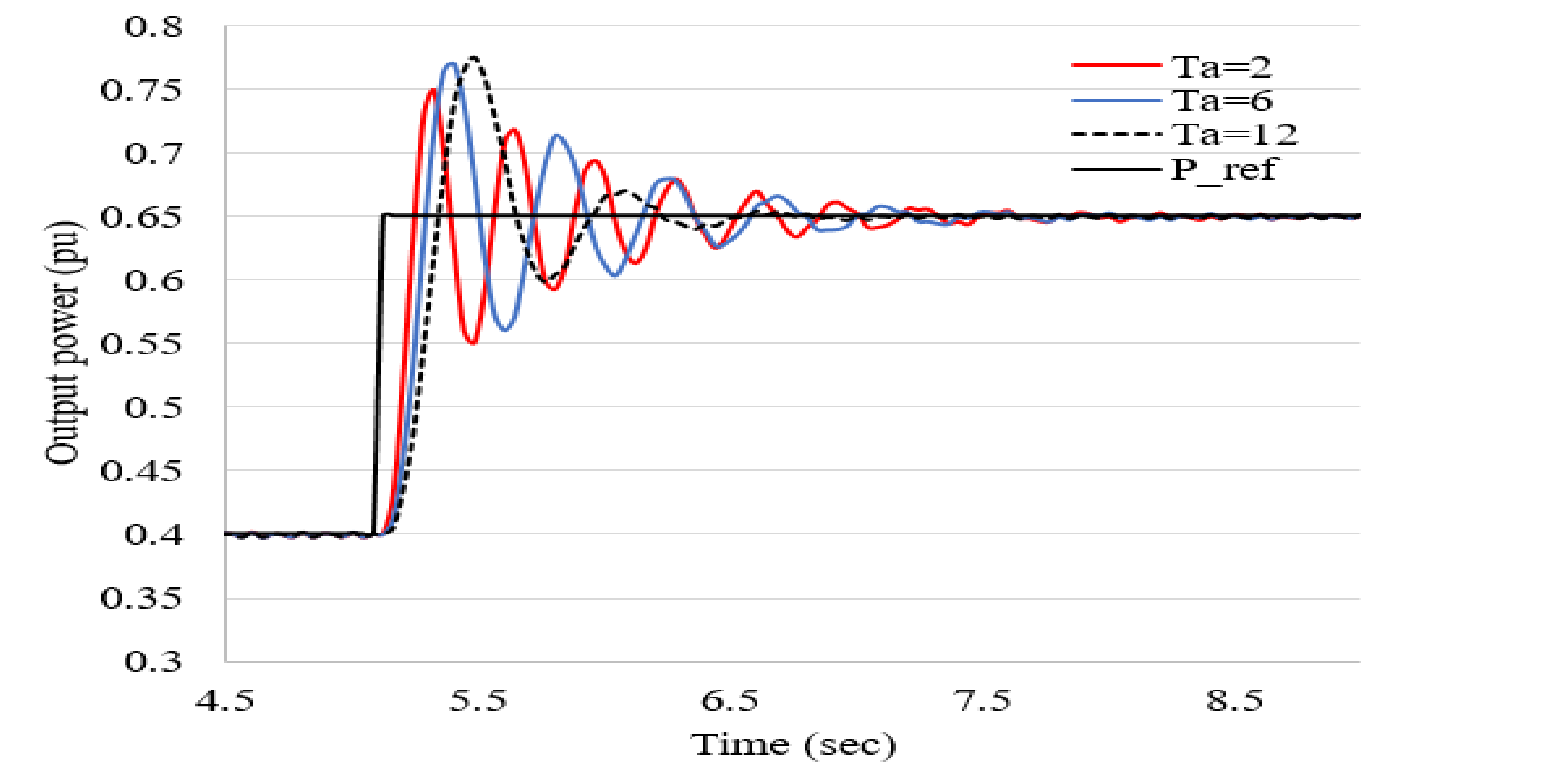
Battery Buck–Boost Converter controller



Battery Buck–Boost converter controller

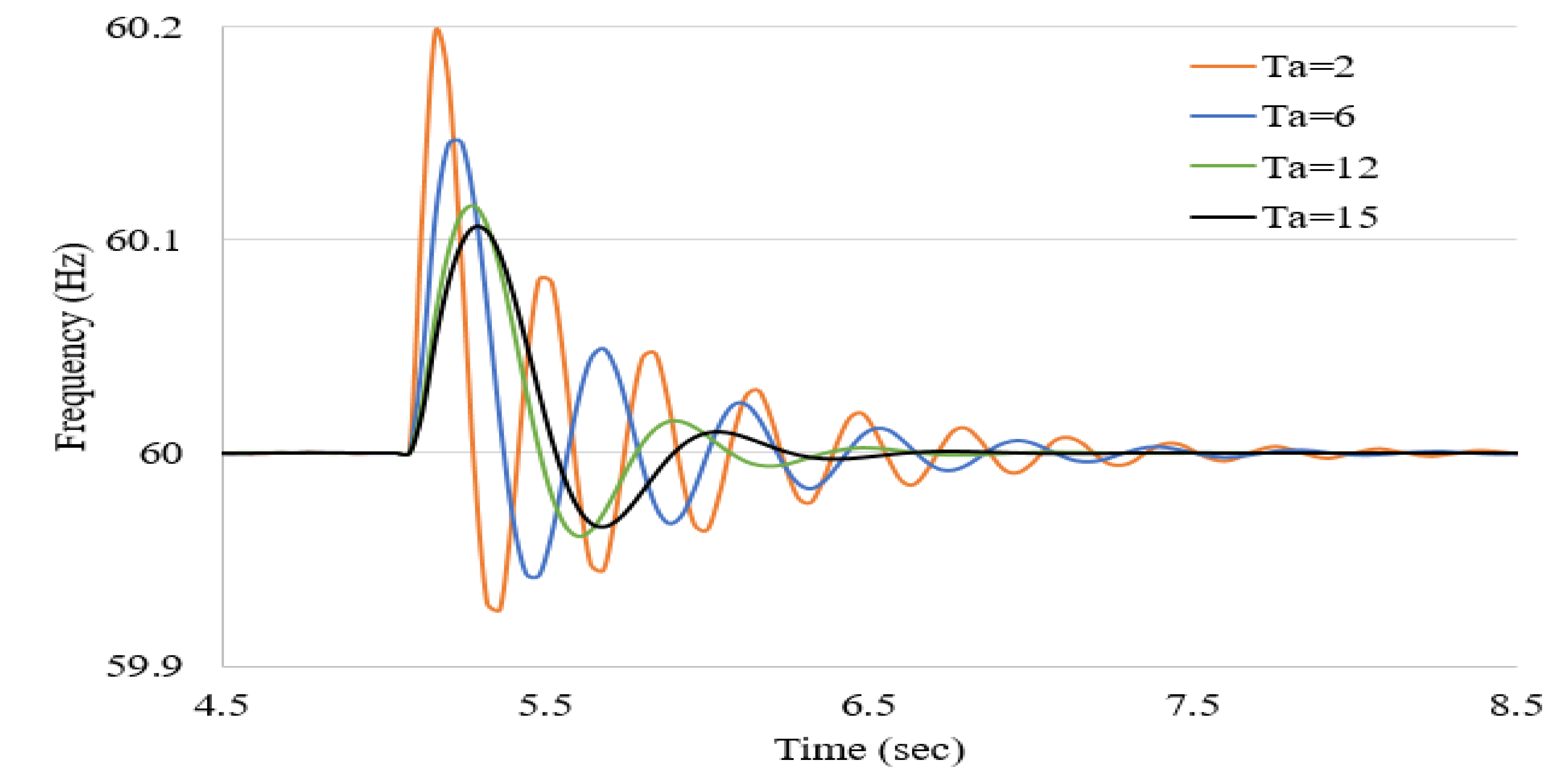
Simulation results:

step power setpoint increase at different inertia time constant



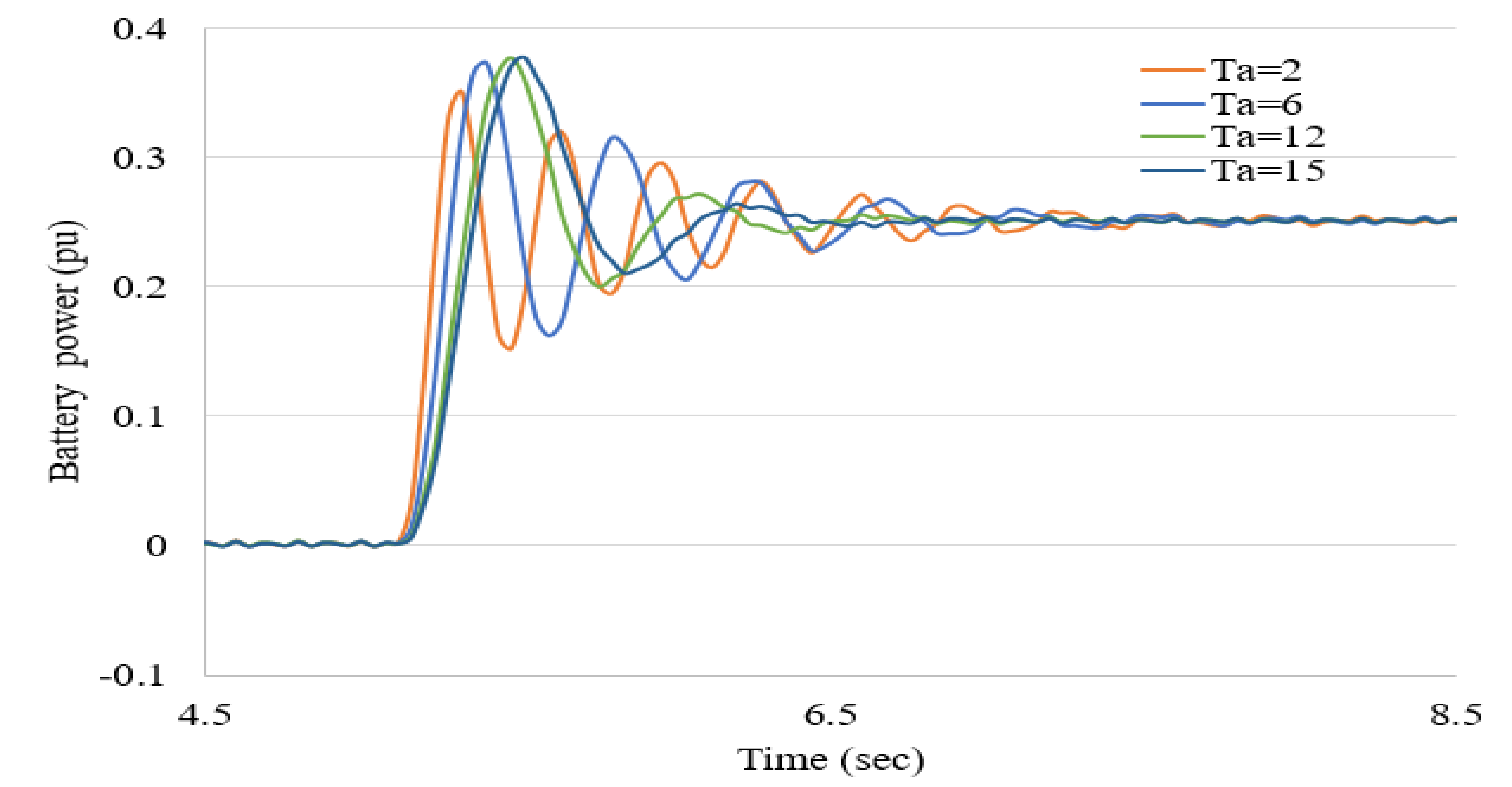
VSG converter active power variation at different inertia time constants (Kd=0.16)

Simulation results: step power setpoint increase



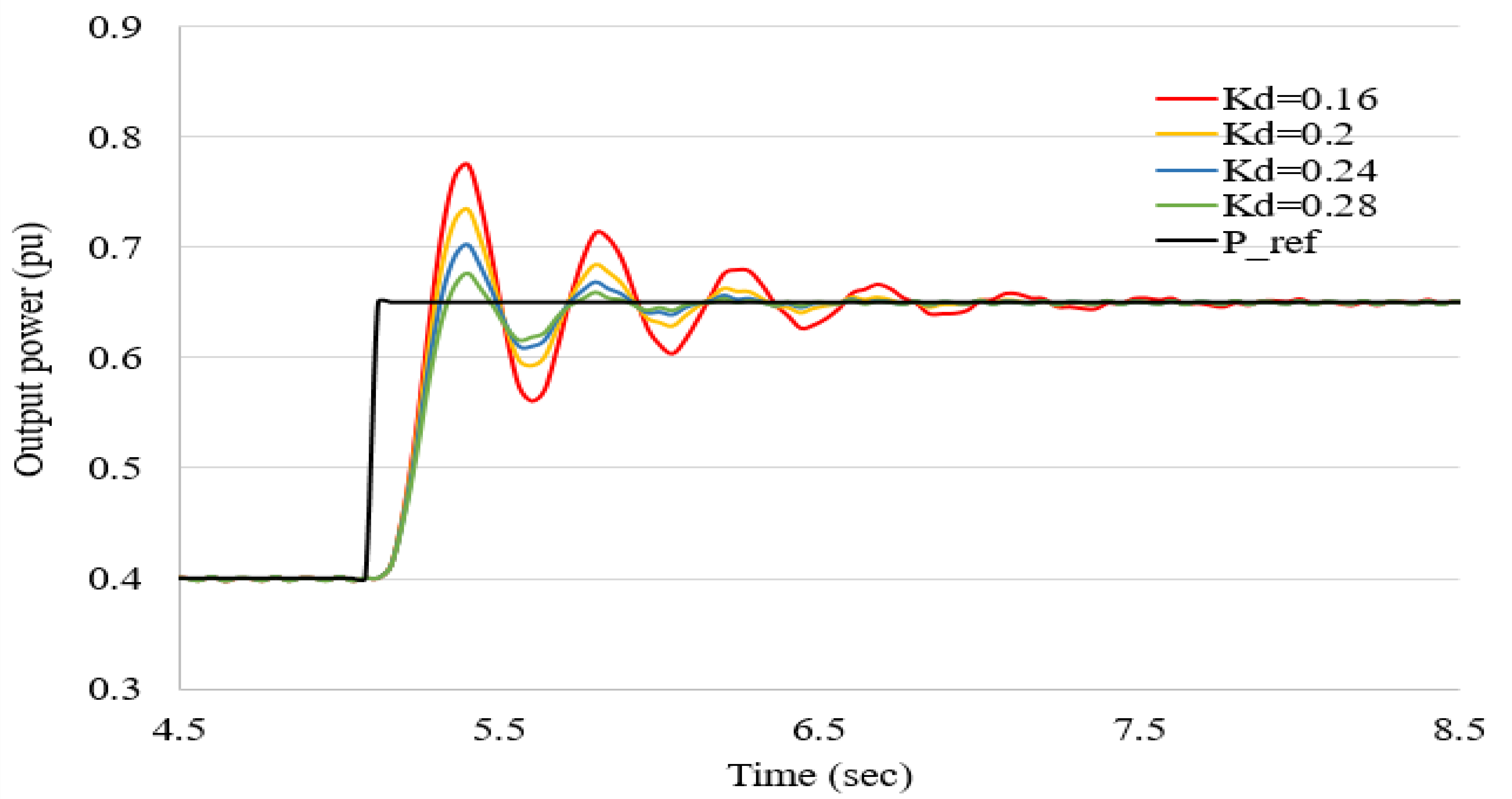
Frequency profile at different inertia time constants (Kd=0.16)

Simulation results: step power setpoint increase



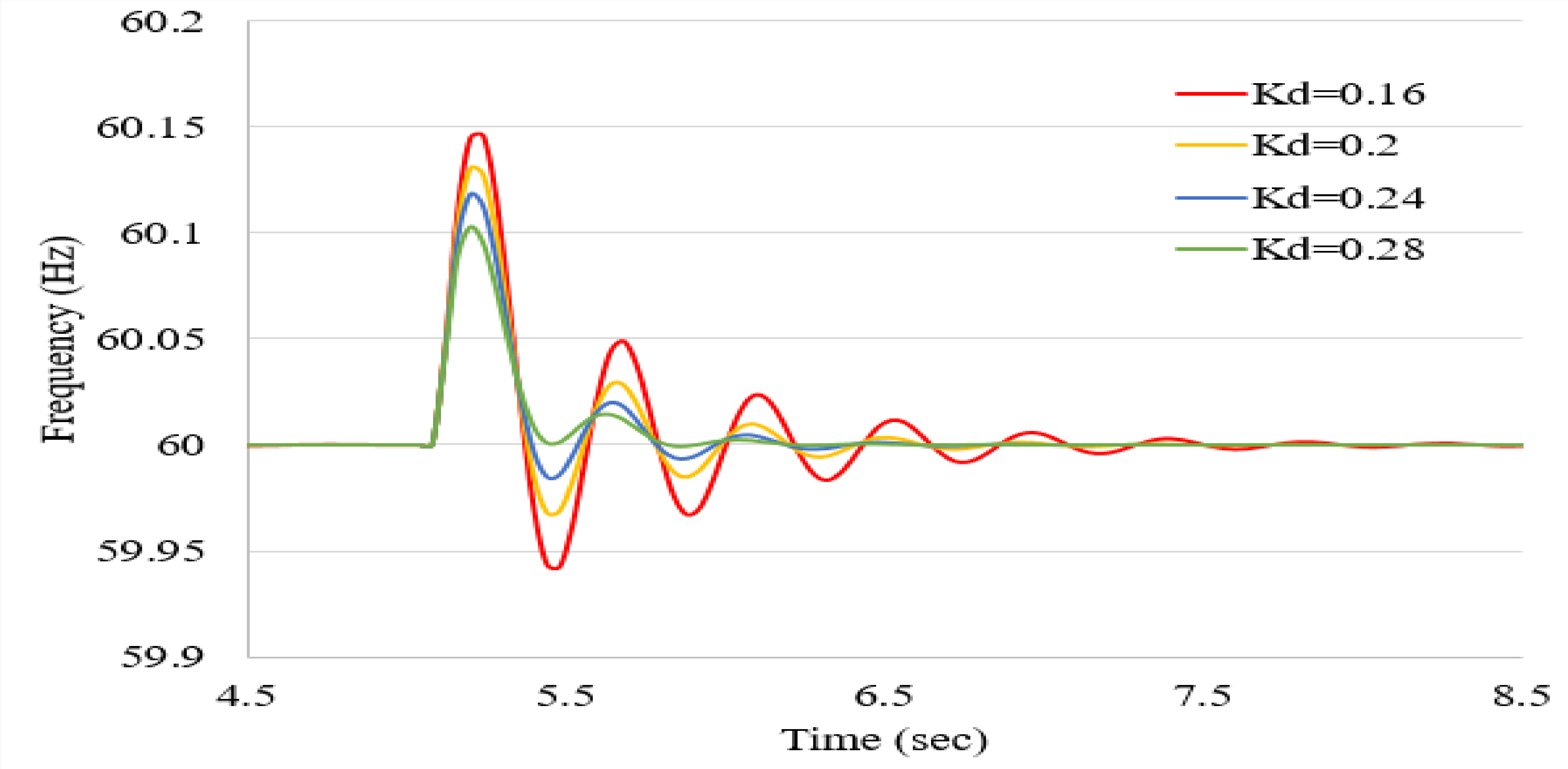
Battery power at different inertia time constants (Kd=0.16)

