

# MICROGRIDS ALS BLUEPRINT FÜR EINE STABILE STROMSYSTEMTRANSFORMATION

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and Casper Roos, Marie Krause, Kirsten Kleis, Maria Jarolin

22. September 2017  
Strommarkttreffen, Berlin



HUMBOLDT-UNIVERSITÄT ZU BERLIN



Sabine Auer, Strommarkttreffen, Berlin, 22. September 2017



# CoNDyNet ALS FORSCHUNGSUMGEBUNG

## CoNDyNet

STROMNETZE

Forschungsinitiative der Bundesregierung



MAX-PLANCK-GESELLSCHAFT



JACOBS  
UNIVERSITY



JÜLICH  
FORSCHUNGSZENTRUM



FIAS Frankfurt Institute  
for Advanced Studies



PIK

## Industry



SIEMENS



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# ZANZIBAR: 3 MONATIGES BLACKOUT



BBC  
NEWS

## Week-long blackout hurts Zanzibar

**Businesses in Zanzibar are closing down and residents are bemused as a power cut affecting the whole of the Tanzanian island enters its eighth day.**

The BBC's Frederica Boswell in Zanzibar says there has been little official information about the blackout.

It began after a massive power failure in Tanzania; power was restored quickly on the mainland, but not in Zanzibar.

There are concerns that without running water, usually pumped into homes, there could be an outbreak of cholera.

It is Zanzibar's worst power crisis for years, our correspondent says.

