TRANSNET BW

entso-e sdp meeting

FREQUENCY STABILITY

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Grimsel, 30th July 2015

AGENDA

01 Introduction

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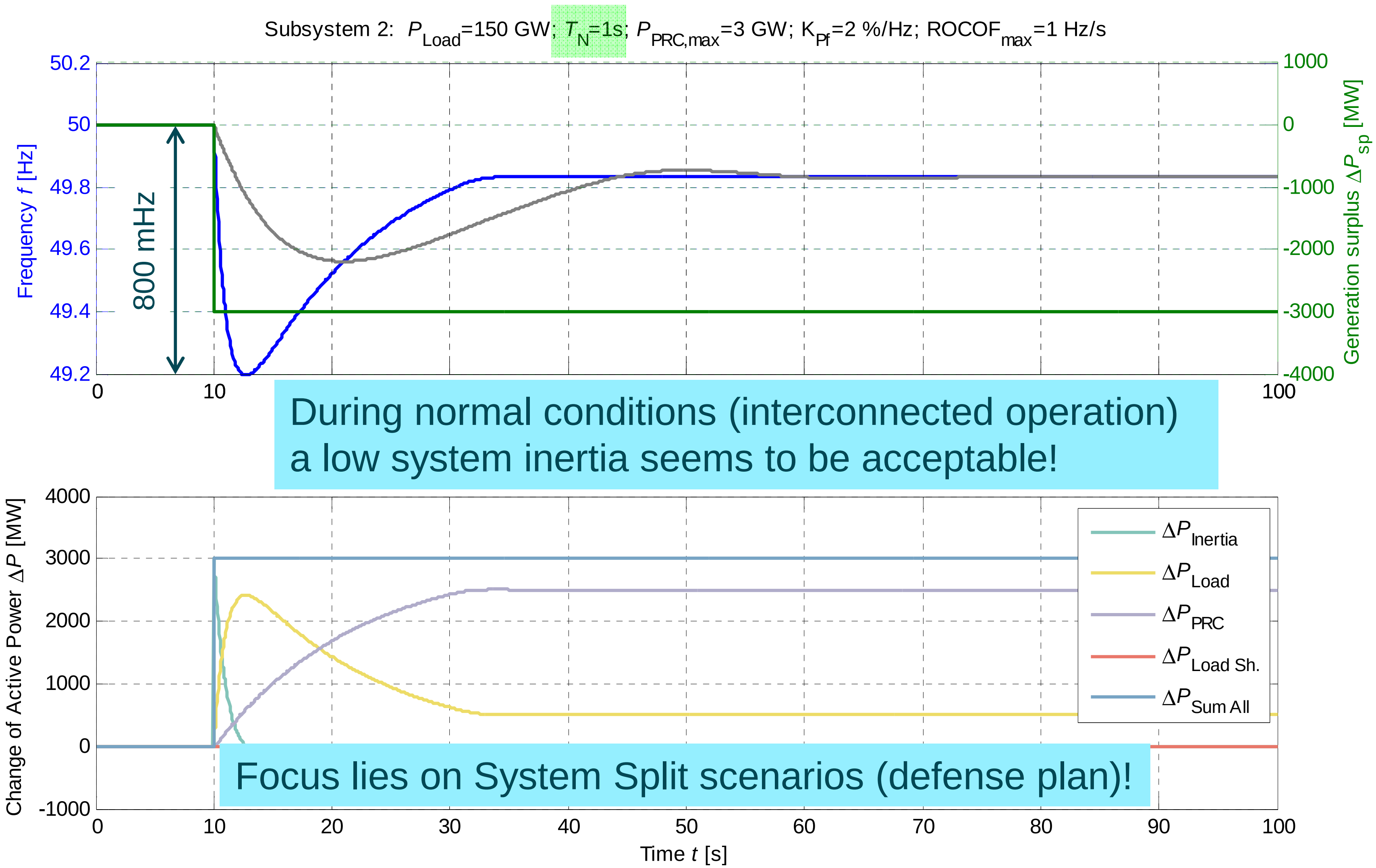
DISTINCTION BETWEEN STANDARD INCIDENT AND DEFENSE PLAN

- Standard incident: incidents ≤ 3 GW
  - Allowed frequency deviations:
    - dynamic: ≤ ±800 mHz
    - stationary: ≤ ±180 mHz
  - Primary Control designed for standard incident:
    - Reserve of 3 GW within CE
    - Full activation within 30s

- Defence plan: incidents >> 3 GW
  - Frequency deviations: 47,5 Hz ≤ f ≤ 51,5 Hz
  - Counter measure:
    - LFSM-O & LFSM-U
    - Load shedding

Introduction

DECREASING SYSTEM INERTIA



During normal conditions (interconnected operation) a low system inertia seems to be acceptable!

