WHEN TRUST MATTERS

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Kermit *a simulation tool to analyze the* ***frequency containment and restoration response*** *of power systems, especially useful in the case of large amount of renewable generations*

June 16 *WinGrid Workshop Power System Balancing and Operation with Large Shares of Wind Power*

Wouter de Boer, Maurin Hörler

woensdag 16 juni 2021

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  frequency restoration response
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- Questions?

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What is Kermit?

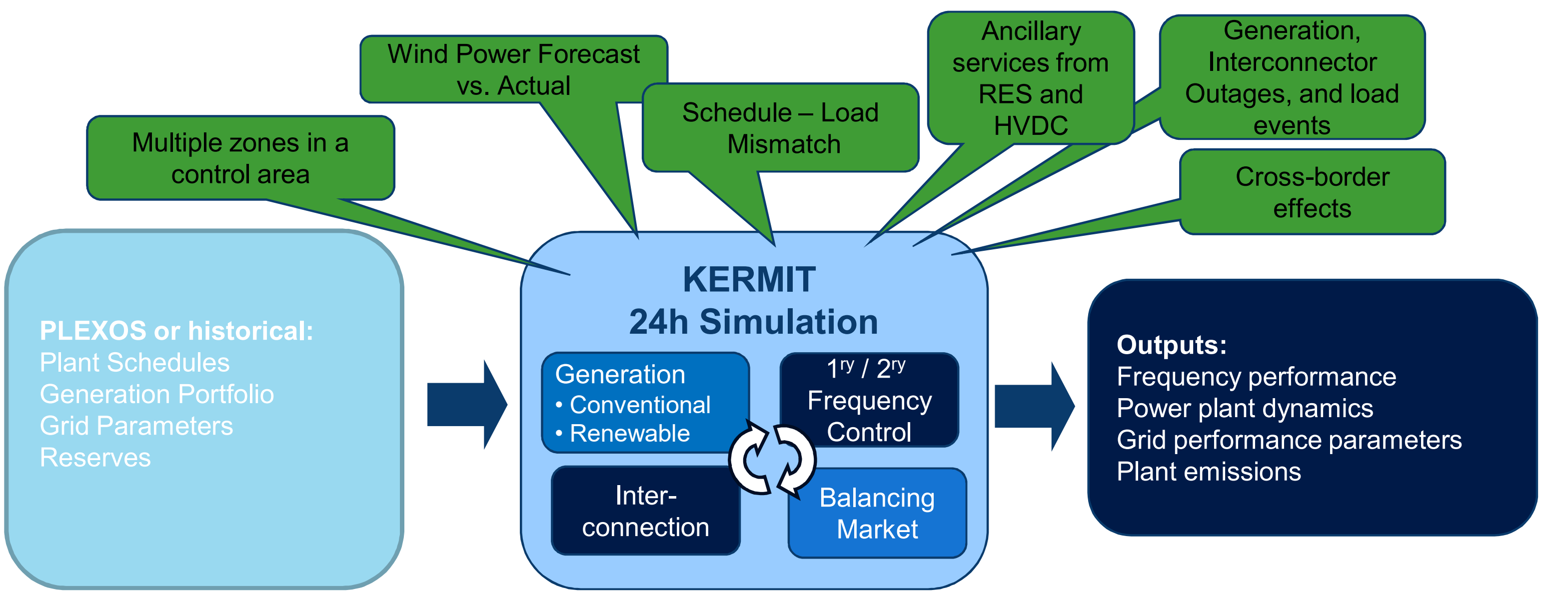
What is KERMIT?

- An in-house tool developed by DNV in Europe and US
- **Simulates real-time power system dynamics**
  - Dynamics of conventional power plants
  - Frequency response – AGC control
  - Time varying generation (e.g. wind farms) and loads
  - Bulk power interconnection dynamics

- Core functionality: **To Quantify the impact of variable power sources on system operation**, e.g.
  - Effect of adding wind or solar to the generation mix
  - Effect of events like unit trips
  - Impact of forecasting errors

