

Dr. Reinhilde D'hulst ◀

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Presentation ◀



# Active Distribution Grids

TECHNICAL SESSION 2

SREDS19 · DOHA, QATAR · DEC. 1, 2019



# About the Speaker

Dr. Reinhilde D'hulst

- 2004 Master in Electrical Engineering
- 2009 PhD in Electrical Engineering
- Since 2009 Researcher at VITO working on:
  - modeling, simulation and optimization of (distribution) networks
  - development of smart grid solutions for electricity (distribution) grid-related issues
  - flexibility assessment and control algorithms for demand response.
  - ...





# The Challenges



Larger currents, less predictable, more concurrency

Cost 'Fit & Forget' strategy grows strongly



# The Opportunities



More measurements



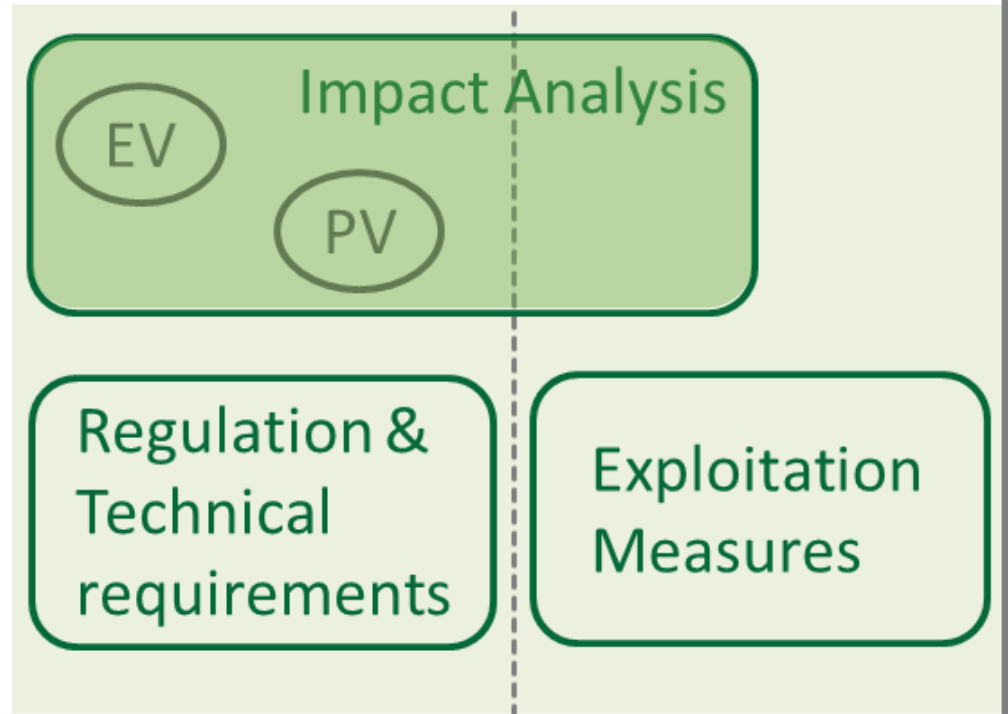
Developments in  
big data, machine learning, ...