Focus lies on System Split scenarios (defense plan)!

Introduction

CHALLENGE SYSTEM SPLIT

- System Splits (→ *Defense Plan*) arise as a consequence of cascading protection tripping and divide the interconnected system into two or several islanded zones
- Danger of cascading protection tripping increases in case of high loaded transmission systems with transnational power transits
- High power transits ***before*** a system split lead to high power imbalances ***after*** the system split
- Parts of the European transmission system are increasingly loaded up to their limits
- Due to the increasing necessity of transmission needs, the absolute transmission capacities are increased (grid development)

- In case of a system split the potential power imbalances increase considerably

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Introduction

TOPIC MINIMUM INERTIA HAS TO FOCUS ON SYSTEM SPLIT (DEFENCE PLAN)

/ High power transits lead to high power imbalances in case of a system split

/ High power imbalances in combination with (locally) low system inertia lead to high frequency gradients (Rate of Change of Frequency – RoCoF)

/ In case of a system split areas with over- and areas with under-frequency arise

/ Relevance for Frequency Stability:

- / Frequency has to be kept within the permitted frequency ranges
- / Rate of Change of Frequency has to be limited

⇒ Time response of Over- & Under-Frequency actions is of outmost importance!

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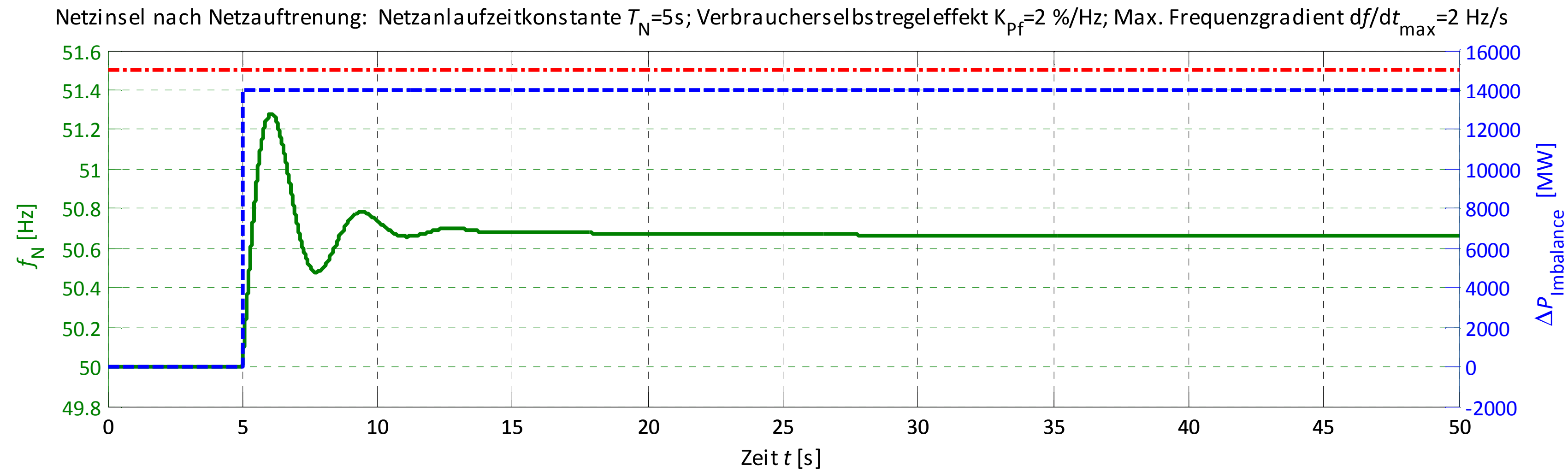
OVER-FREQUENCY-SCENARIO