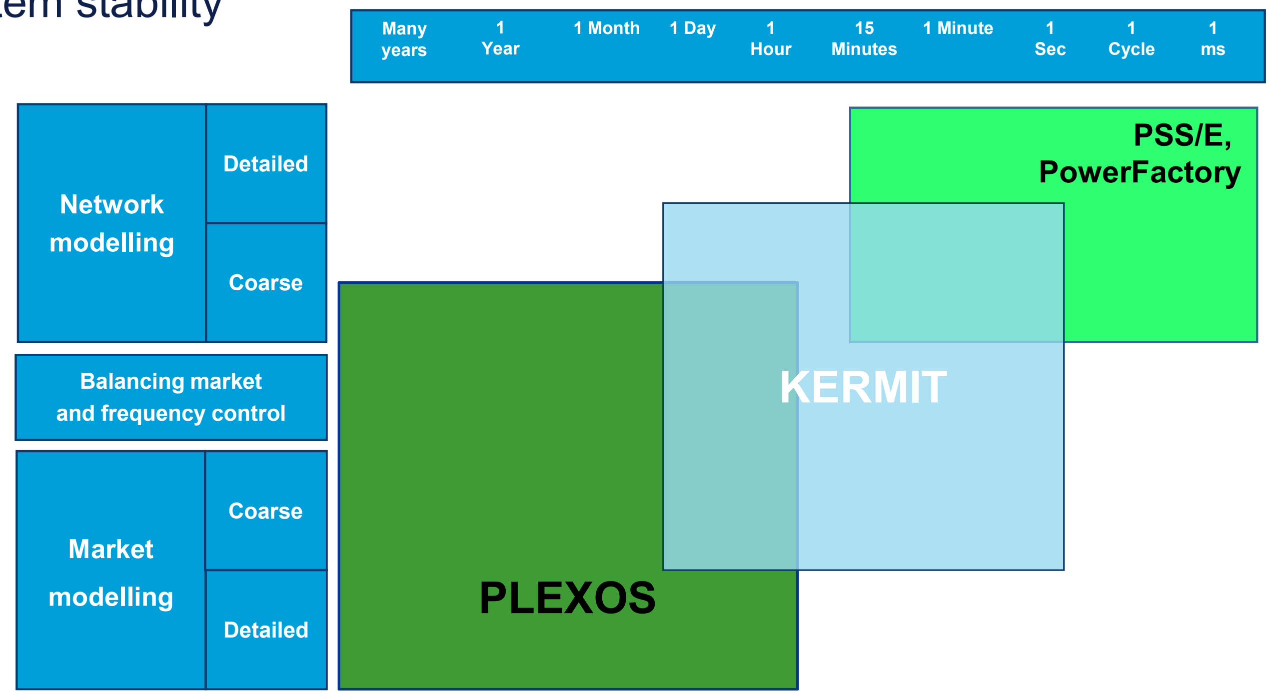
KERMIT – what it does and who uses it

- Simulates the dynamics of power system at an intra-hour timeframe
- Can be used in combination with economic dispatch programs like PLEXOS
- KERMIT allows grid operators to evaluate risk of reliability events and test grid control strategies with high renewables or under new market scheme



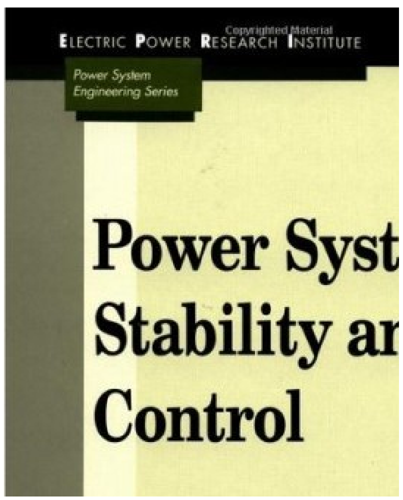
KERMIT bridges gap between market and power system models

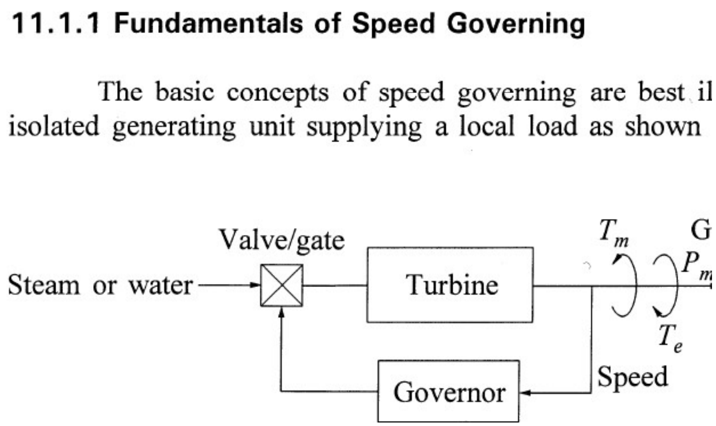
- KERMIT can be combined with several tools for a broader perspective, spanning portfolio planning to system stability



KERMIT fundamentals

- KERMIT is based upon equations in KUNDUR, Power System Stability and Control (1994), section 11.1 Active Power and Frequency Control
- Generator models IEEE models and simplified models





11.1.1 Fundamentals of Speed Governing

The basic concepts of speed governing are best il
isolated generating unit supplying a local load as shown

Source: Kundur, Power System Stability and Control. McGraw-Hill, inc. 1994.