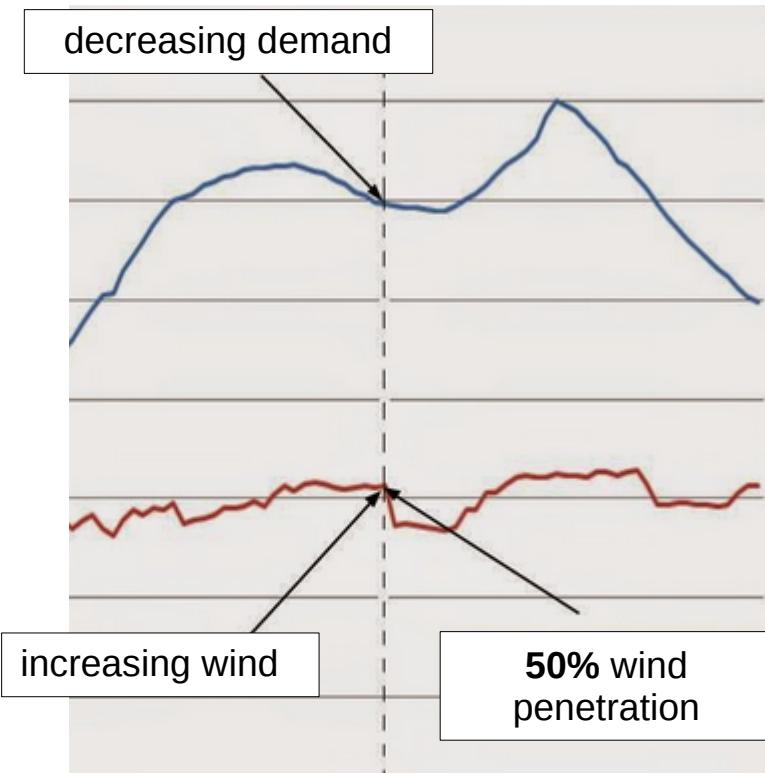


The price of water has doubled on the island

# INSELN WERDEN “GRÜN”



**Penetrations Limit (55% für Ireland)**

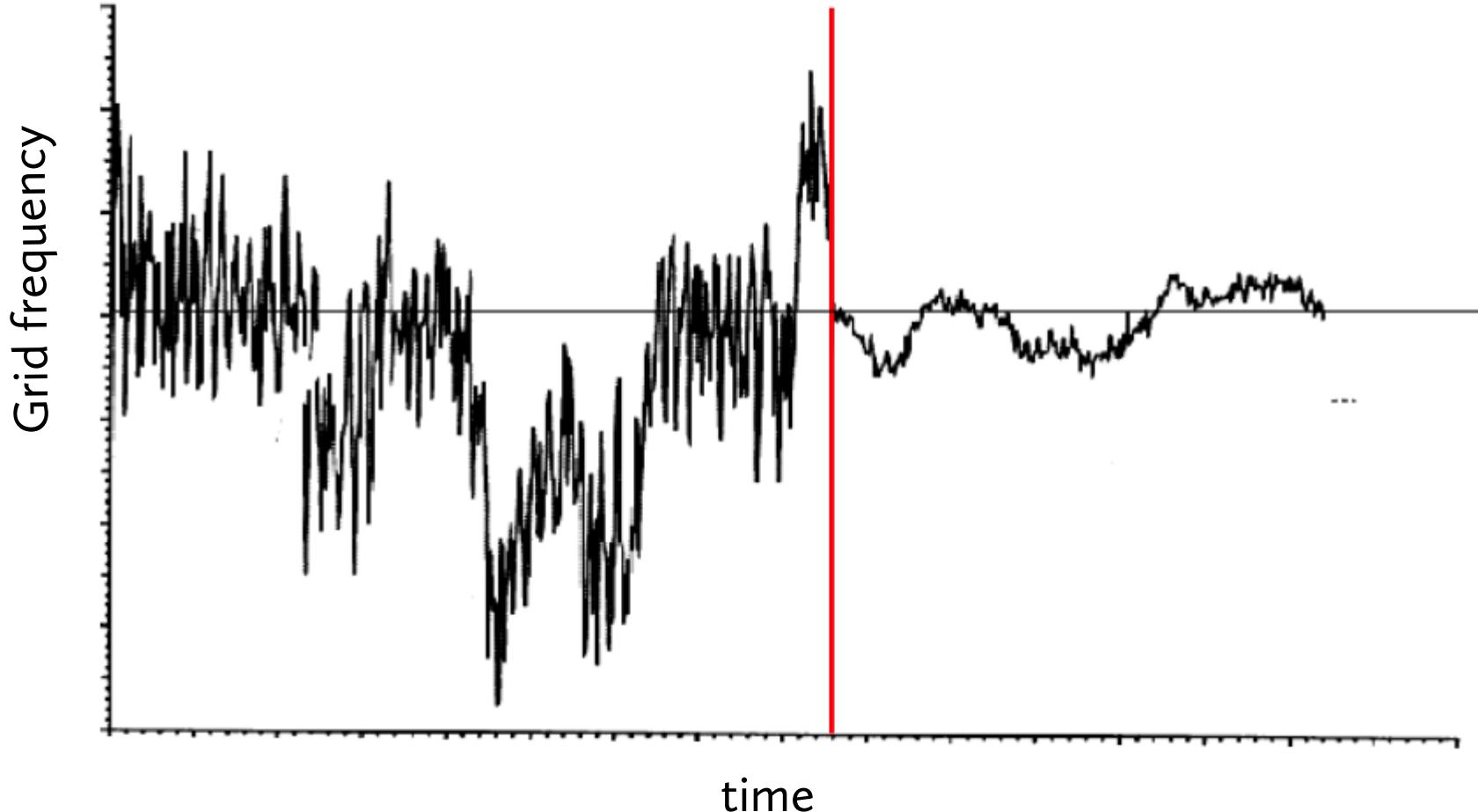


Auf Grund dynam. Netzstabilität



# UMSO KLEINER, UMSO SCHWIERIGER

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Bildquelle:Energie-Museum Berlin

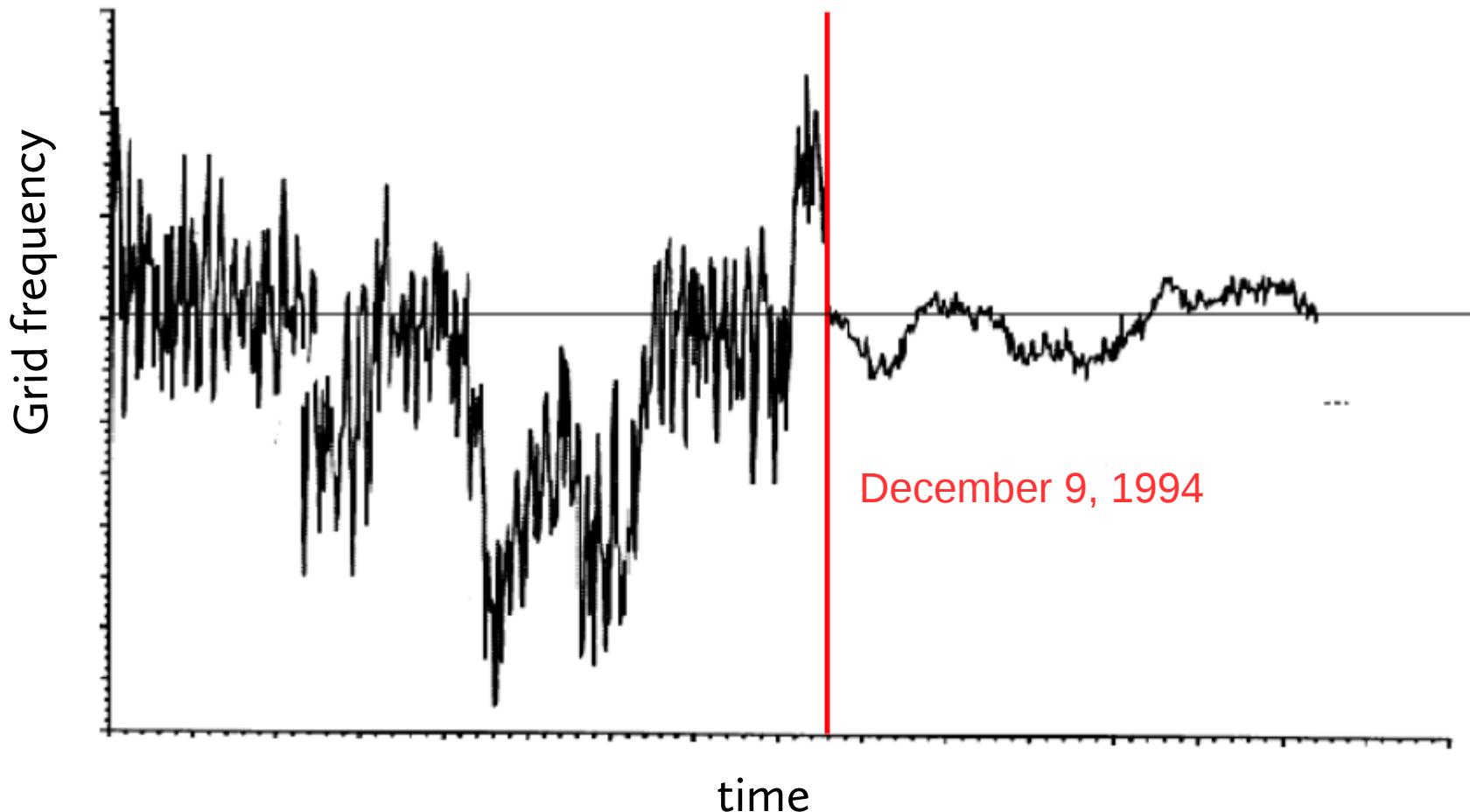
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# UMSO KLEINER, UMSO SCHWIERIGER