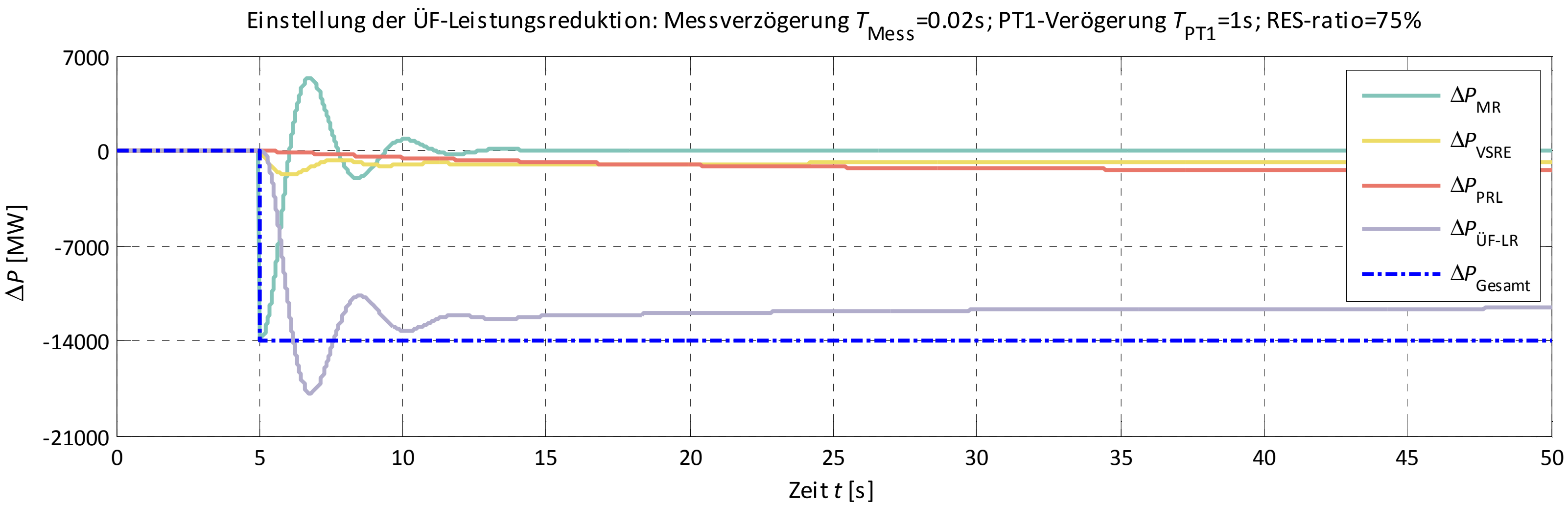
Over-frequency Island after system split:

- Load of the Power System & Power Imbalance:
  - $P_{\text{Load}} = 70$ GW
  - $\boldsymbol{\Delta P_{\text{Imbalance}} = 14}$ **GW** ($\Delta P_{\text{Imbalance}} / P_{\text{Load}} = 20\%$)
- Infeed related to the load: 120%
  - Non-synchronous share: 95%
  - Conventional share: 25% (conventional power plants operated at 50%, no contribution to over-frequency infeed reduction)
- Inertia of the Power System:
  - $T_N = 5$ s
- Resulting maximum Rate of Change of Frequency (RoCoF) as a result of system split:
  - $df/dt_{max} = 2$ Hz/s $\left(\frac{df}{dt} = \frac{\Delta P_{\text{Stör}}}{P_{\text{Netzlast}}} * \frac{f_0}{T_{\text{Netz}}} \quad \text{mit } \frac{df}{dt} = 2\frac{Hz}{s};\ f_0\text{=50Hz}\right)$