Power excange between clusters wih the **Swing equation**

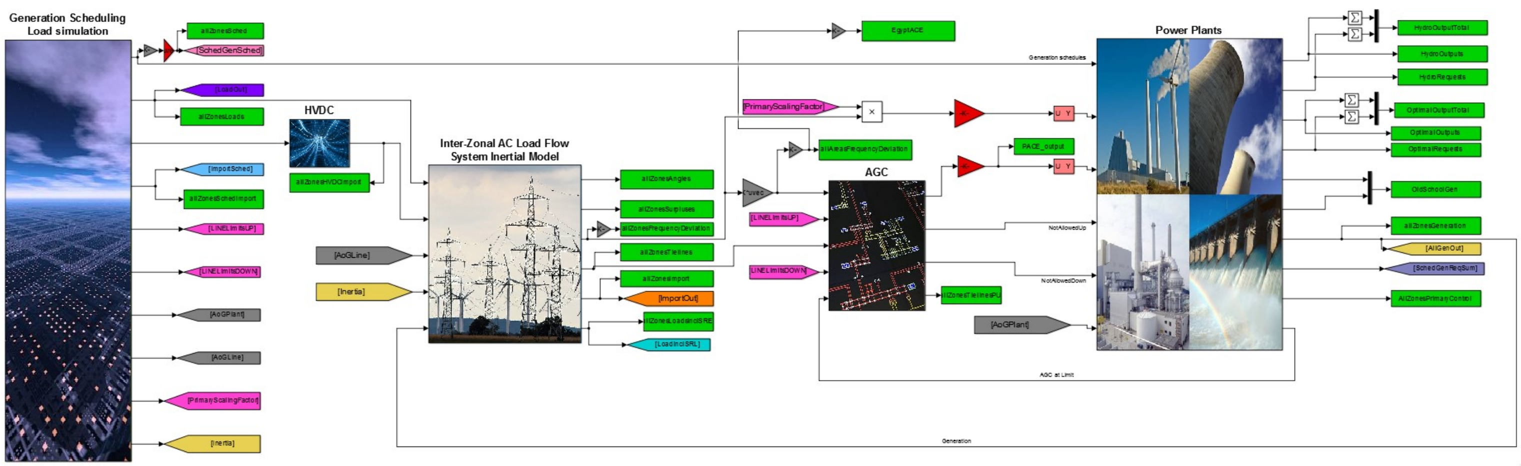
$$\delta = \int 2\pi \Delta f \, dt$$

Control actions

- Control actions:
  - Inertia
  - Self-regulating load
  - Primary Control / Frequency Containment Reserve (FCR);
    - can be composed by a number of mitigating measures
  - Secondary Control / Frequency Restoration Reserve (FRR) / Automatic Generation Control (AGC)

KERMIT implementation in MATLAB/Simulink

- Excel file for input data
- Simulink GUI running MATLAB code
- Model is scalable and fast
- Typical simulation span: midnight to midnight



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Questions which can be addressed with Kermit

Questions that KERMIT can address

- What is the **impact of increasing renewables** on grid balancing and frequency control in your system?
- Can the grid handle **increased ramping from HVDC** interconnections, renewables or changing market dynamics?
- Is the current **market design** capturing the full potential of fast regulation resources such as batteries?
- Will a **new technology** perform properly when integrated into a grid?

Frequency response with new technology support

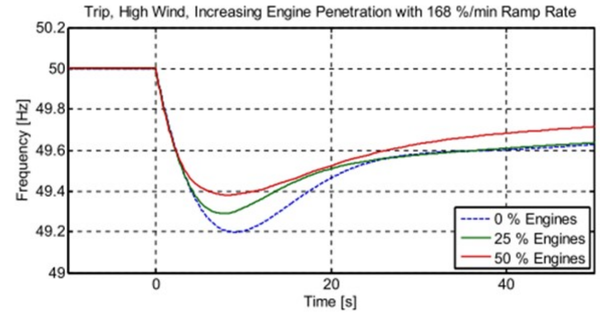
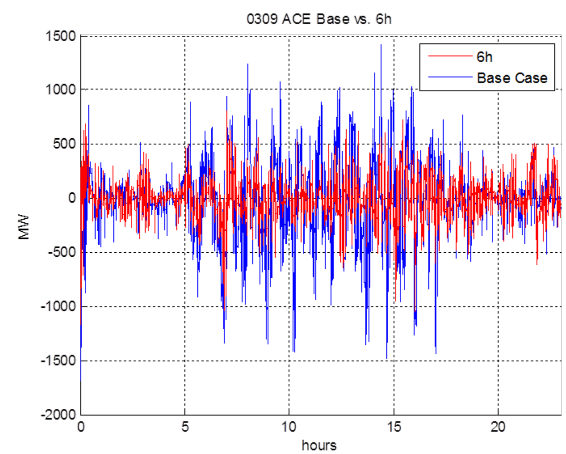


Figure 14: Trip event with increasing combustion engine penetration, high wind, first 50 seconds.

ACE with vs. without storage mitigation



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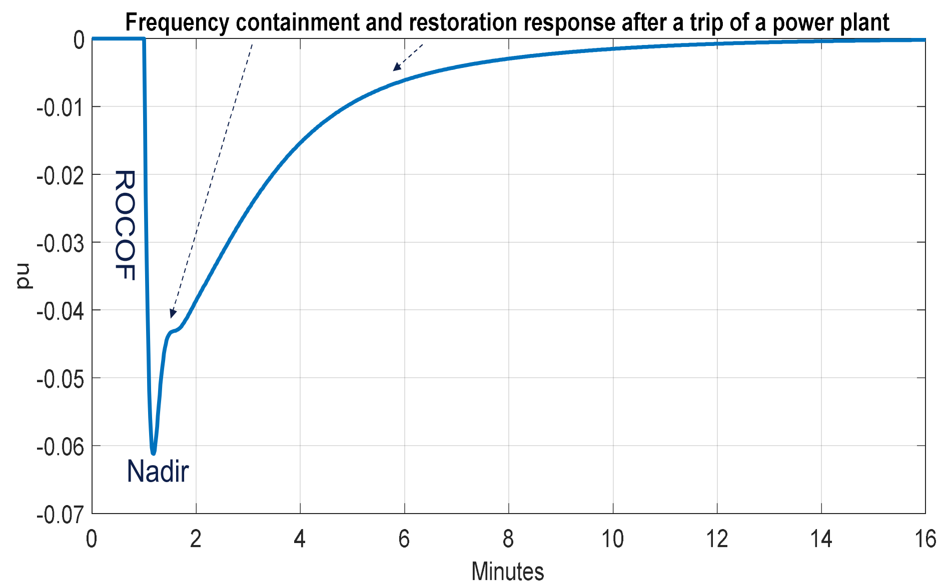
Points of attention further in this presentation