Simulation results: step power setpoint increase



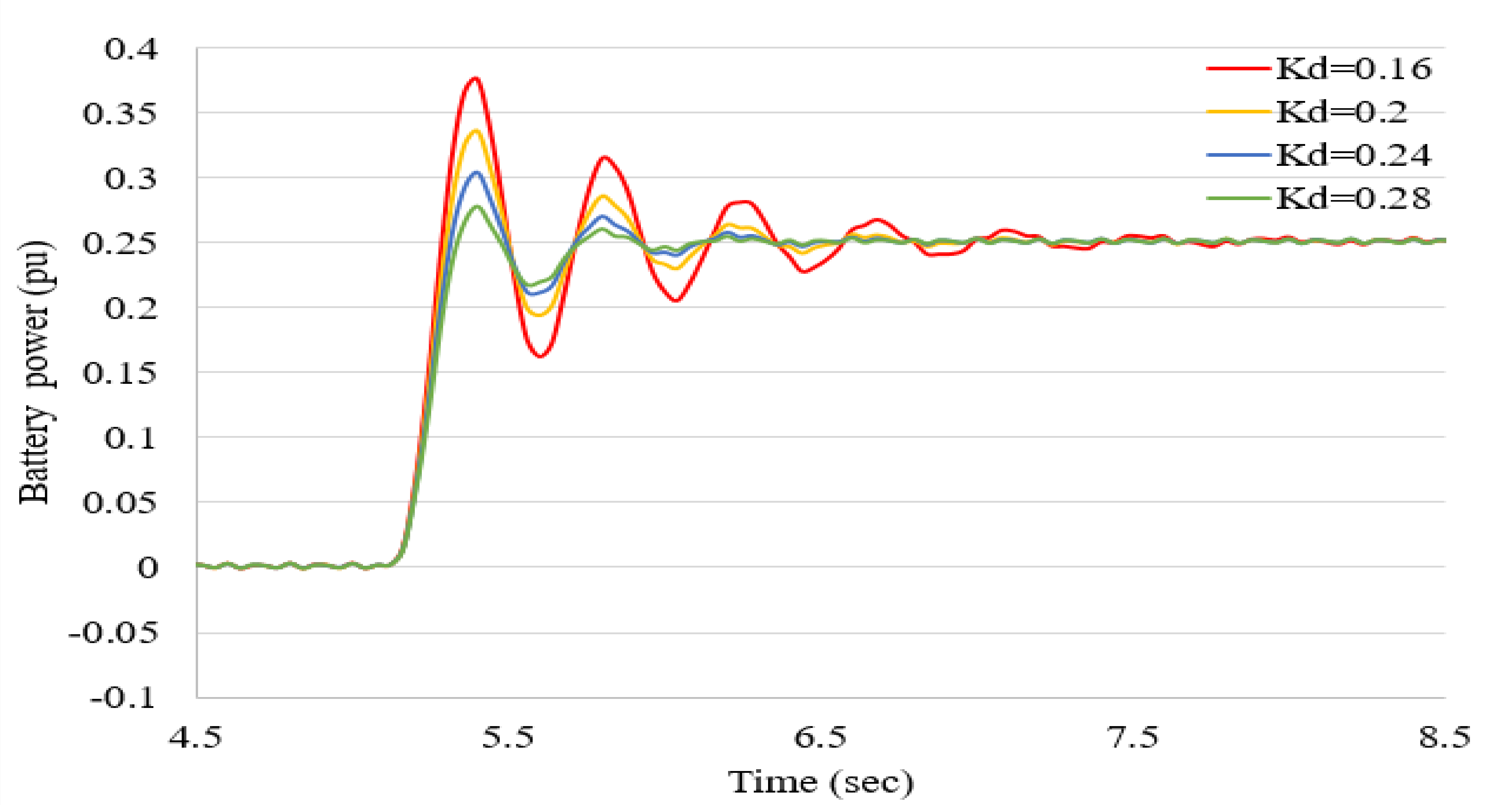
VSG converter active power variation at different damping constants (Ta=6)

Simulation results: step power setpoint increase



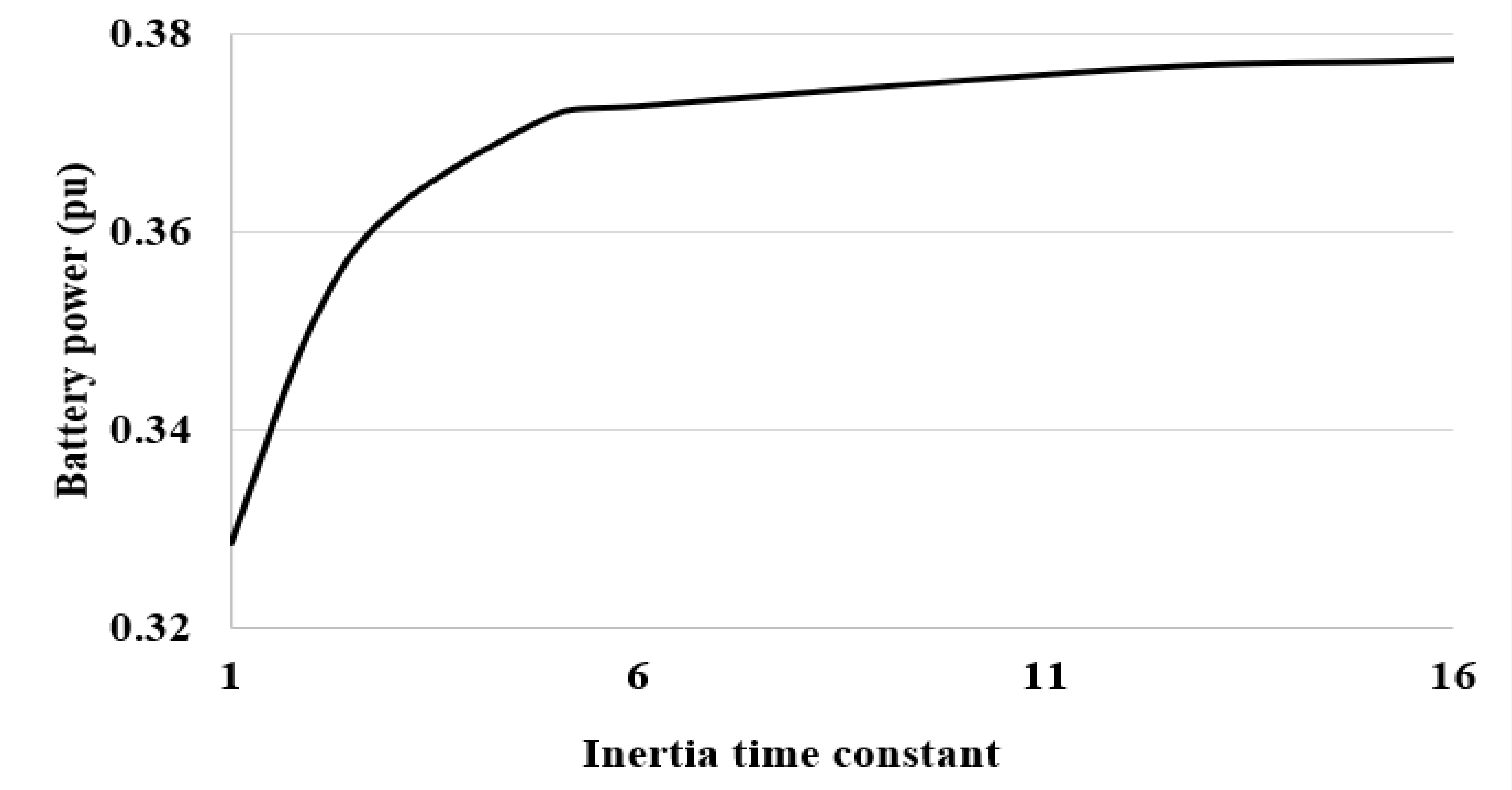
Frequency profile at different damping constants (Ta=6)