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Westberlin verbindet sich wieder mit Kontinentaleuropa

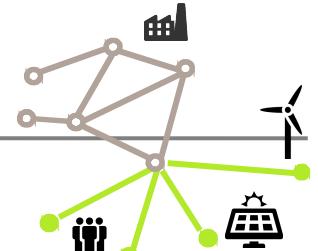


Bildquelle:Energie-Museum Berlin

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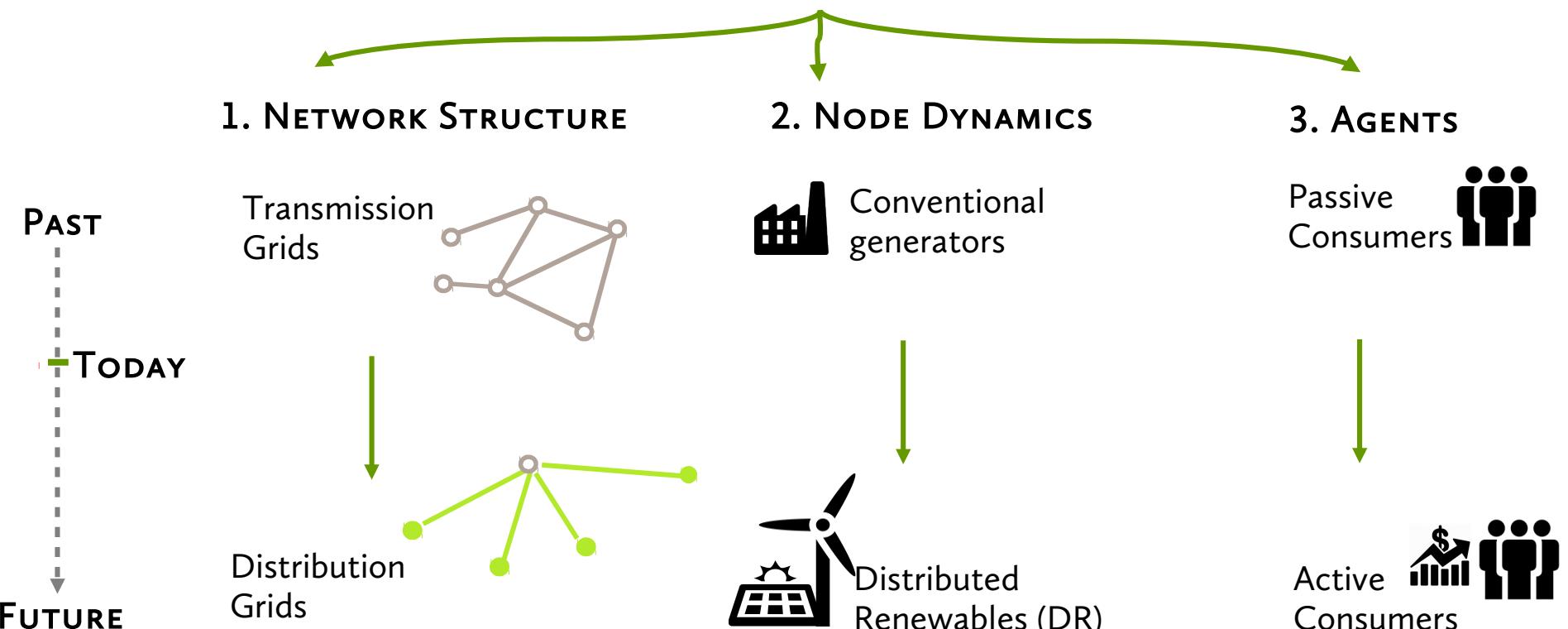
# FRAGEN ZUR STABILITÄT GRÜNER NETZE