- ROCOF
- Nadir
- The frequency containment and
- The frequency restoration response of power systems



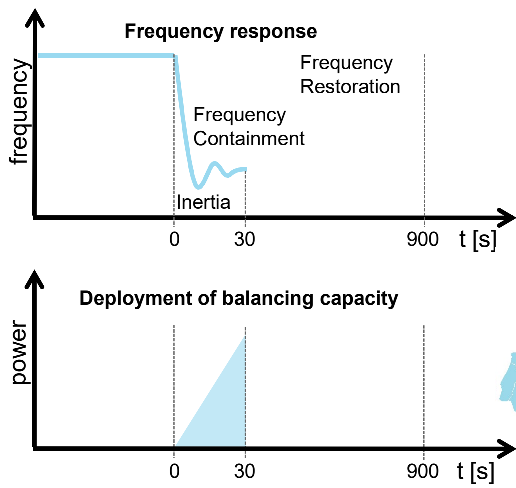
Topics in the case of large amount of renewable generations and/or analysing new concepts

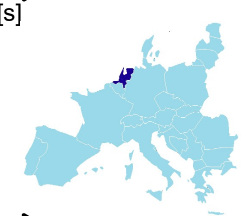
Power Balancing

Frequency containment and frequency restoration response of power systems

Frequency stability and power imbalance modelling

System response during trip of generator





- Imbalance can be caused by:
  - Generator and/or network trips
  - Prediction errors for load and/or generation, especially renewable generation

Source: Frunt, 2011.

Frequency containment reserves, requirements and implementation

- ENTSO-E
  - A proportional control maintains the balance between generation and load
  - A 3000MW disturbance should lead to a quasi steady-state frequency deviation of 200mHz
  - The frequency must be stabilized within 30 seconds

- Implementation in NL until Jan 2014
  - All units with Pnom > 60MW → 1% reserve
  - All units with 5MW < Pnom < 60MW → 3% reserve
- Primary control market since Jan 2014 → TSO single buyer market
  - Offfered bids completely activated at Δf +/- 200mHz

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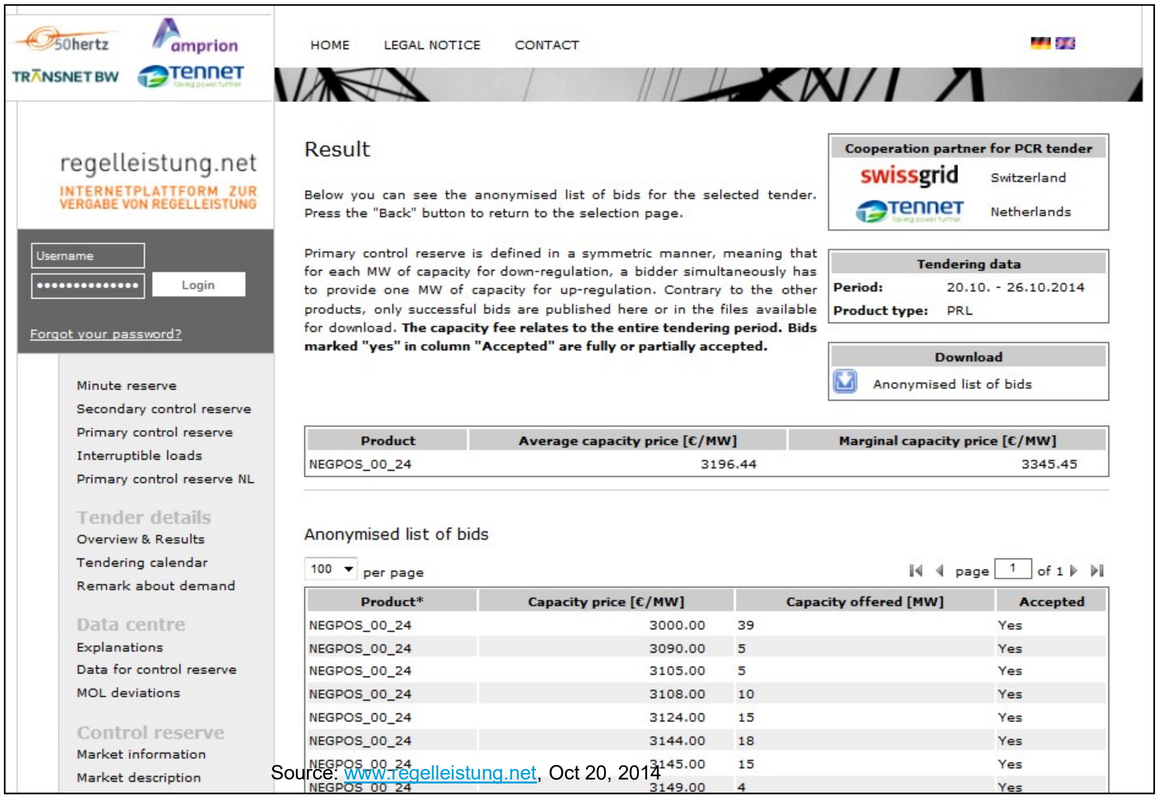
Trading platform for primary reserves (FCR) cross border used in Europe



50hertz amprion TRANSNET BW TenneT

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INTERNETPLATTFORM ZUR VERGABE VON REGELLEISTUNG

Username
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Minute reserve
Secondary control reserve
Primary control reserve
Interruptible loads
Primary control reserve NL

Tender details
Overview & Results
Tendering calendar
Remark about demand

Data centre
Explanations
Data for control reserve
MOL deviations

Control reserve
Market information
Market description

Result

Below you can see the anonymised list of bids for the selected tender. Press the "Back" button to return to the selection page.