Simulation results: step power setpoint increase



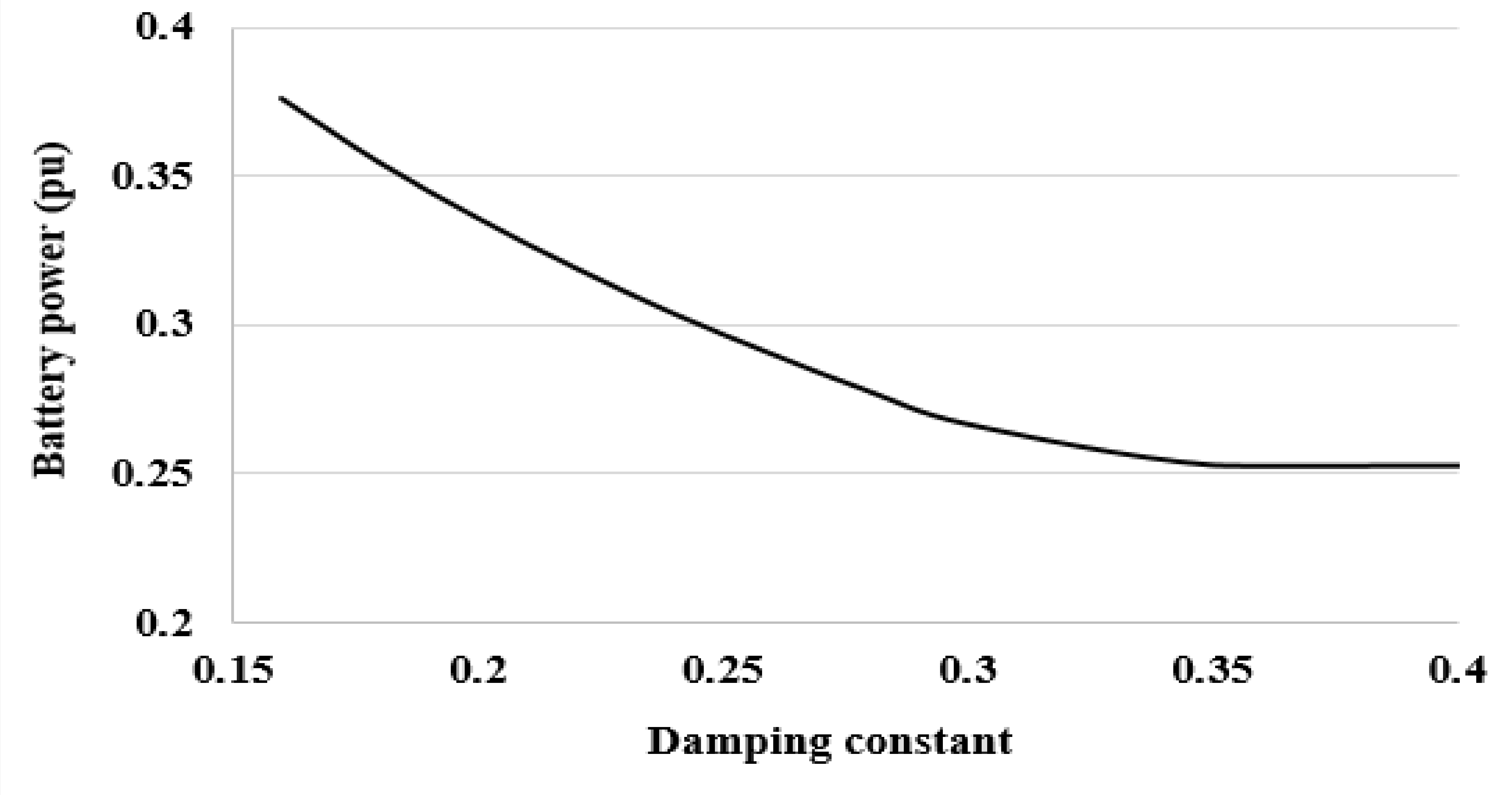
Battery power at different damping constants (Ta=6)

Simulation results: step power setpoint increase



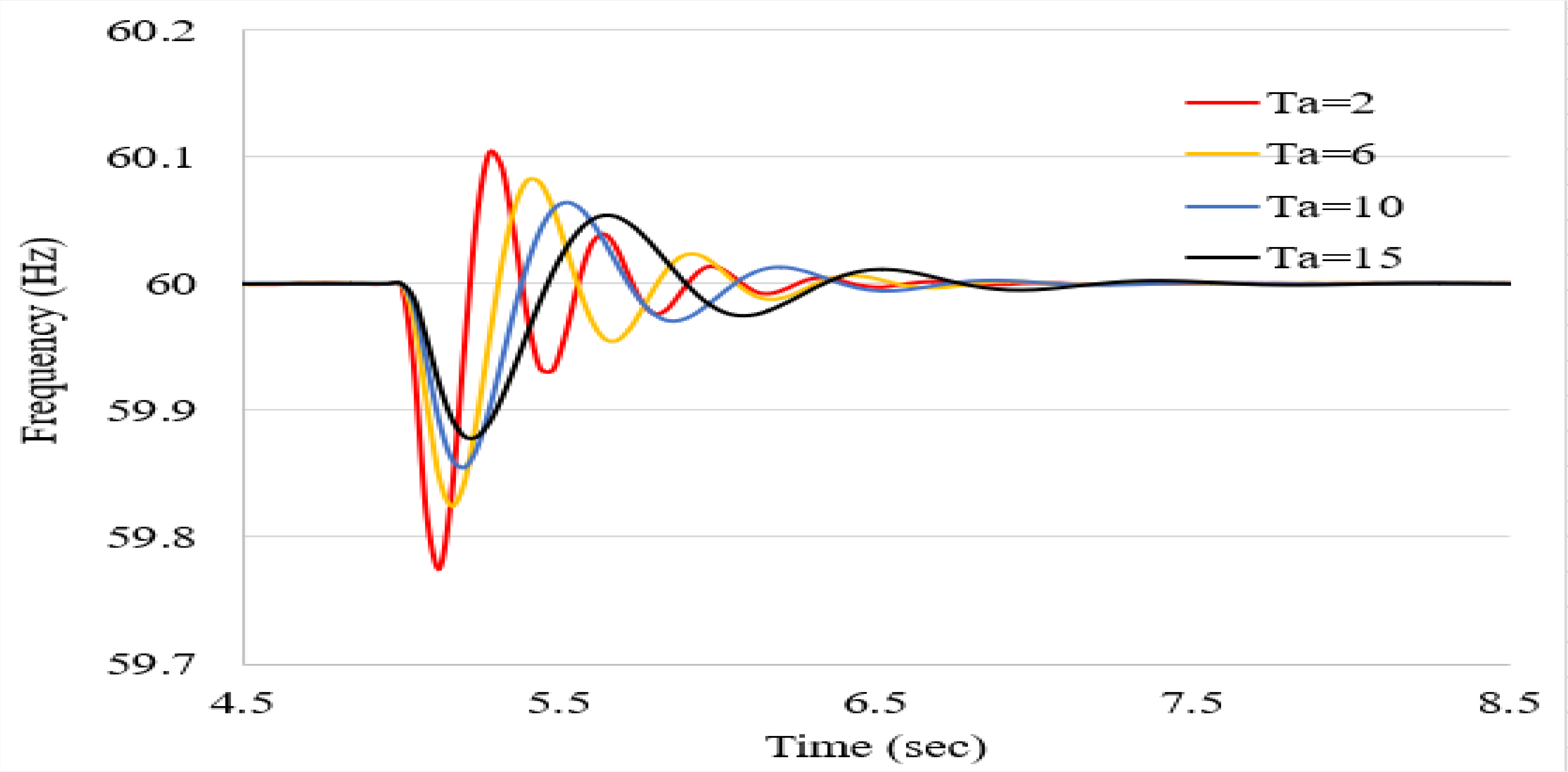
Battery generated power variation with respect to the inertia time constant