Introduction

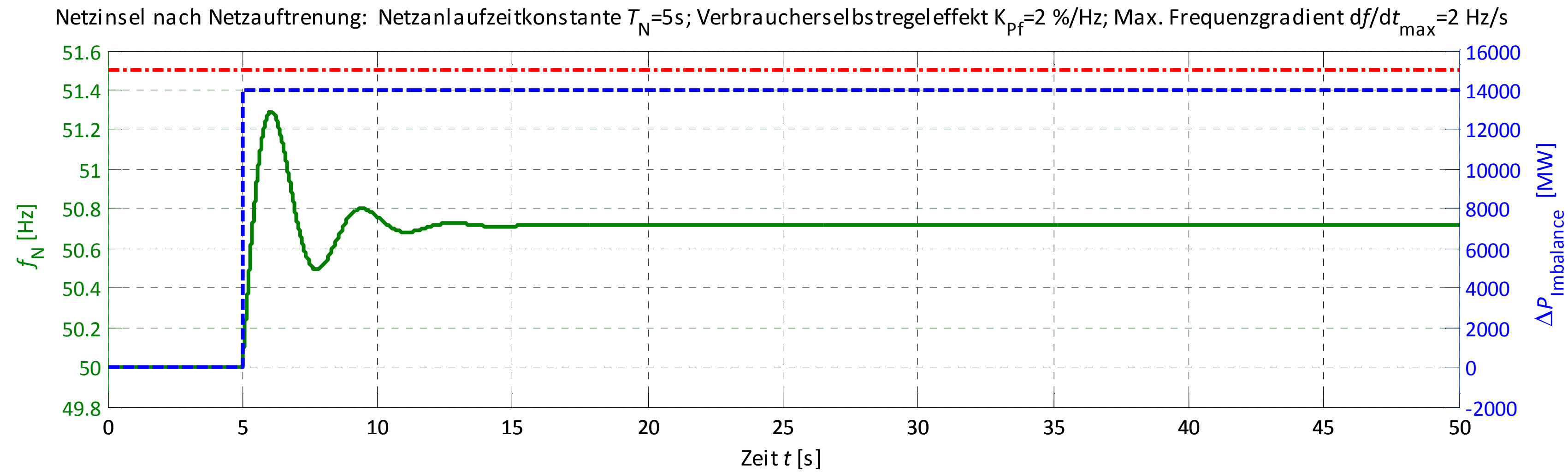
OVER-FREQUENCY-SCENARIO (WITH PRC)

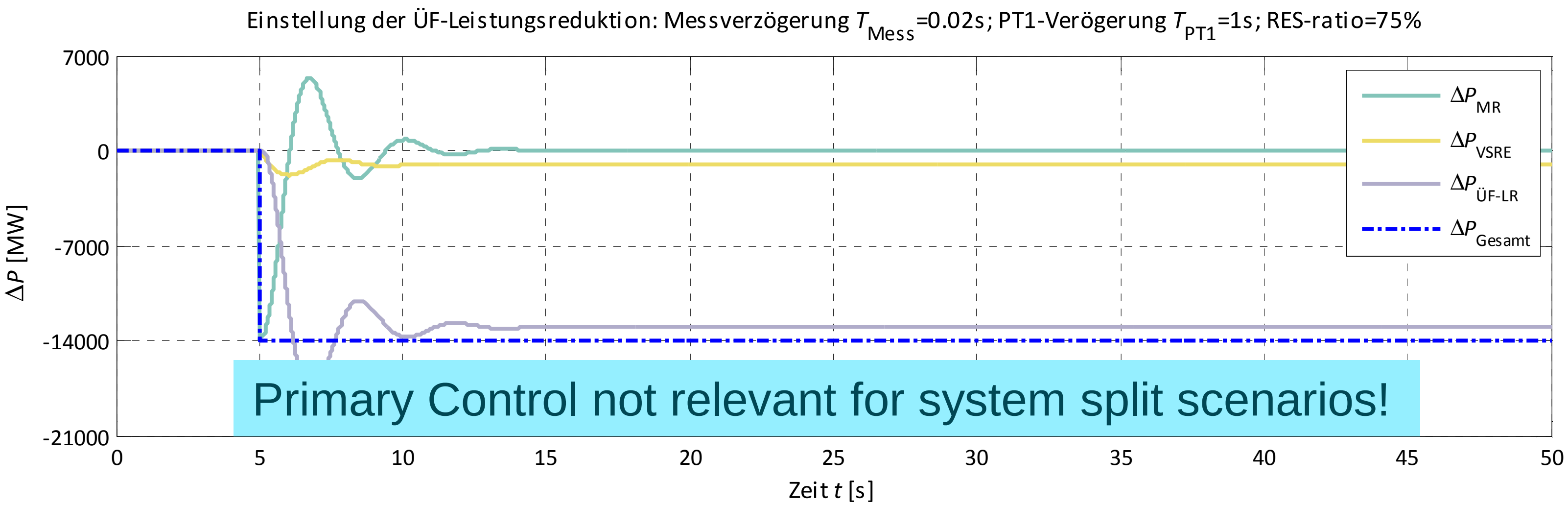




Introduction

OVER-FREQUENCY-SCENARIO (WITHOUT PRC)