Primary control reserve is defined in a symmetric manner, meaning that for each MW of capacity for down-regulation, a bidder simultaneously has to provide one MW of capacity for up-regulation. Contrary to the other products, only successful bids are published here or in the files available for download. **The capacity fee relates to the entire tendering period. Bids marked "yes" in column "Accepted" are fully or partially accepted.**

Cooperation partner for PCR tender
swissgrid Switzerland
TenneT Netherlands

Tendering data
Period: 20.10. - 26.10.2014
Product type: PRL

Download
Anonymised list of bids

Product	Average capacity price [€/MW]	Marginal capacity price [€/MW]
NEGPOS_00_24	3196.44	3345.45

Anonymised list of bids

100 per page page 1 of 1

Product*	Capacity price [€/MW]	Capacity offered [MW]	Accepted
NEGPOS_00_24	3000.00	39	Yes
NEGPOS_00_24	3090.00	5	Yes
NEGPOS_00_24	3105.00	5	Yes
NEGPOS_00_24	3108.00	10	Yes
NEGPOS_00_24	3124.00	15	Yes
NEGPOS_00_24	3144.00	18	Yes
NEGPOS_00_24	3145.00	15	Yes
NEGPOS_00_24	3149.00	4	Yes

Source: www.regelleistung.net, Oct 20, 2014

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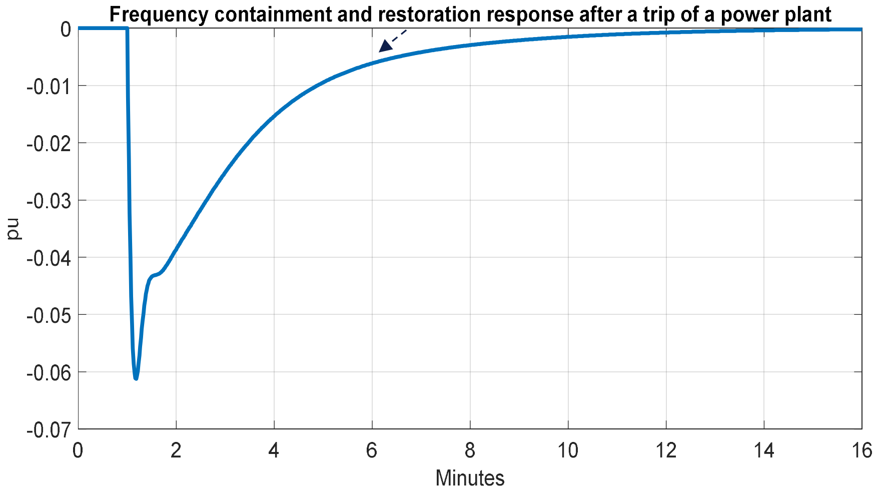
Frequency **restoration** reserves, requirements and implementation



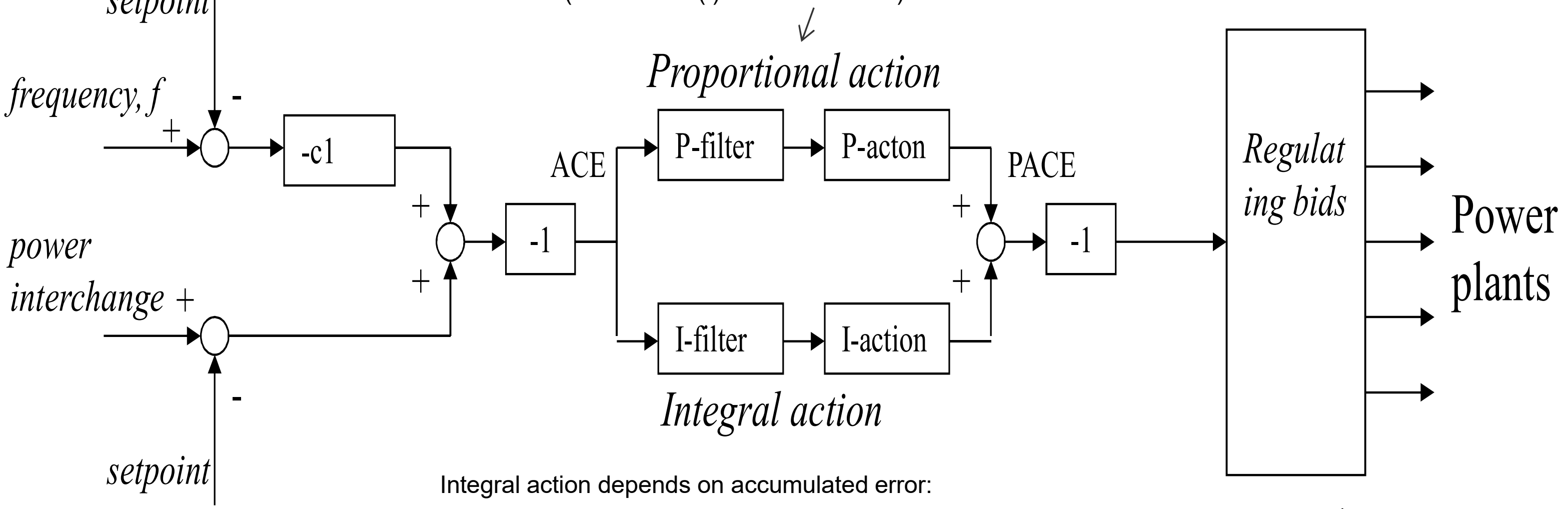
- ENTSO-E
  - Restore the power balance in each zone and restore the frequency
  - PI-controller
  - Restore the frequency within 15 minutes after a large disturbance