Simulation results: step power setpoint increase



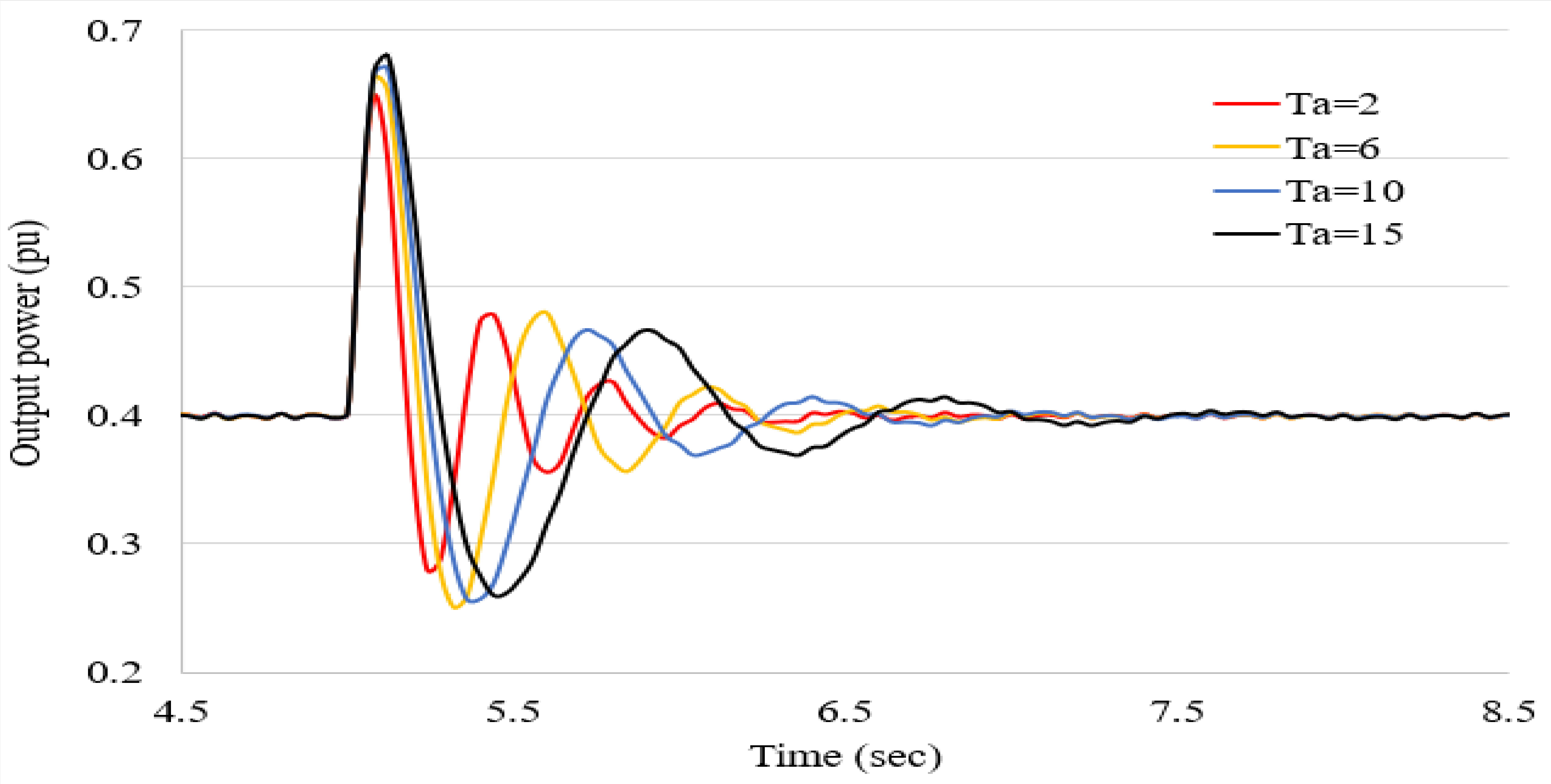
Battery power variation with respect to damping constant

Simulation results: sudden increase in load



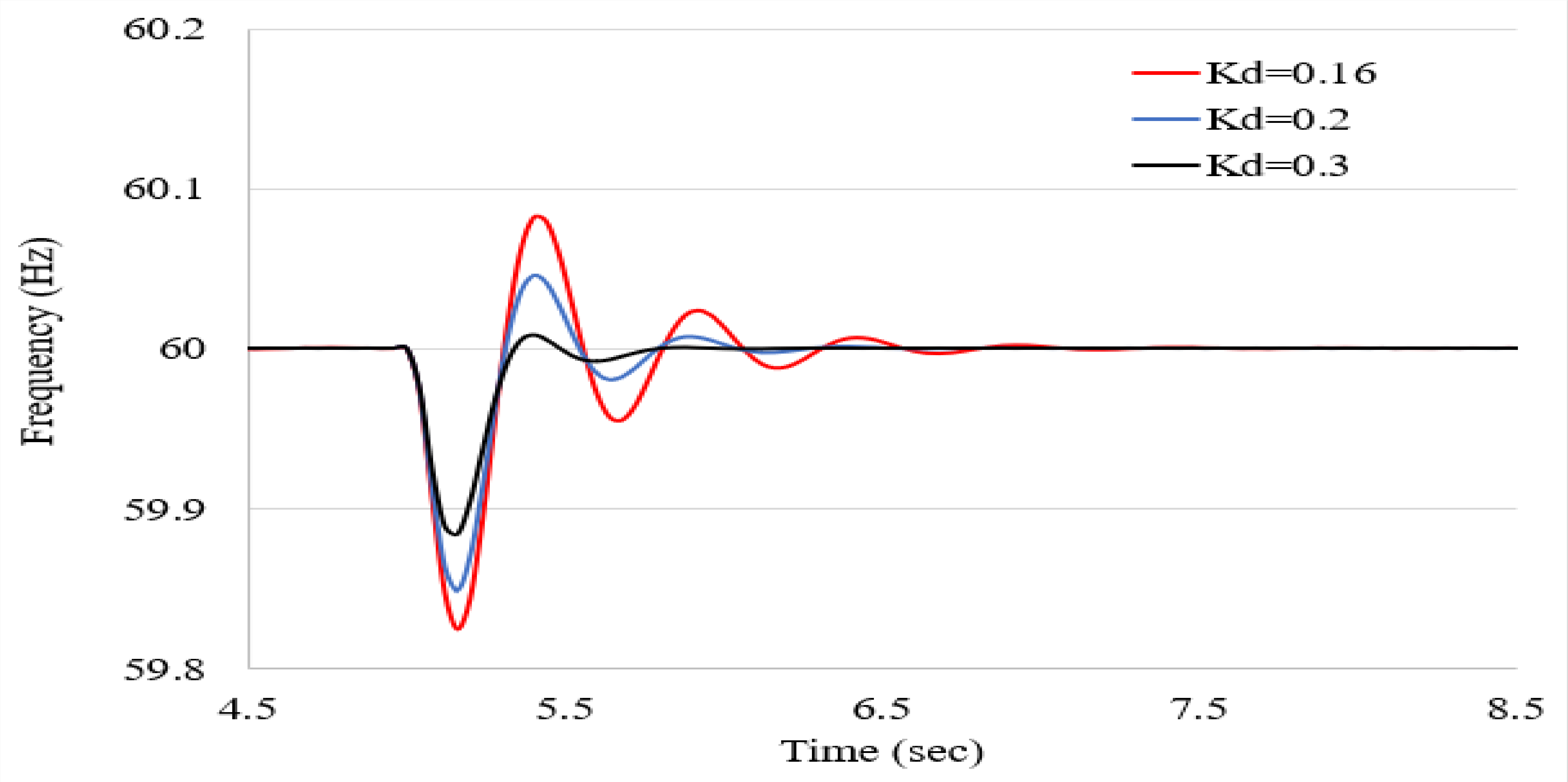
Frequency profile at different inertia time constants (Kd=0.16)