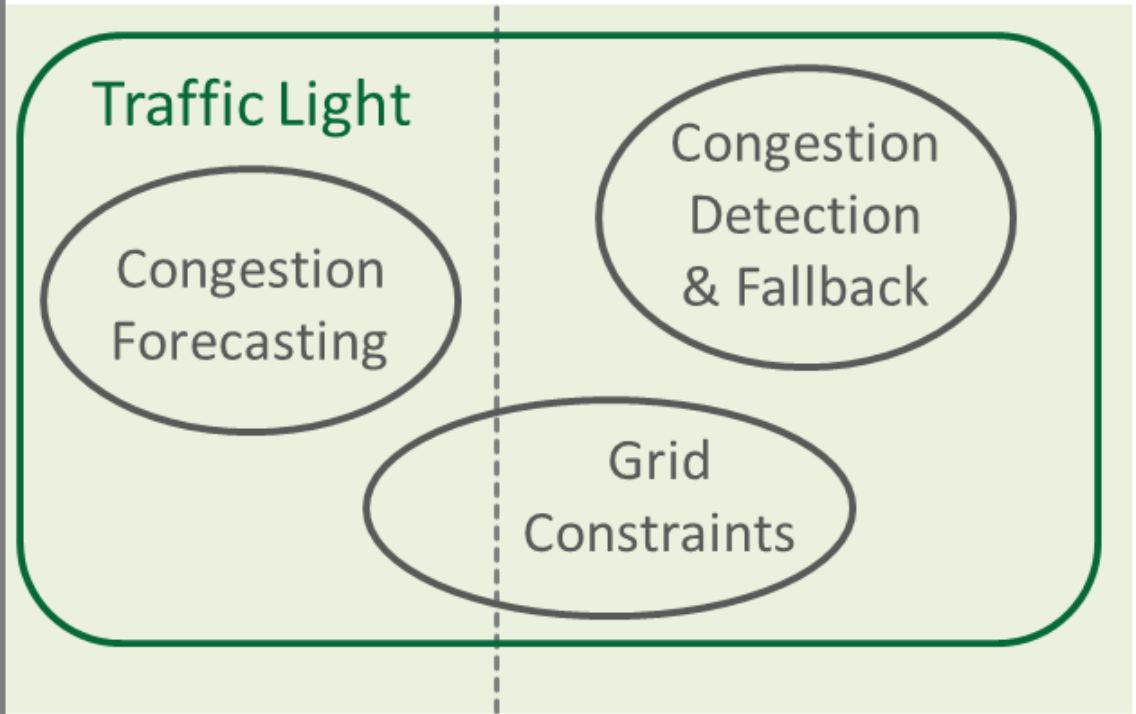
Maximize  
the grid utilization

‘Fit & Forget’ → Active Grid Management

# Planning

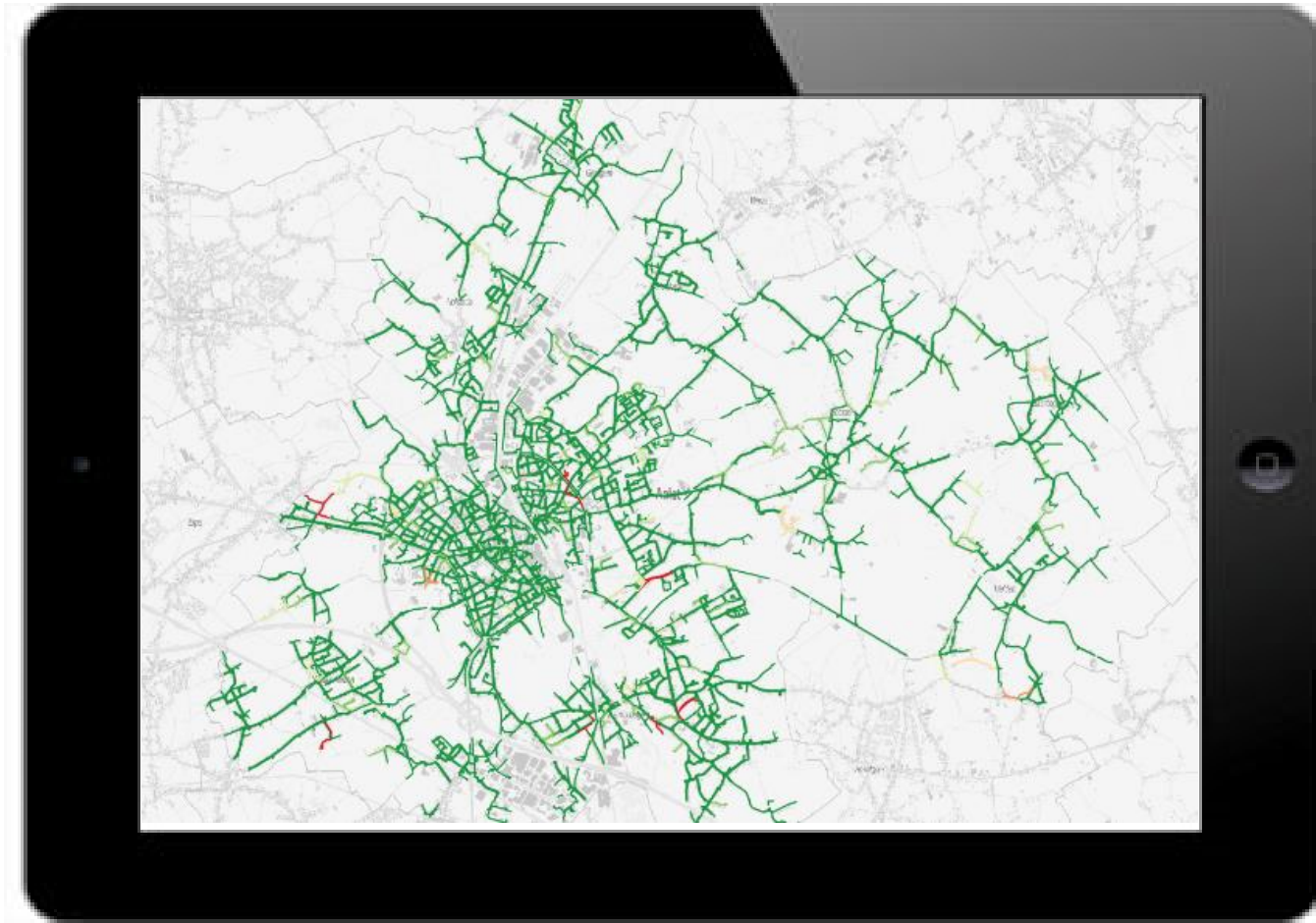


# Operations



## Active Distribution Networks

*Maximize the grid utilization*



**One platform**

**All LV grid calculations**

Statistical approach to handle  