AGC mechanism

Proportional action depends on present error:

$$P_{\text{out}} = K_p \, e(t)$$

(error term e(t) here is the ACE)



Integral action depends on accumulated error:

$$I_{\text{out}} = K_i \int_0^t e(\tau) \, d\tau$$

e.g. maximum
rate of change
7%/min of bid

Other ACE requirements

- ENTSO-e is also having a measure to keep ACE within acceptable deviations, based on ACE statistics

Synchronous Area Fr
Agreement (SA
for

- Measure in which other issues can be judged:
  - Forecast errors of VRES
  - Amount of reserves
  - Other mitigating measures

LFC-Block	Belonging LFC-Area
OST	OST
APG	APG
SHB	NOS BiH, HOPS, ELES
Elia	Elia
ESO	ESO
SG	SG
CEPS	CEPS
TNG, TTG, AMP, 50HZT, EN, CREOS	TNG, TTG, AMP, 50HZT, EN, C

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Challenges with large amount of renewable generation.

An example: Ireland

Challenges with large amount of renewable generation *Ireland*

- Ireland is having a relative small and sensitive grid

- Ireland is having in 2020 65% installed System Non-Synchronous Penetration (SNSP) and intends to grow to 95% SNSP in 2030

- Is having a structured way to implement and check described in →

EIRGRID

System Services
Future Arrangement
Scoping Paper

Challenges with large amount of renewable generation *Ireland*

For 2020 they did design and implement the


Conceptual market org
for the provision of in
system services: role
associated market de
regulatory frame
D3.2
European
Horizon 2020

Category	Scarcity	Potential System Services
Frequency Stability & Control	Insufficient contingency reserve	DS3 FFR, POR, SOR, TOR, RR
	Lack of inertia	DS3 SIR
Voltage Control	Lack of Steady state reactive power	DS3 SSRP
	Lack of dynamic reactive power	DS3 DRR, DS3 FPFAPR
	Lack of system strength	DS3 DRR
Rotor angle	Lack of synchronising	DS3 DRR

Challenges with large amount of renewable generation
Ireland

Technical topics summarised:

- Frequency Stability & Control
- Ramping
- Voltage Stability
- Rotor Angle Stability
- Congestion
- Adequacy

Role of Kermit can be:

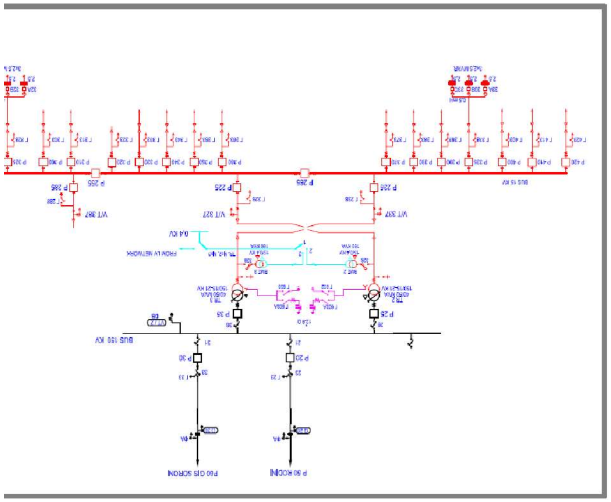
Technical topics summarised:

- Frequency Stability & Control
- Ramping

} Can be dealed with Kermit

- Voltage Stability
- Rotor Angle Stability
- Congestion
- Adequacy

} Herefore you need detailed modeling e.g.→ Need of PSSE or Power Factory



Impression projects

Recent and ongoing projects

EU Horizon 2020: Ad
operation of large Wi

- Ancillary service ad
  to the grid *(Publicat*

Colombian ISO: Integ

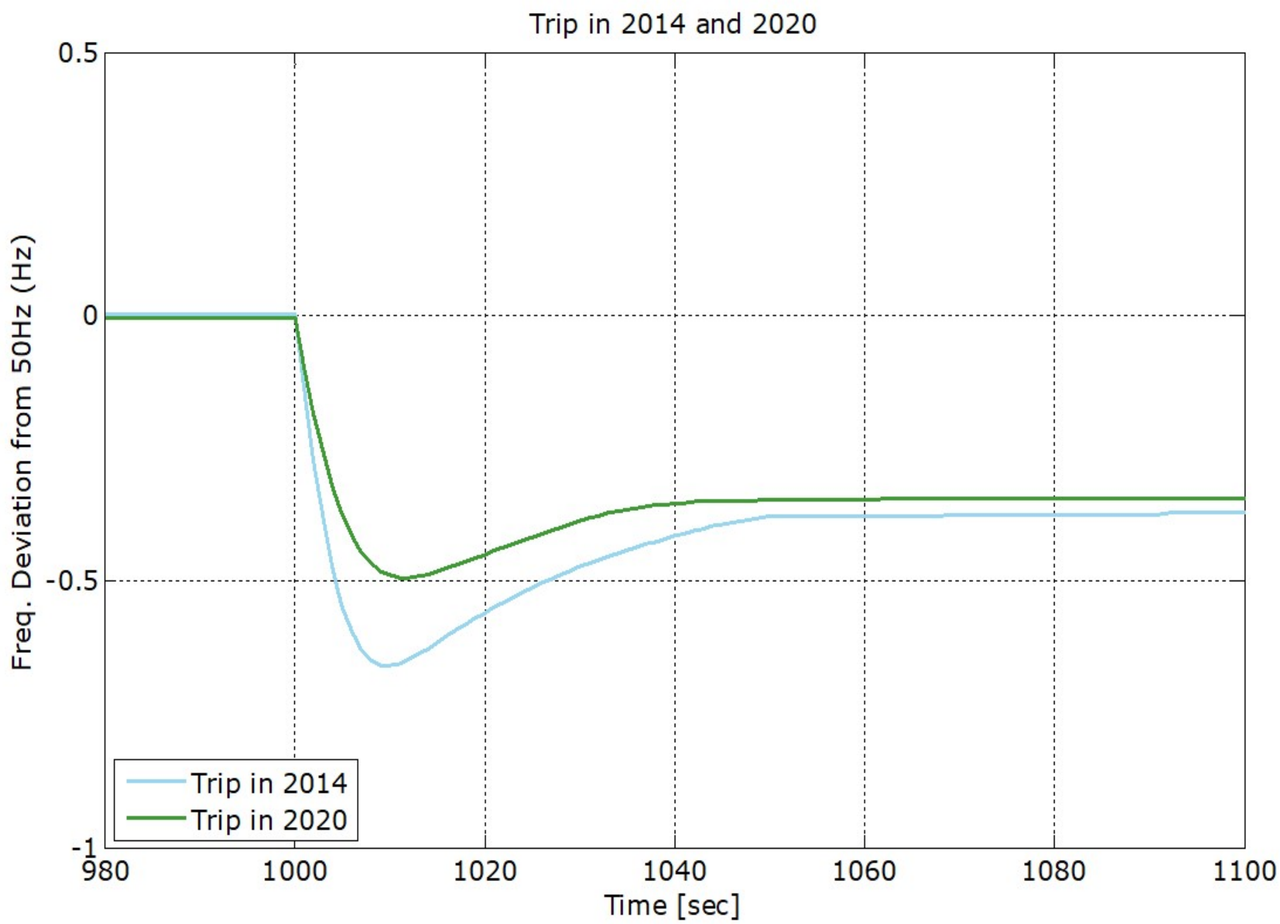
- RES integration stu

Ukraine: Energy syst

- Additional Flexibility

Smart4RES: Test an

- European collabora
- Model validation



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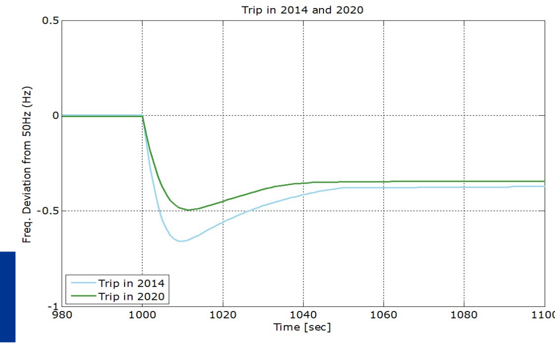
Recent and ongoing projects



EU Horizon 2020: Advanced integrated supervisory and wind turbine control for optimal operation of large Wind Power Plants

- Ancillary service adequacy: To show the potential role of wind farms in providing ancillary services and virtual inertia to the grid *(Publication WIW 2020)*

Colombian ISO: Integrating variable renewable energy technologies in the Colombian grid

- RES integration study: Insight in the feasibility of increasing the penetration of RES in the Colombian power system

Ukraine: Energy system storage (ESS) project

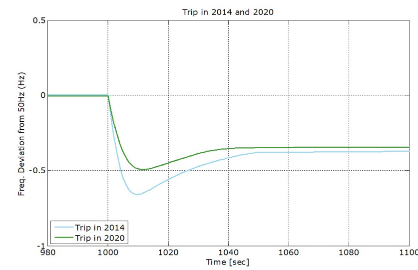
- Additional Flexibility Analysis with KERMIT (FCR from BESS and load shedding).