Overarching Questions:

1. How to improve resilience with new methods developed at PIK?
2. How to enable a dynamically stable integration of renewable energies?

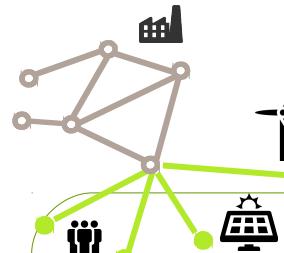
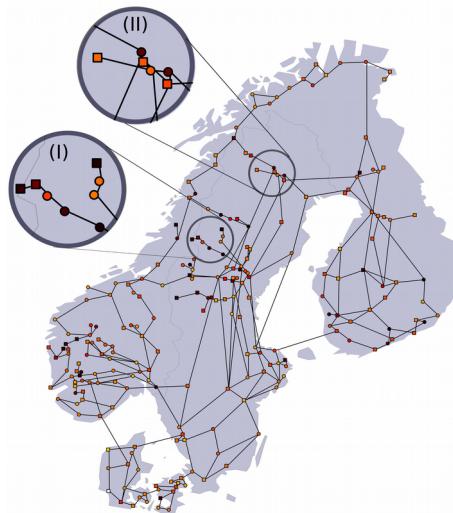
## CONCEPTUAL MODEL



# AUSGEWÄHLTE FORSCHUNGSTHEMEN

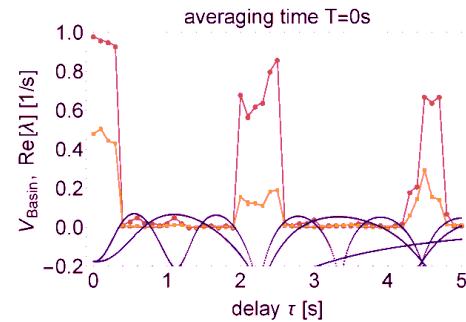
*1. How to improve the grid's resilience?*