missing grid data

3phase, unbalanced power flows

**Maximize use of assets**

**Avoid costly investments**

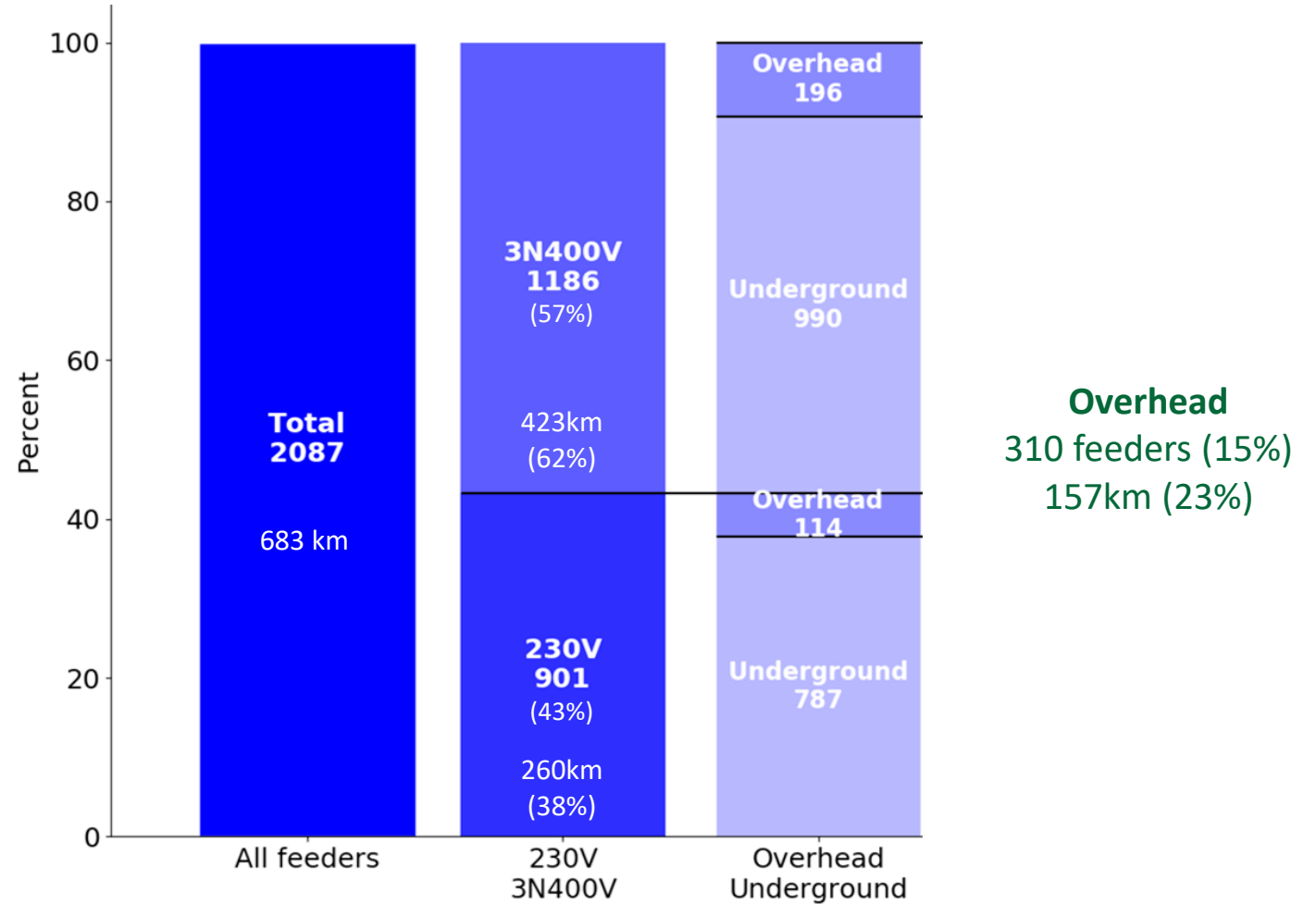
**Support regulation**



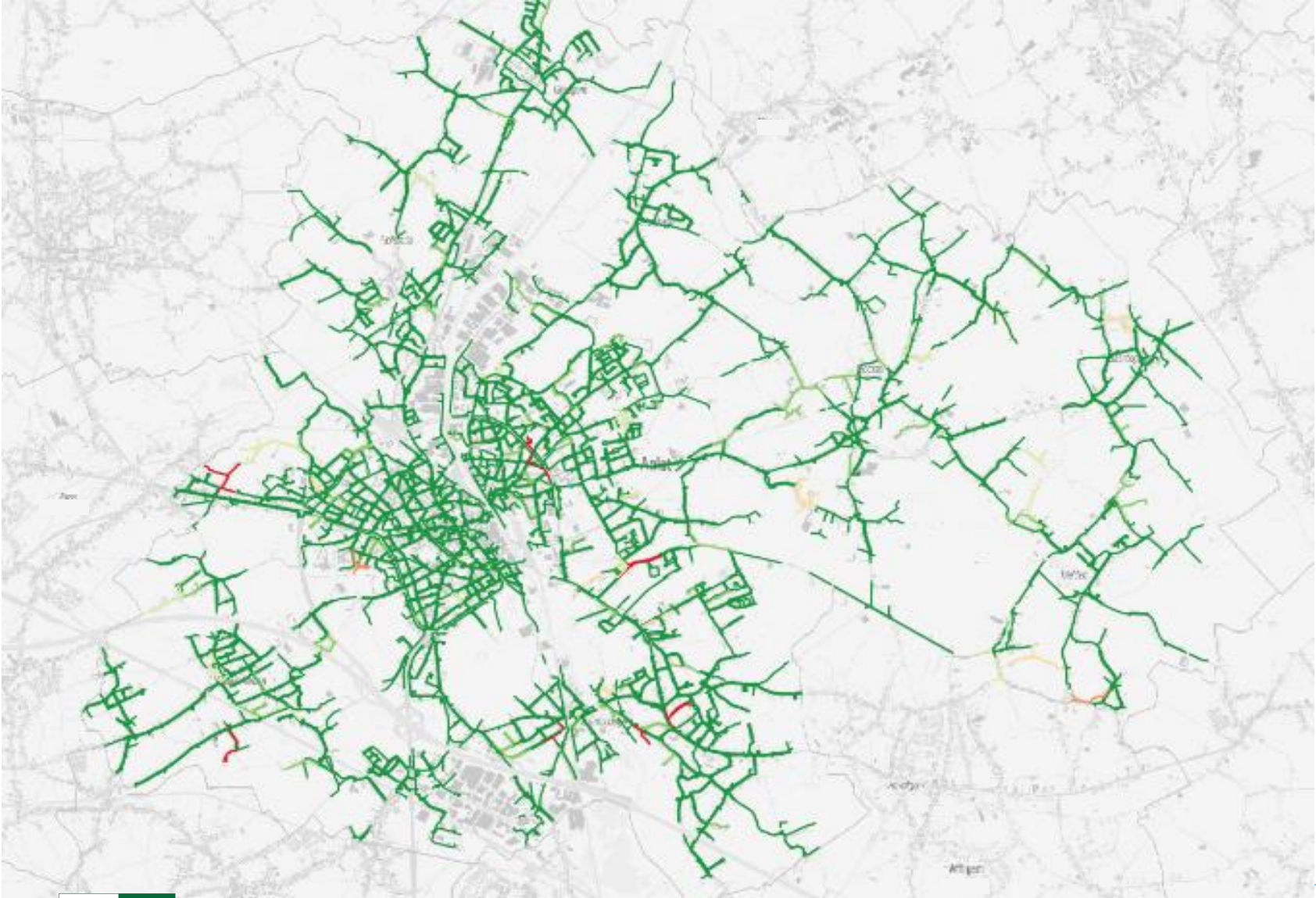
## *EV Charging Impact*

# Area investigated

Flemish center city  
421 transfo's  
2162 feeders  