Introduction

PRIMARY CONTROL NOT RELEVANT FOR SYSTEM SPLITS

- Available power and time response of primary control designed for standard incident
- Available power of primary control too small and slow for system splits with
  - high power imbalances,
  - low inertia and
  - high RoCoFs

- Possible simplifications for the analysis
  - Primary Control (and Secondary Control) can be neglected
  - Input parameters of the analysis in per unit

  ⇨ Results valid independent of the size of the islands (after the system split)

02 Outline of the topic Frequency Stability

Outline of the topic Frequency Stability

IMPACTING FACTORS

/ Inertia & Power Imbalance defines the maximum RoCoF:

$$\frac{df}{dt} = \frac{\Delta P_{\text{Stör}}}{P_{\text{Netzlast}}} * \frac{f_0}{T_{\text{Netz}}} \qquad \text{mit } f_0\text{=50Hz}$$

/ Operating range of generators (RfG and Operation Handbook):

– 47,5 Hz ≤ f ≤ 51,5 Hz

/ Definition of RoCoF withstand capability?

⇒ Frequency (& RoCoF) has to stay within the limits to

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Outline of the topic Frequency Stability

SENSITIVITY MATRIX I

Over-Frequency	Power Imbalance	System Inertia	RoCoF	Dynamic of Loads	Primary Control	Secondary Control
Normal Operation	⃠	✓	✓	✓	✓	✓
System Split (Defence Plan)	✓	✓	✓	✓	✓	✓

Under-Frequency	Power Imbalance	System Inertia	RoCoF	Dynamic of Loads	Primary Control	Secondary Control
Normal Operation	⃠	✓	✓	✓	✓	✓
System Split (Defence Plan)	✓	✓	✓	✓	✓	✓

Outline of the topic Frequency Stability

SENSITIVITY MATRIX II

	OF-IR (Delays & Limitations)		Synthetic Inertia (Delays & Limitations)	
Over-Frequency	Droop Control	Staged Dis-/ Reconnection	Pitch Control (WT)	Rotor inertia (WT)
Normal Operation	✓	✓	✏	✏
System Split (Defence Plan)	✓	✓	✏	✏

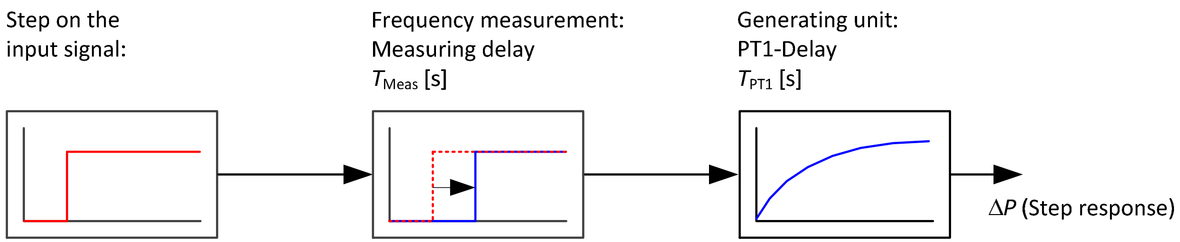
	UF-LS (Measurement & breaker delay)		Synthetic Inertia (Delays & Limitations)	
Under-Frequency	Fixed thresholds	df/dt	Full Load (WT)	Part Load (WT)
Normal Operation	⃠	⃠	✏	✏
System Split (Defence Plan)	✓	✏	✏	✏