Grid resilience  
against large  
perturbations

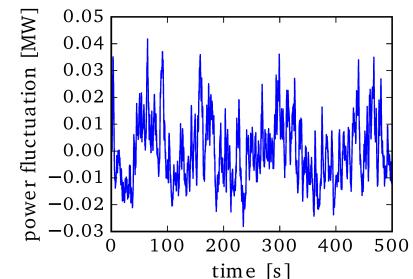


*2. How to enable a dynamically stable integration of renewable energies?*

How inverters  
change the grid  
dynamics



Robustness towards  
intermittent  
fluctuations

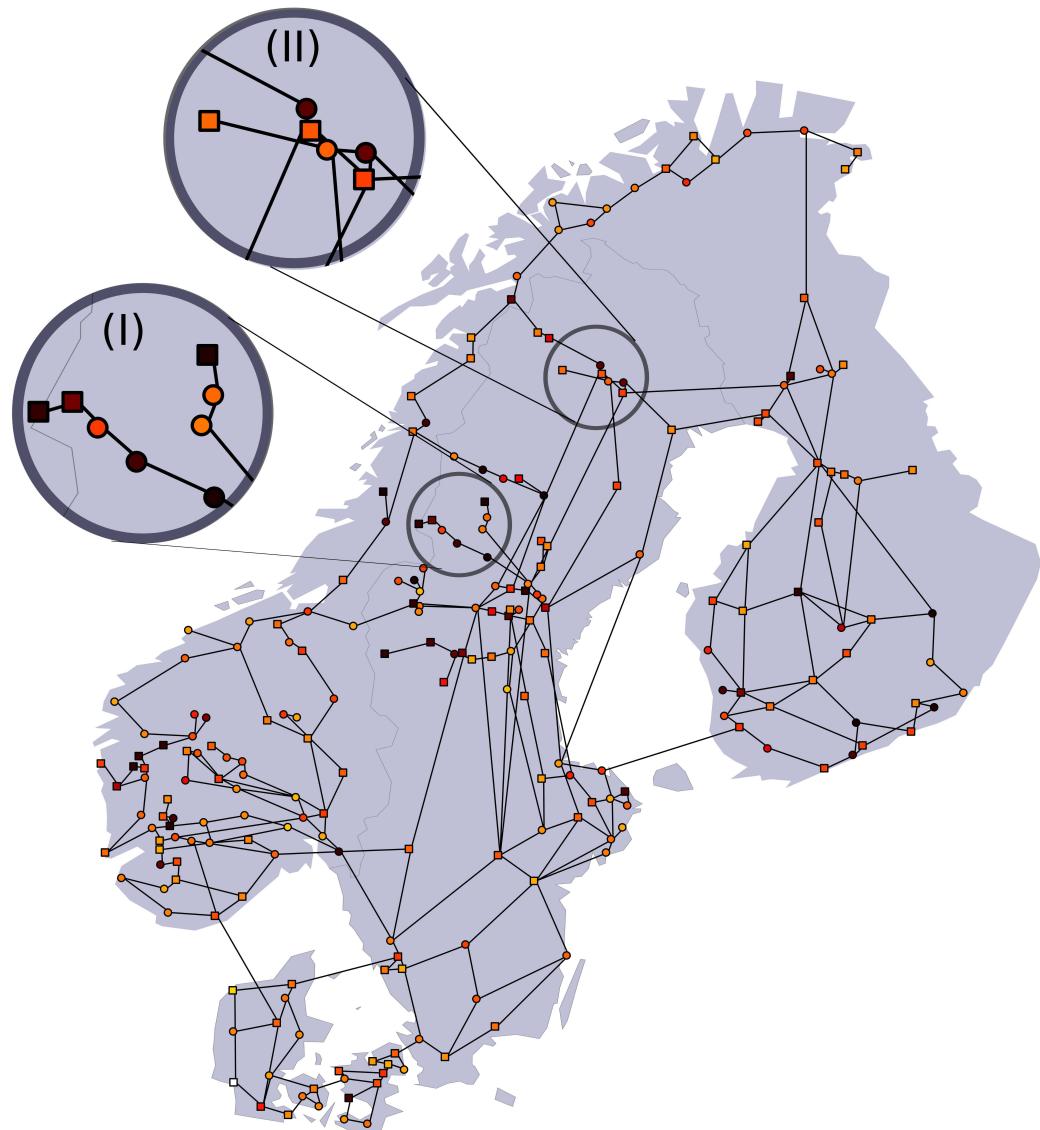
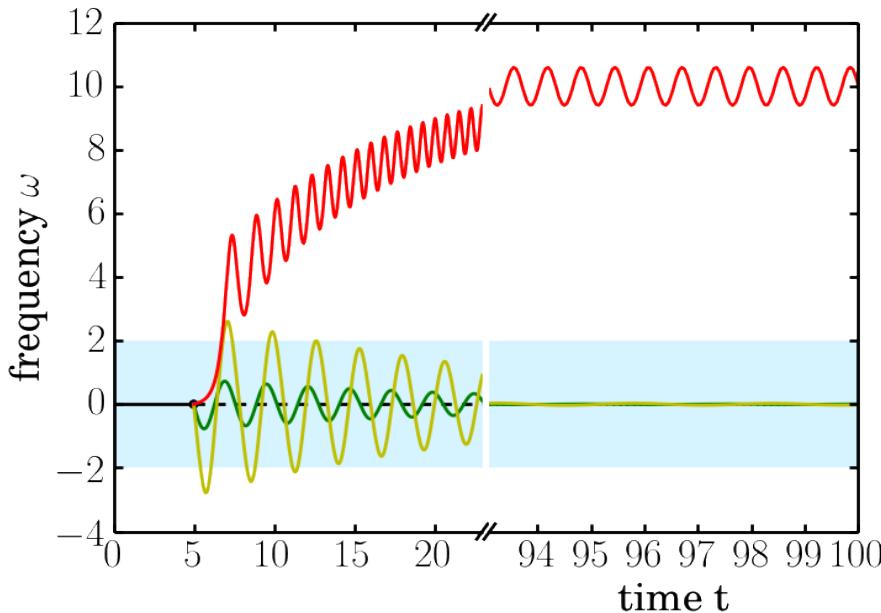


# NETZRESLIENZ

... gegenüber Extremereignissen

Identifizierung von  
Schwachpunkten im Netz

Durch neue Stabilitätsmethoden  
(Basin Stability, Survivability)

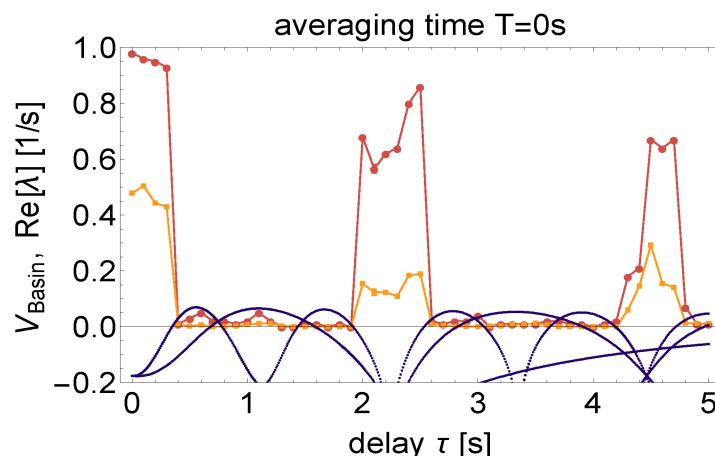


S. Auer et. al. (2015) EPJ ST

# LEISTUNGSELEKTRONIK & NETZSTABILITÄT

“netzfolgend”