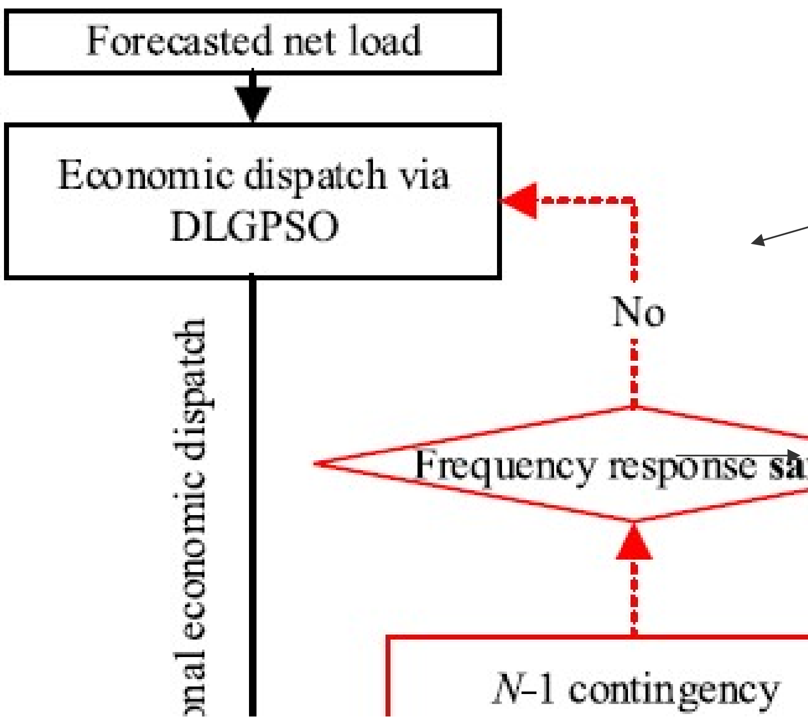
Smart4RES: Test and validation Project

- European collaborative R&D Project funded under the H2020 program
- Model validation

Kermit in Smart4Res project

System operator advisory system for evaluating synchroneous inertia adequacy; case Rhodos





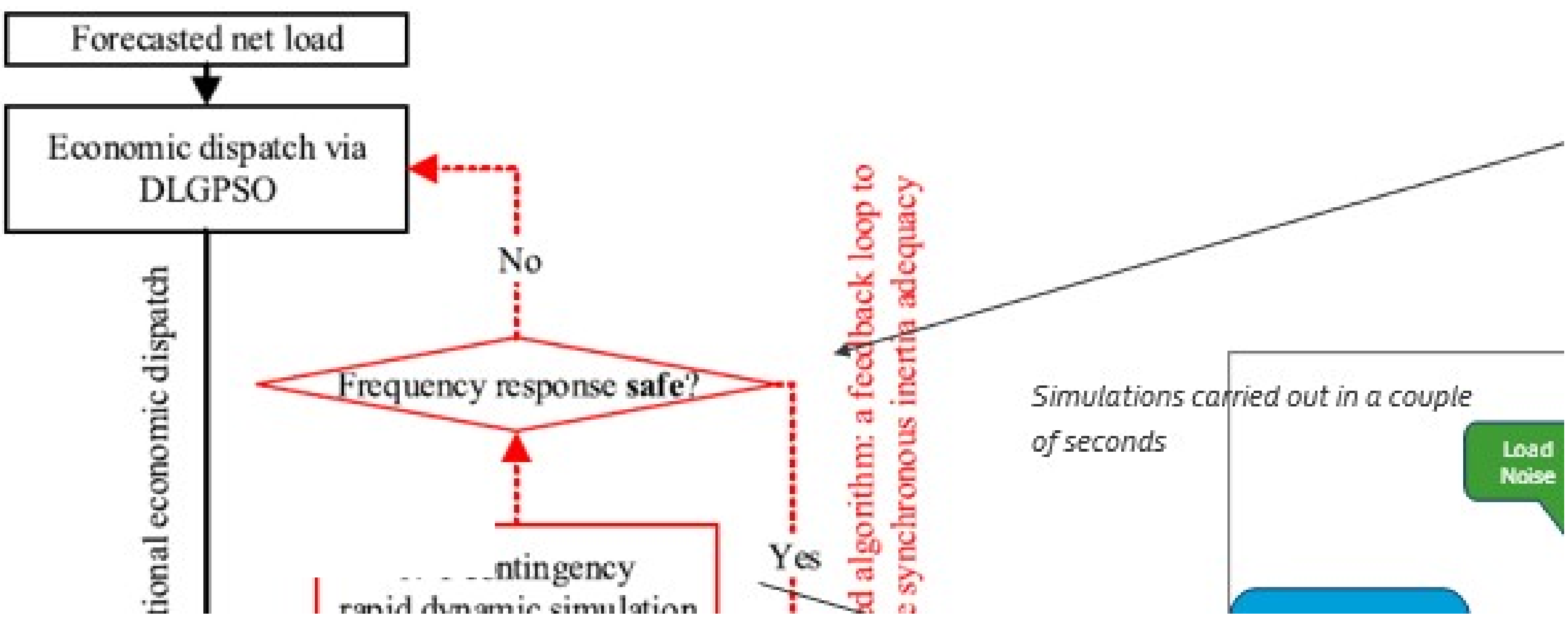
Smart4Res is having a two steps approach

- A dynamic simulation platform in PSS/E was develope Rhodes island power system. This was performed acco received by HEDNO

ANN

System operator advisory system for evaluating synchroneous inertia adequacy; alternative option

Current main focus:
Set up Kermit for Rhodos simulations



Demo of Kermit in the Smart4Res project

Maurin Hörler

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Questions?

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Thanks for attention!

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