03 Example: over-frequency infeed reduction

Example: over-frequency infeed reduction

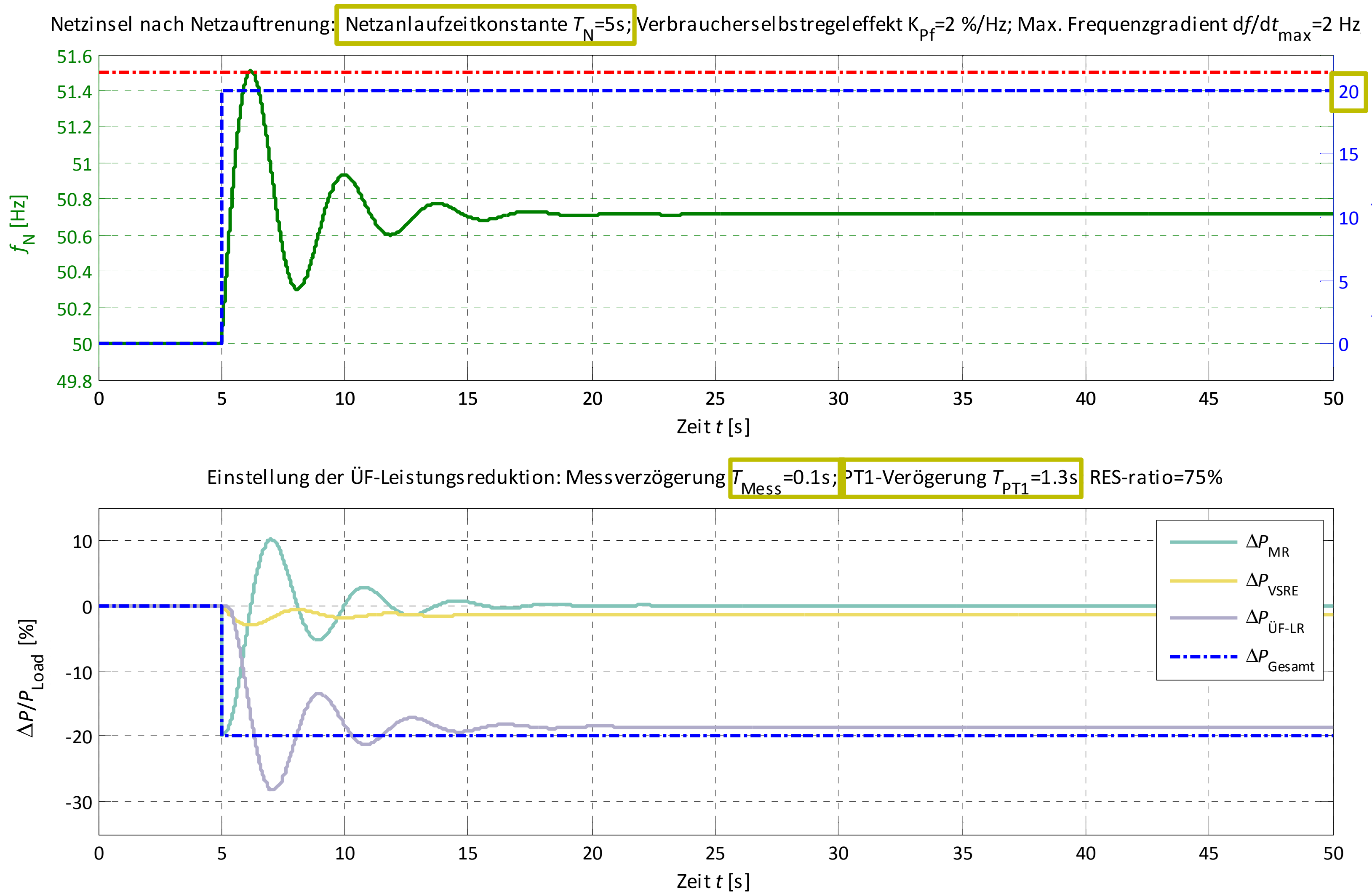
SIMPLIFIED MODELLING OF THE OVER-FREQUENCY LOAD REDUCTION

Simplified behaviour of the Over-Frequency Infeed Reduction (OF-IR) of the generating units:



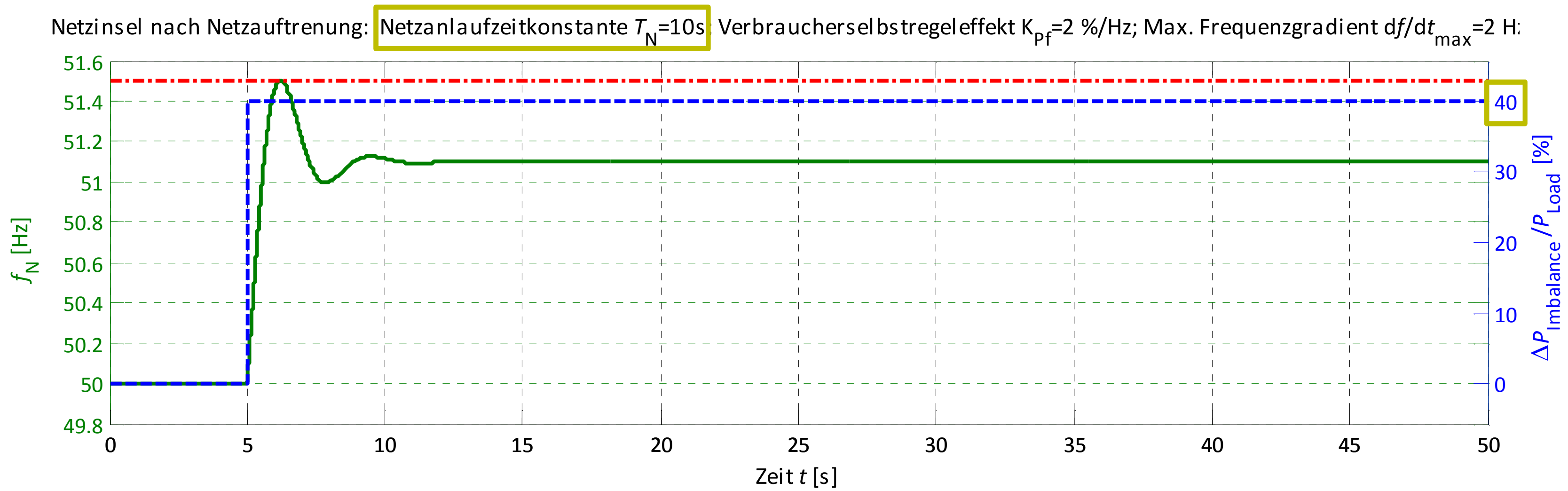
Example: over-frequency infeed reduction