Simulation results: sudden increase in load



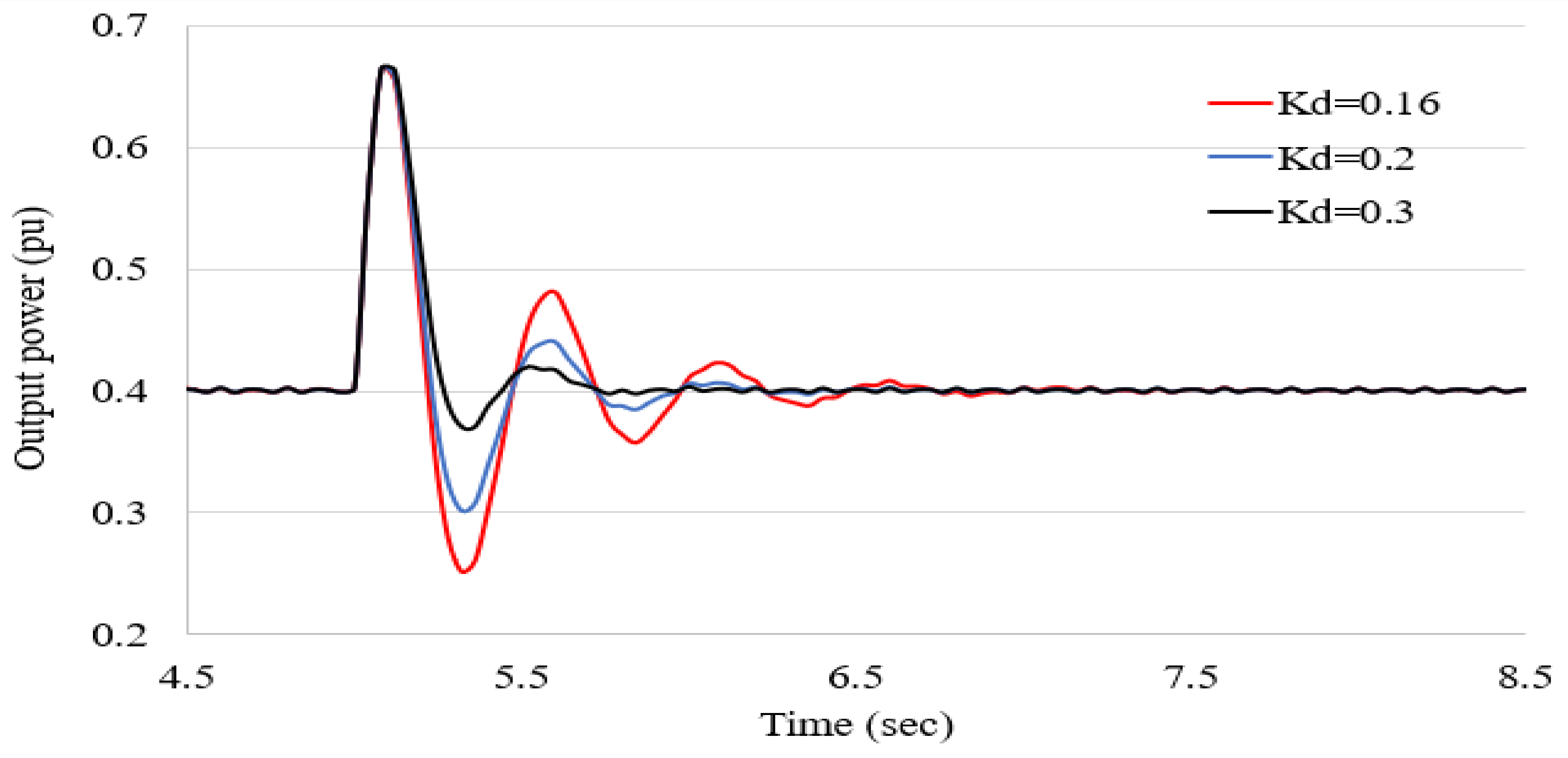
VSG active power variation at different inertia time constants (Kd=0.16)

Simulation results: sudden increase in load



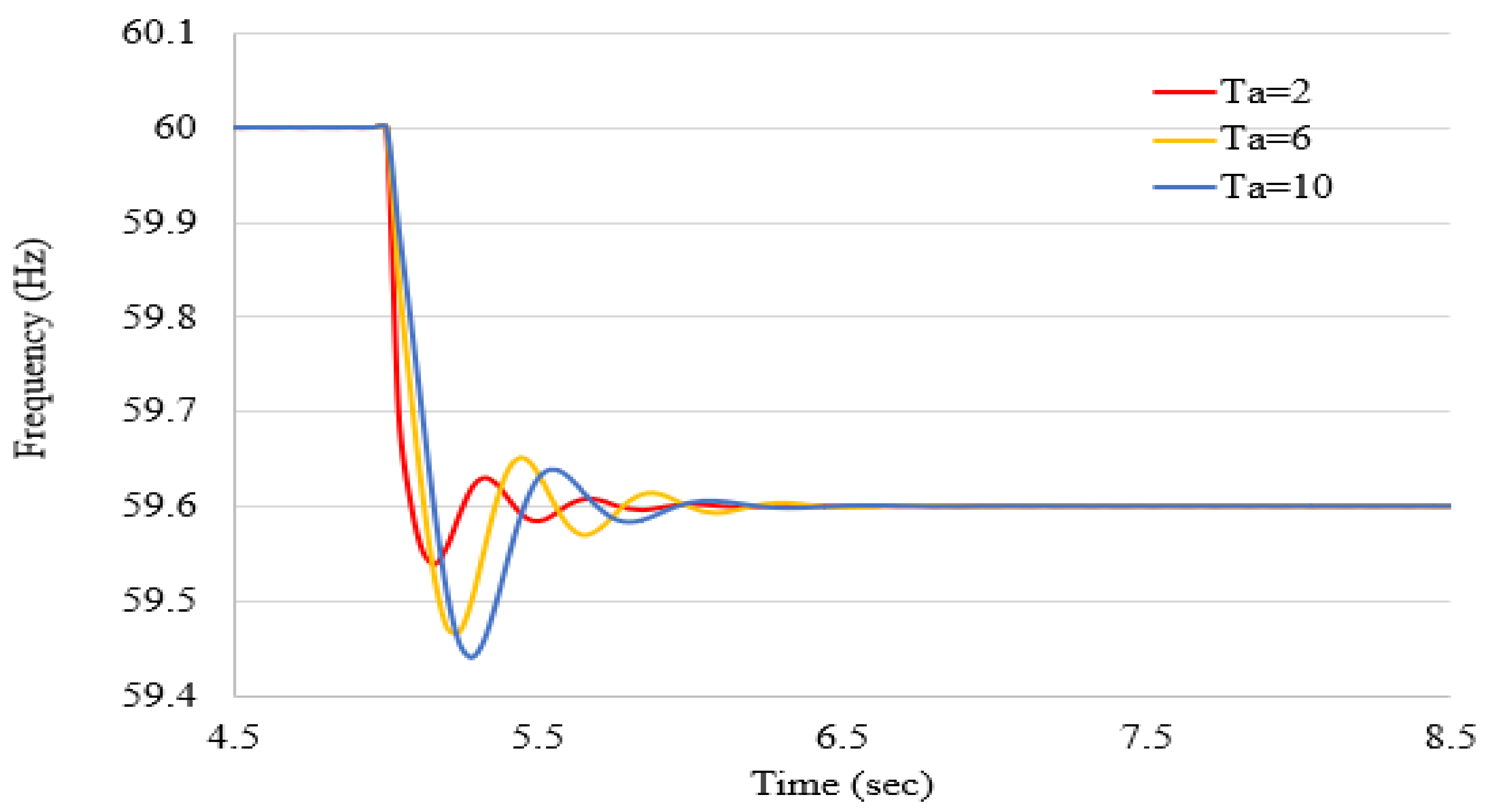
Frequency profile at step increase in load (Ta=6)

Simulation results: sudden increase in load



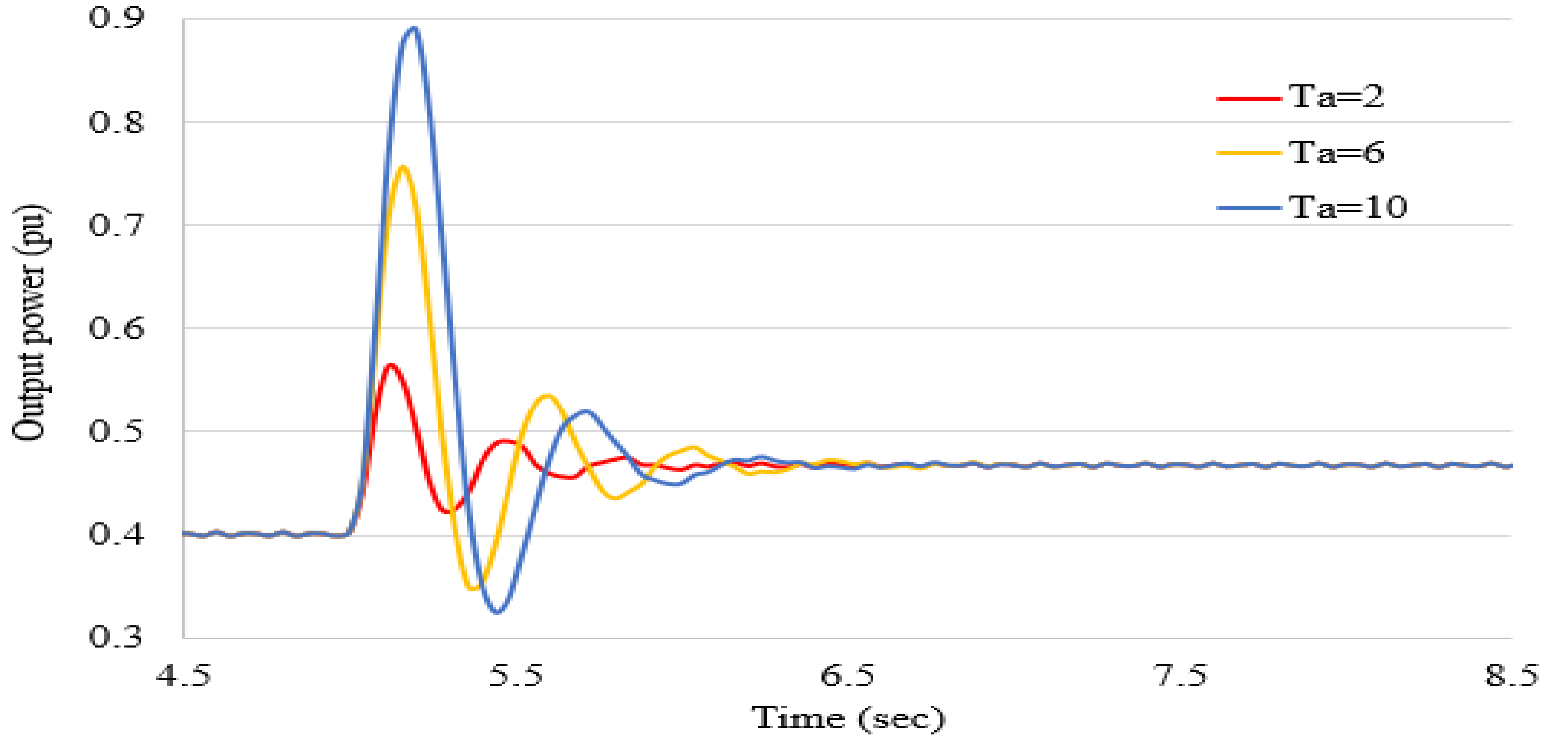
Output power profile at step increase in load (Ta=6)