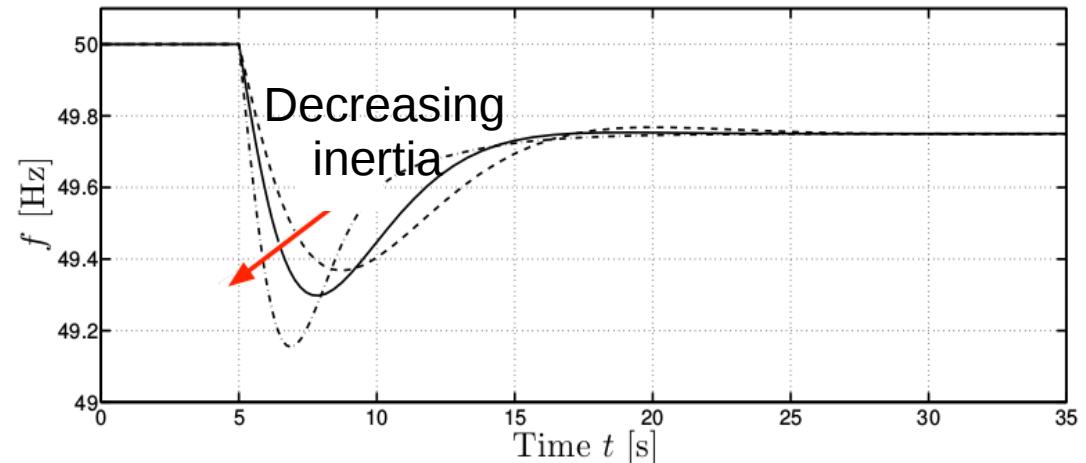
→ Mess- & Reaktionszeiten



“a response based on  $dP \sim df/dt$  [...] has been found to have adverse impact on system stability if it contains even minor delays in measurement and control actions” ENTSO-E guidance document

“netzbildend”