44452 connections



# 0% EV situation

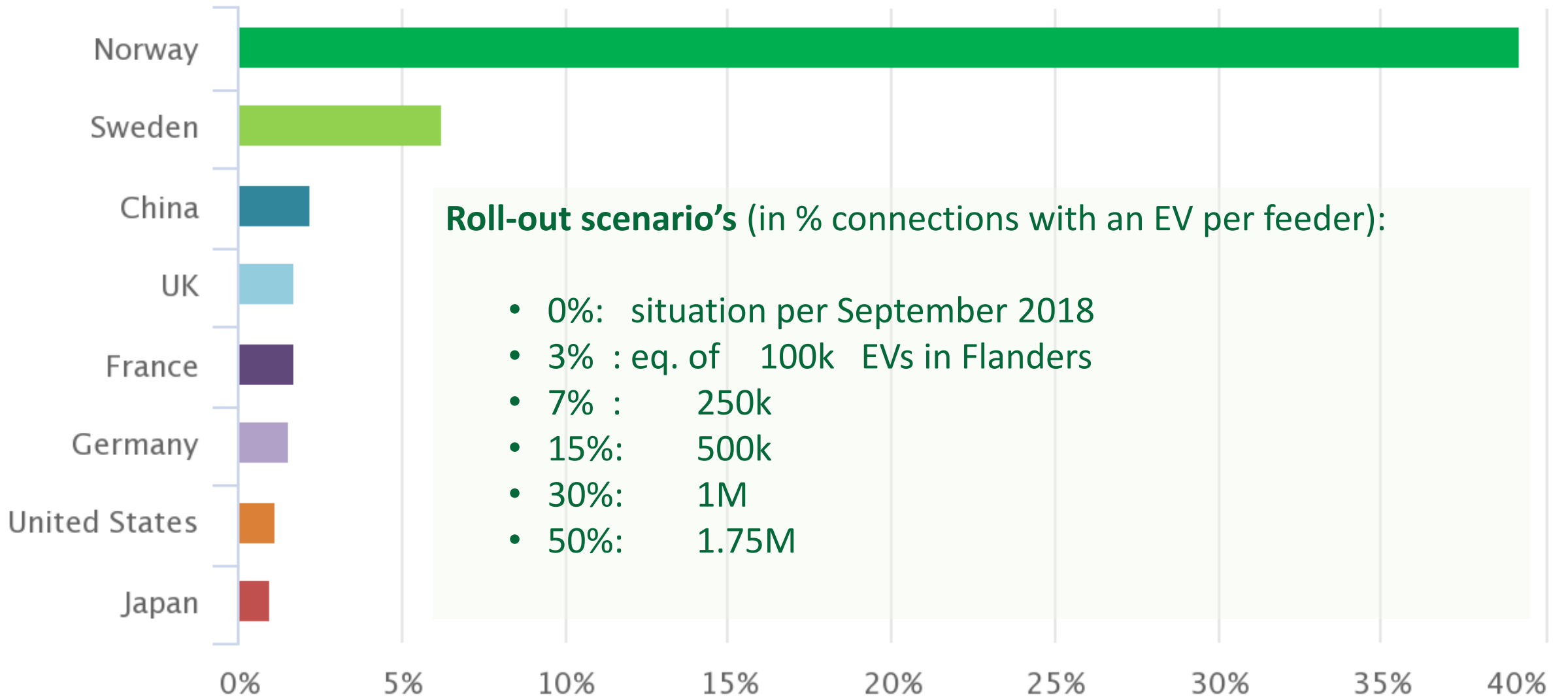


Classification	Colour	Probability of congestion
Impossible	Dark green	0 %
Very Unlikely	Green	0 – 20%
Unlikely	Light Green	20 – 40%
Possibly	Yellow	40 – 60%
Likely	Orange	60 – 80%
Very Likely	Red	80 – 100%

The image shows two men in blue work uniforms working on an electrical control panel. The man on the left is focused on a task, while the man on the right looks towards the camera. The panel is filled with various electrical components, including switches and wiring. A semi-transparent white box with green text is overlaid on the center of the image.