Simulation results: microgrid frequency change



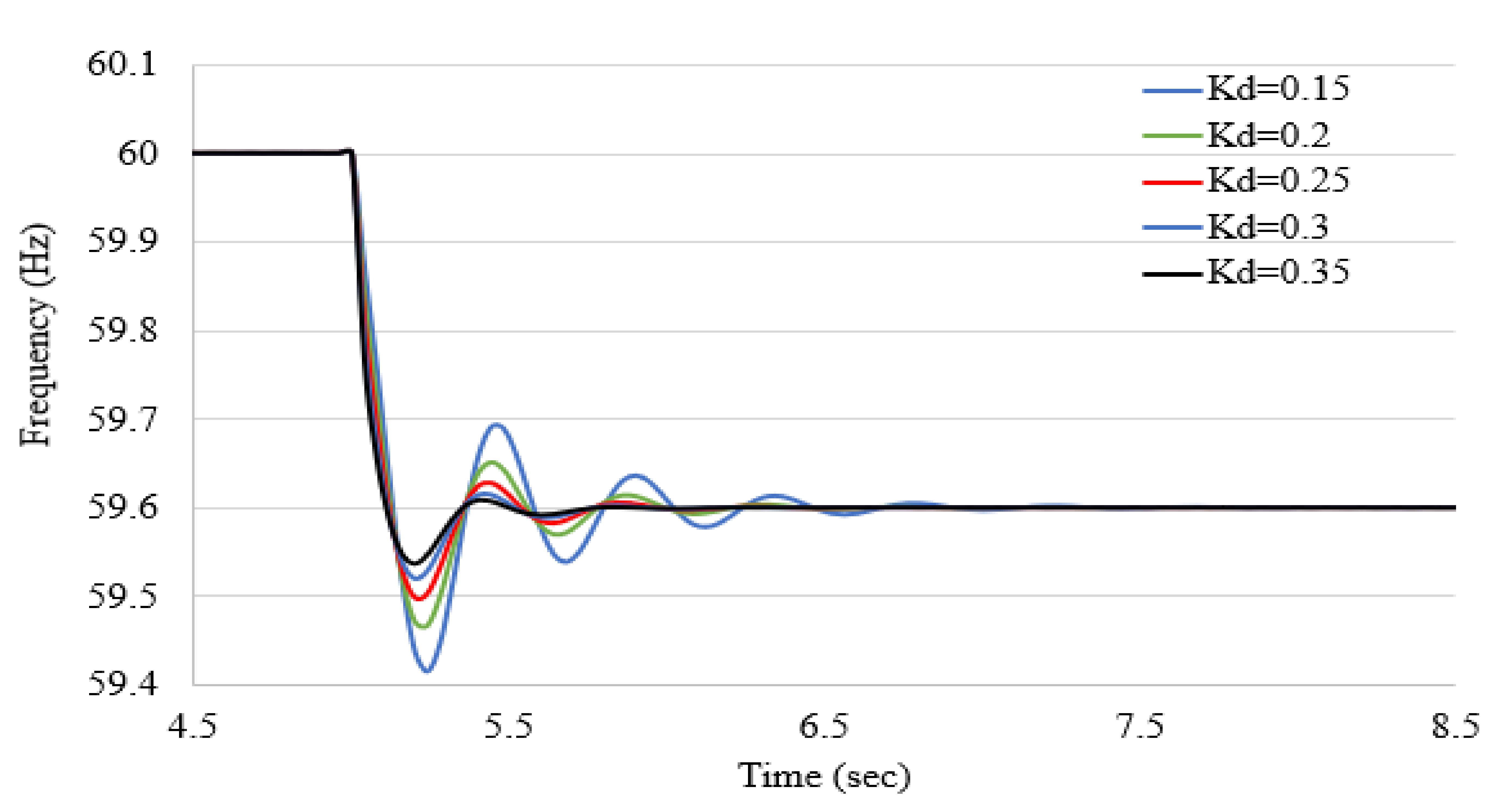
VSG frequency change in response to a microgrid frequency change (Kd=0.2)

Simulation results: microgrid frequency change



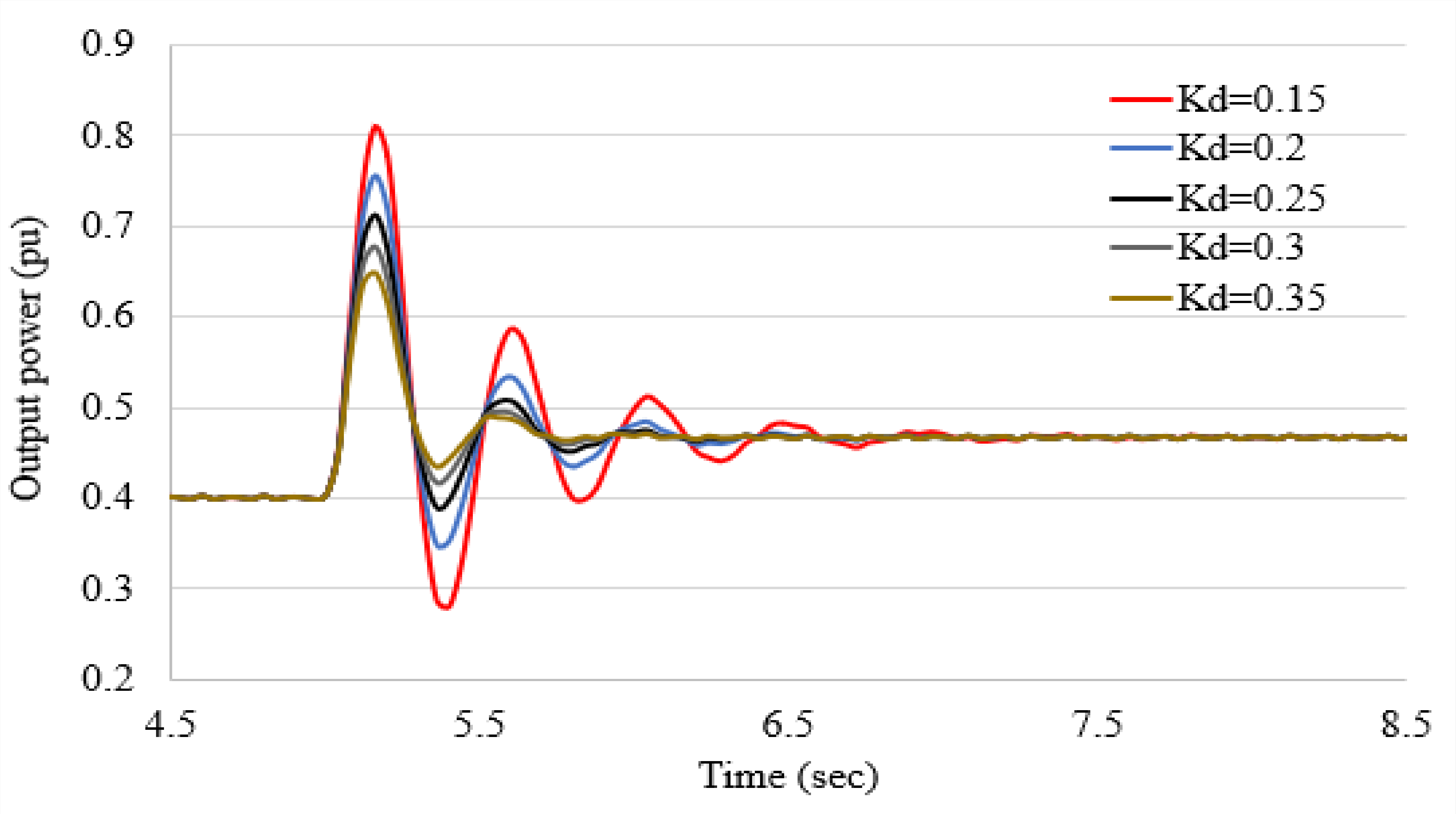
Output power in response to a microgrid frequency change (Kd=0.2)