→ frequenzformend & virtuelle Trägheit

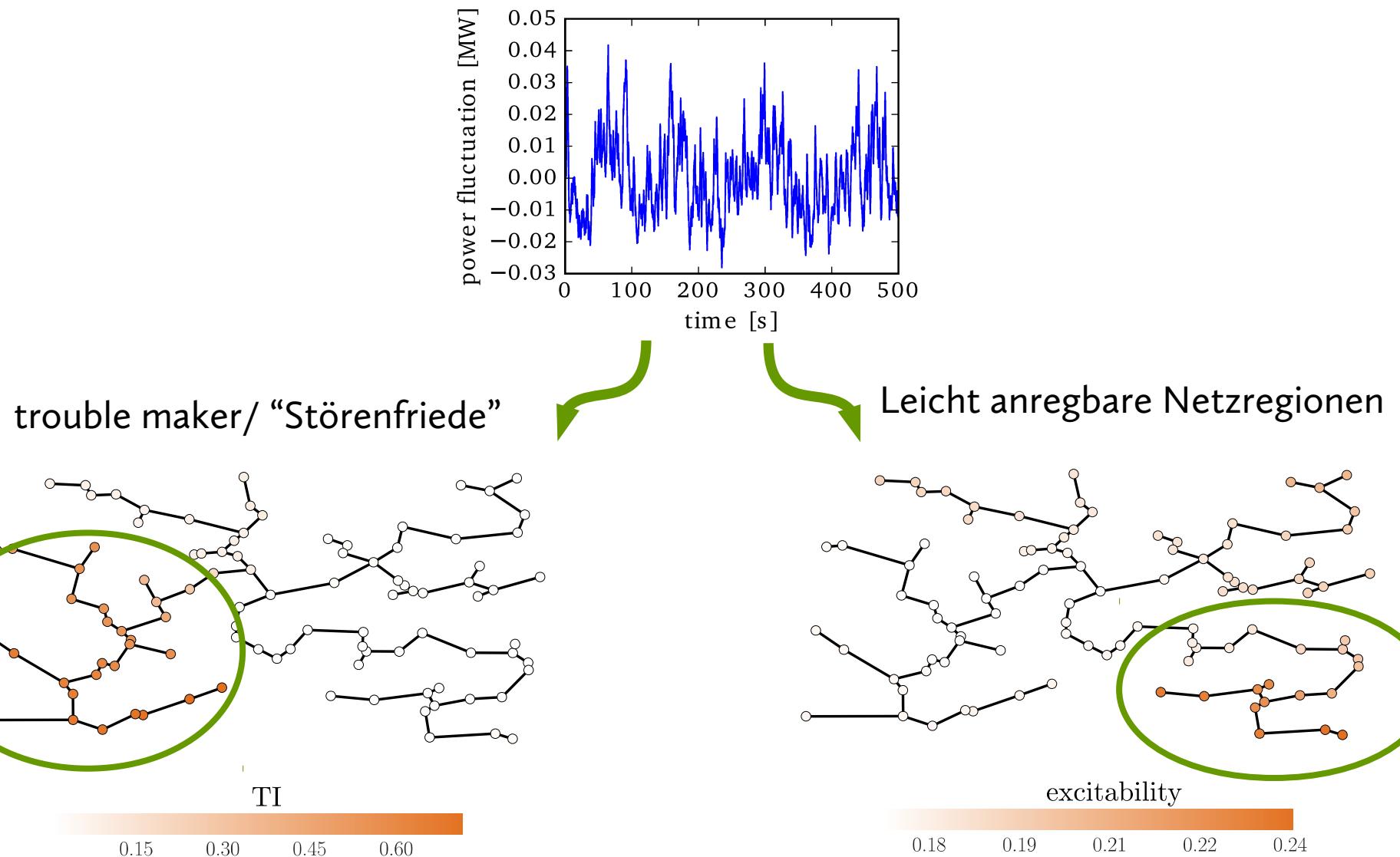


Warum brauchen wir virtuelle Trägheit?

- EE-Einspeiselimits & Abregelung (z.B. Irland)

B. Schäfer, C. Grabow, S. Auer et. al. (2015) EPJ ST

# ROBUSTHEIT GEGENÜBER FLUKTUATIONEN





Forschungstransferprojekt am PIK: *elena* (Electricity Network Analysis)

- Beratung zur Ermöglichung von 100% EE Stromnetzen
- enge Zusammenarbeit mit dem PIK
- Open-Source Python libraries für statische und dynamische Netzmodellierung

QINUS  
smart energy design



Sabine Auer



Christina Horn



Tim Kittel

# TEAM AND PARTNERS

elena  
international

## TEAM



Sabine Auer



Christina Horn



Tim Kittel

## ACADEMIC PARTNERS



Paul Schultz



Dr. Frank Hellmann

## PARTNERS



**ACEP**  
Alaska Center for Energy and Power

openmod  
open energy  
modelling initiative

**CLIMATE ANALYTICS**

**QINOUS**  
smart energy storage

**energy nautics**  
solutions for sustainable development

**XRG**  
Simulation GmbH



**Bürgerwerke**  
Energie in Gemeinschaft

**MICRO ENERGY**  
INTERNATIONAL



Prof. Raisch



Lia Strenge



Prof. Dörfler



Technische  
Universität  
Berlin

**TU**  
berlin

**P I K**

**ETH** Zürich



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# PILOT PROJEKT

# 2 Microgrid Kommunen in Alaska

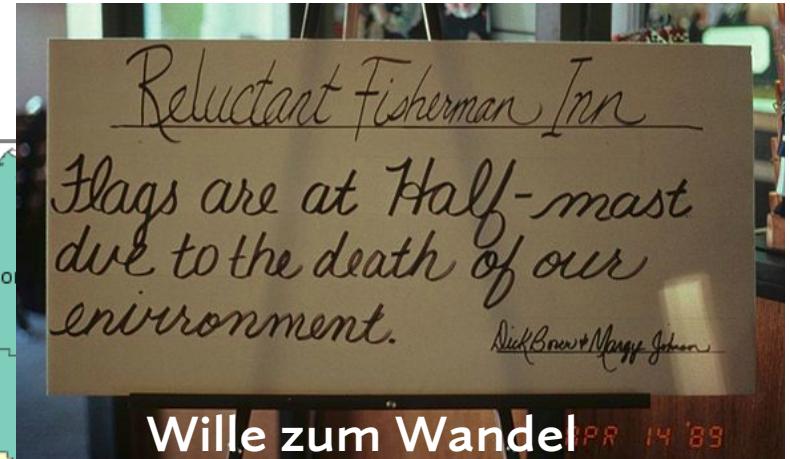
**Dieseltransport → hohe Energiekosten**



An aerial photograph of a coastal town, likely Haines, Alaska. The town is nestled at the base of a range of mountains, some of which are covered in snow. In the foreground, there's a large industrial or port area with several buildings and docks. To the right, a marina is visible with many boats. The town itself is surrounded by dense forest. The water is a deep blue-green color.