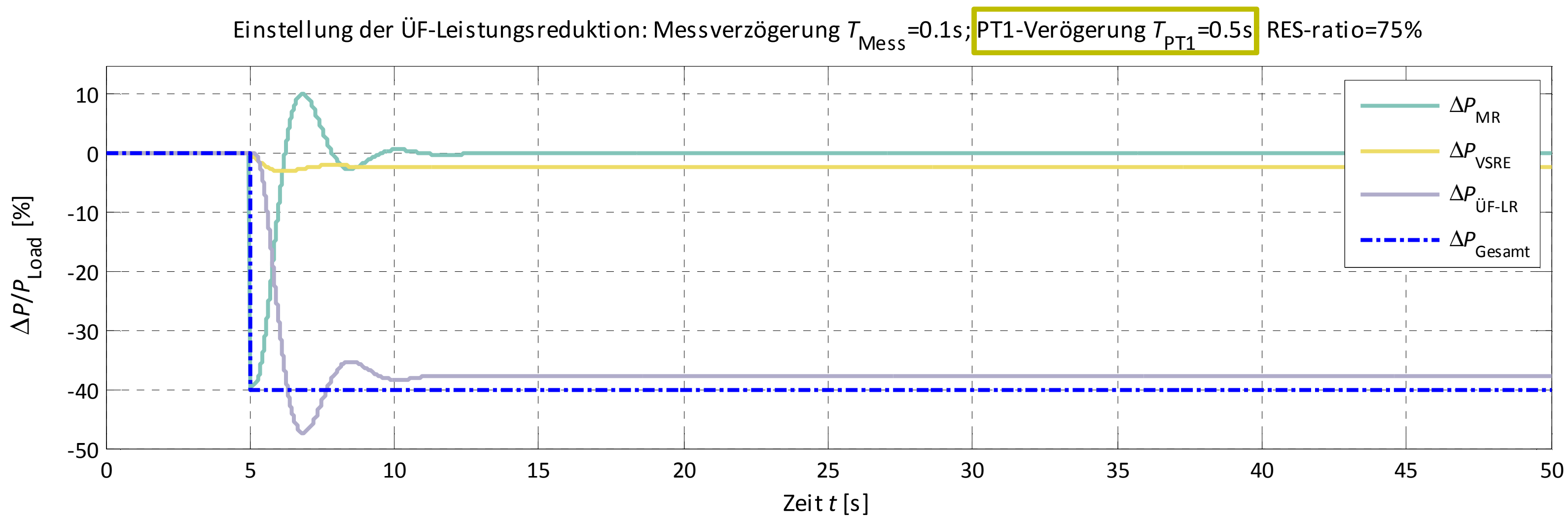
OVER-FREQUENCY SCENARIO - SENSITIVITIES



Example: over-frequency infeed reduction

OVER-FREQUENCY SCENARIO - SENSITIVITIES





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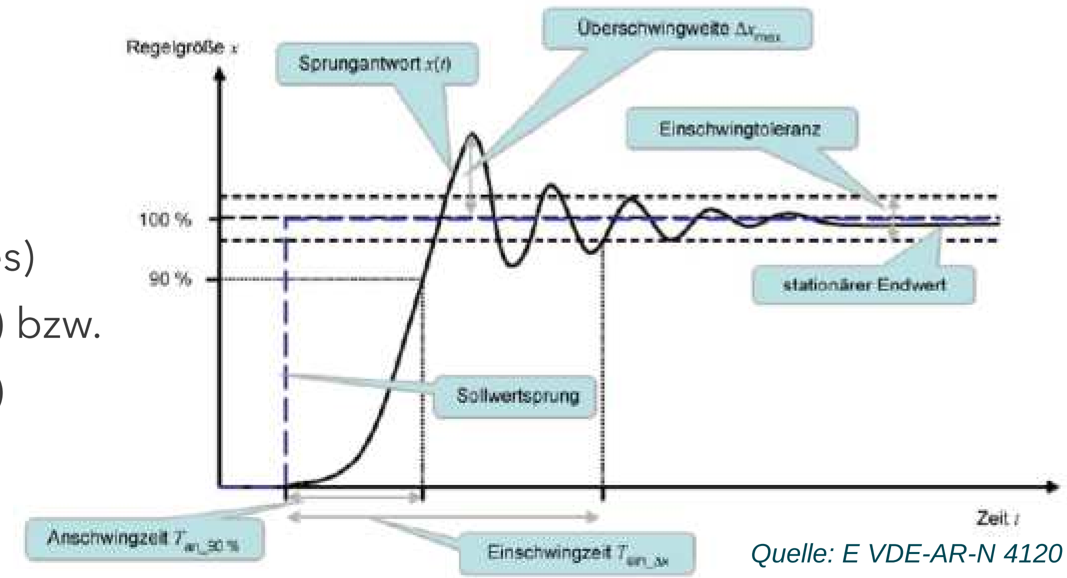
Example: over-frequency infeed reduction

NECESSARY TIME RESPONSE OF THE OF-IR

- RfG:
  - Initial delay ≤ 2s

- TAR HS/MS/NS (German dso rules)
  - $T_{an\_90\%} \leq 2s$ (Typ 2-Einheiten) bzw.
  - $T_{an\_90\%} \leq 5s$ (Typ 1-Einheiten)



Quelle: E VDE-AR-N 4120

- Comparison to Over-Frequency scenario with $\Delta P_{Îmbalance} / P_{Load} = 40\%$
  - $T_{an\_95\%} \leq 1{,}6s$

➡ BUT: Only valid if all generating systems accomplish such a fast time response!

Example: over-frequency infeed reduction

TECHNOLOGY-SPECIFIC TIME RESPONSE

04 Summary & Outlook

SUMMARY

- Distinction between standard incident and defense plan is important
- Topic minimum inertia has to focus on system split (defence plan)
- Primary Control not relevant for system splits
- Recommended simplifications:
  - Neglecting Primary (and Secondary) Control
  - Input parameters of the analysis in per unit → results valid independent of the size of the islands (after the system split)

- Impacting factors of the topic Frequency Stability are identified and a
- Sensitivity Matrix was introduced

Summary & Outlook

OUTLOOK

- Hans Abele & Joachim Lehner would like to invite the spd subgroup “Inertia” to Stuttgart in September/October 2015 for a kick-off meeting

  - Proposed Agenda:
    - Detailed presentation & discussion of the Frequency Stability analysis done so far (Hans Abele & Joachim Lehner)
    - Further procedure (all)