Simulation results: microgrid frequency change



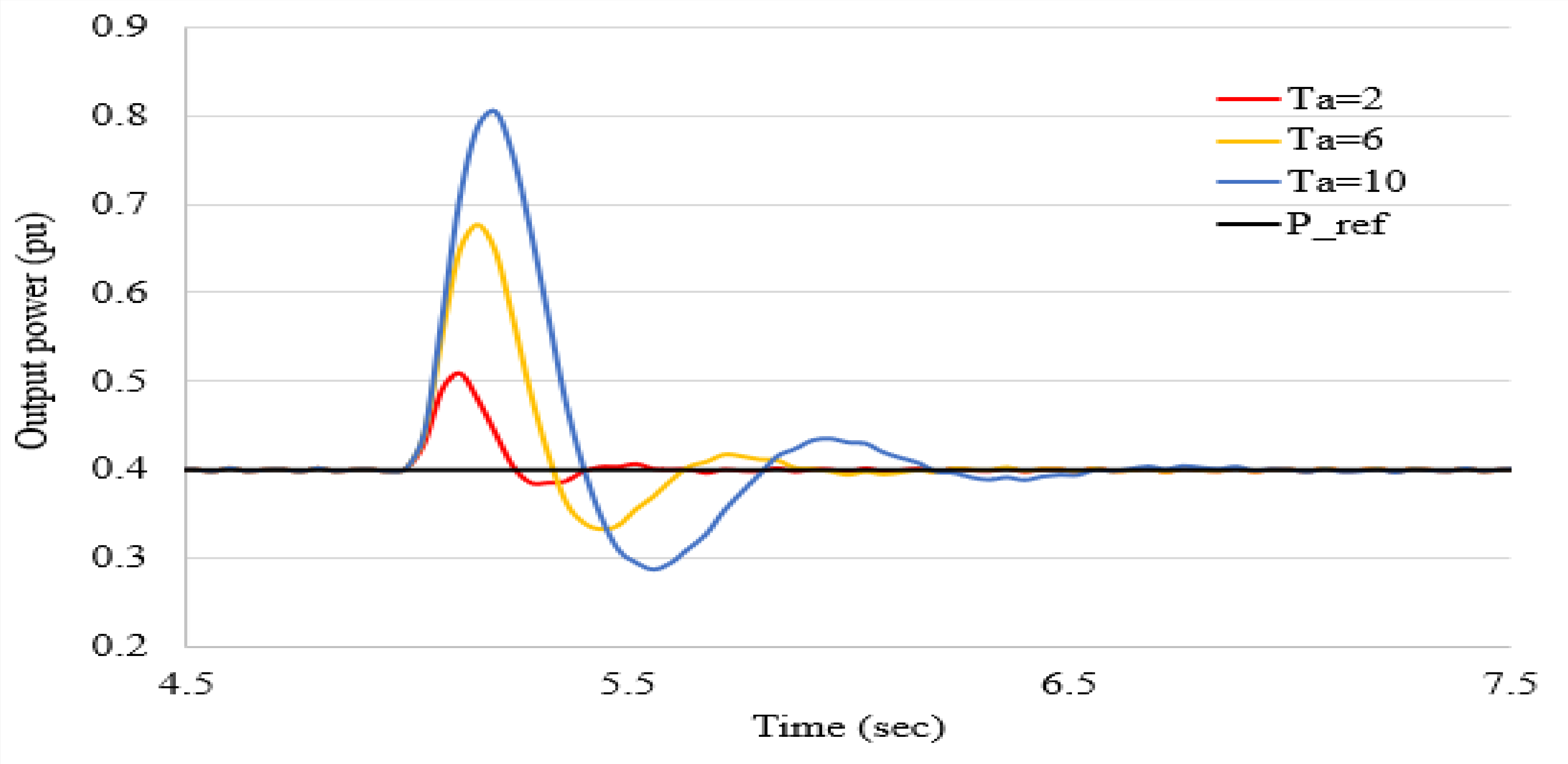
VSG frequency change in response to a microgrid frequency change (Ta=6)

Simulation results: microgrid frequency change



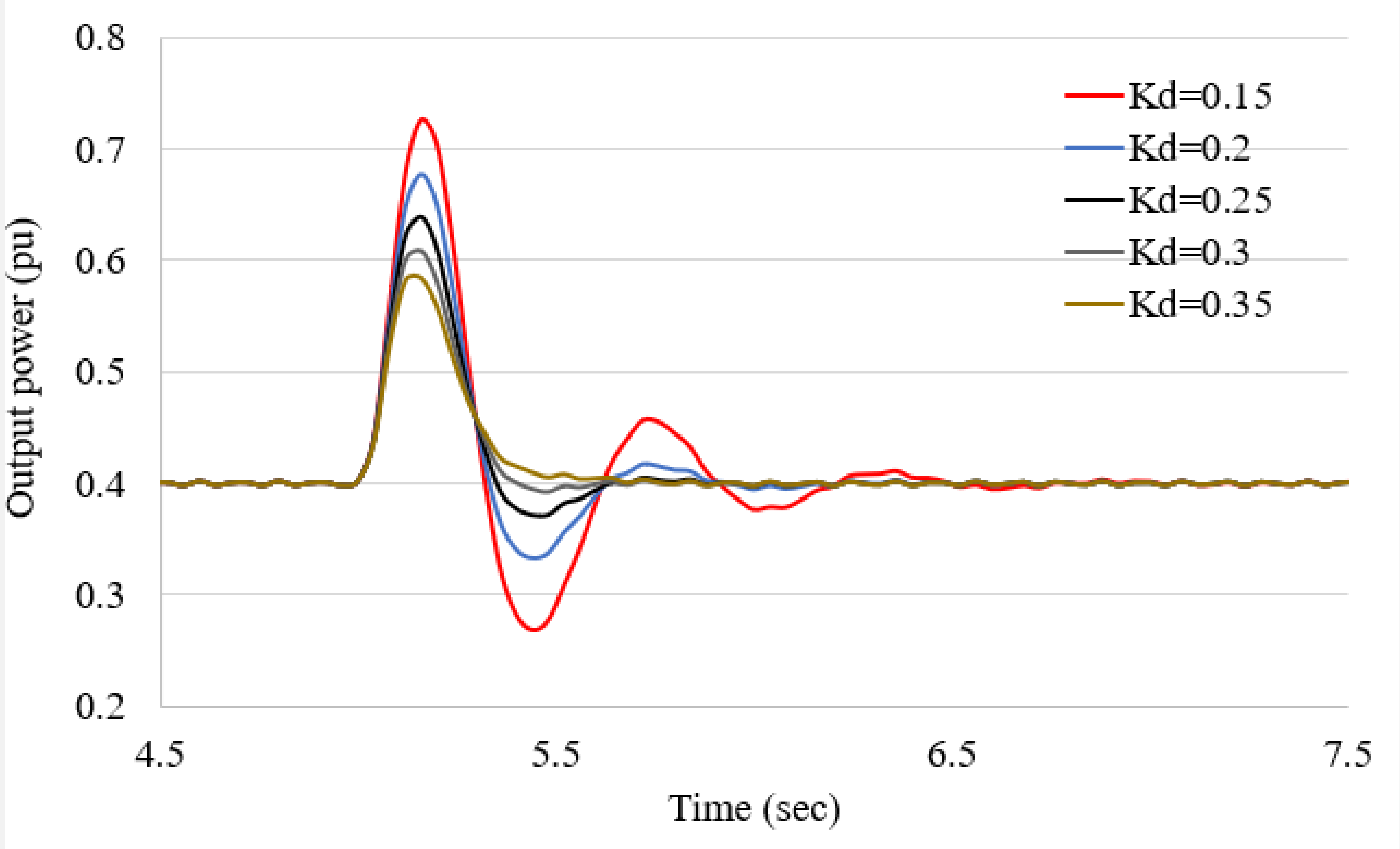
Output power in response to a microgrid frequency change (Ta=6), (Kw=0)

Simulation results: microgrid frequency change



Output power in response to a microgrid frequency change (Kd=0.2), (Kw=0)

Simulation results: microgrid frequency change



Output power in response to a microgrid frequency change (Ta=6)

Conclusion

- Frequency fluctuation depend on the rotor inertia and damping cnstants.
- VSG controlled based grid forming converter combined with ESS can emulate CSG's behavior.
- VSG parameters can be changed to mimic the inertial features of many CSG
- VSG supports the system frequency and improve its performance (RoCoF and frequency nadir).
- The impact of different values of constants affect the ratings of the converter and the ESS.
- The converter and the ESS power and energy increase when the inertia time constant increases
- The converter and the ESS power and energy increase when the damping constant decreases
- VSG controllers can promote expanding RERs in the power grids.

THANK YOU FOR ATTENTION

QUESTIONS

For any questions, please contact me at:
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