Aleutians West

# Lokale Ressourcen



# Wille zum Wandel



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**Danke für die Aufmerksamkeit!**



# BACK-UP SLIDES

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elen  
international

# RENEWABLE GENERATOR DYNAMICS

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Inverters can be programmed in different modi to do:

## 1) Droop control for frequency stabilization

input signal:  $\omega_i(t)$ , output:  $P_i(t)$ ,  
measurement time for  $\omega_i(t)$  would lead to:  
 $P_i(t) \propto \omega_i(t - \tau)$  (B. Schäfer et. al., EPJ ST 2016)

$$u_I(t) = P_i(t) = P_{d,i} - \frac{1}{\tilde{k}_{P_i}} \omega_i(t)$$

## 2) Droop control for frequency setting (virtual synchronous machines or “netzbildend”)

input signal power deviation  $P_i(t) - P_{d,i}$ ,  
output signal:  $\omega_i(t)$   
low pass measurement of power:  
 $\tau_{P_i} \dot{P}_{M,i}(t) = -P_{M,i}(t) + P_i(t)$  (Schiffer et. al.  
IEEE, 2013)

$$u_I(t) = -\frac{1}{k_{P_i}} \omega_i(t) = P_i(t) - P_{d,i}$$

$P_{d,i}$  - desired active power setpoint  
 $P_i$  - actual active power  
 $k_{P_i}$  - droop constant



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Two ways to perceive inverters

- 1) first leads delayed differential equations
- 2) other approach from Schiffer et. al. IEEE, 2013

droop control for  
frequency stabilization

$$P_{M,i}(t) - P_{d,i} = -\frac{1}{k_{P_i}} \omega_i(t) \quad &$$

low pass measurement  
(acts as integrator)

$$\tau_{P_i} \dot{P}_{M,i}(t) = -P_{M,i}(t) + P_i(t)$$



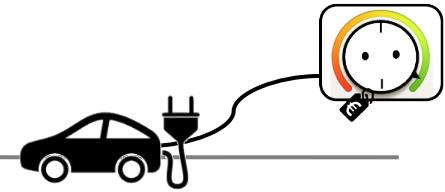
$$H_i \dot{\omega}_i(t) = -D_i \omega_i(t) + P_{d,i} - P_i(t)$$

$$P_i = \sum_j K_{ij} \sin(\theta_i - \theta_j - \alpha_{ij})$$

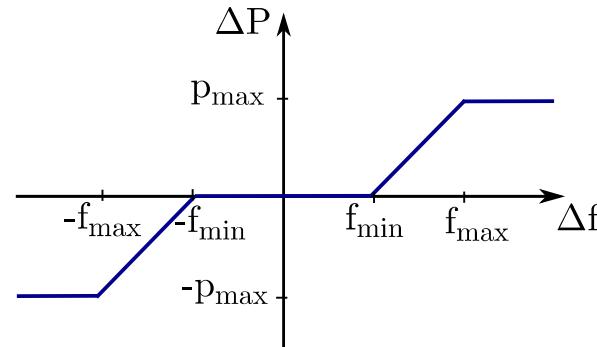
with **virtual inertia**  $H_i = \tau_{P_i}/k_{P_i}$  and damping  $D_i = 1/k_{P_i}$



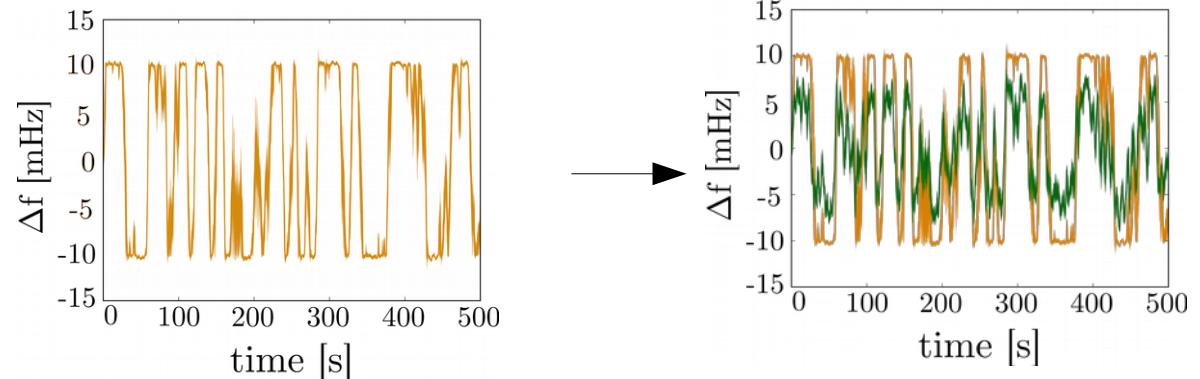
# SMART ELECTRIC VEHICLE CONTROL



Avoid demand synchronization  
**With demand ramping**



Reduce switching/ battery degradation  
**by randomization**



Assure effectiveness  
**by decentral control**