## Congestions investigated:

- Feeder overcurrents (above line protection rating)
- Feeder undervoltage ( $U_{\text{nom}} - 10\%$ )
- Feeder overvoltage ( $U_{\text{nom}} + 8\%$ )



**Roll-out scenario's (in % connections with an EV per feeder):**

- 0%: situation per September 2018
- 3% : eq. of 100k EVs in Flanders
- 7% : 250k
- 15%: 500k
- 30%: 1M
- 50%: 1.75M

*Electric car market share in the top eight Electric Vehicle Initiative countries (IEA 2017)*



## 4 charging modes

- ⚡ Mono phase 16A charging: 1ph16A
- ⚡ Three phase 16A charging: 3ph16A
- ⚡ Mono phase 32A charging: 1ph32A
- ⚡ Three phase 32A charging: 3ph32A

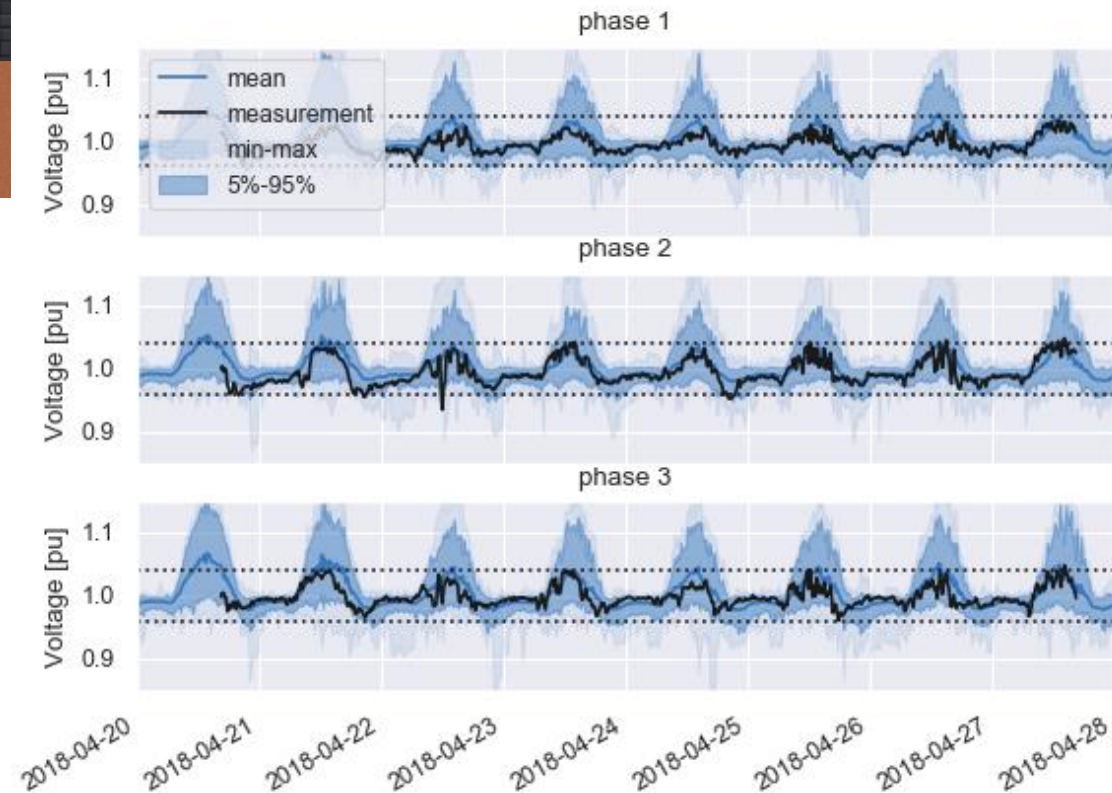
# Calculating impact

## *power flow specific for Low Voltage networks*

- ✓ 3 phase, unbalanced
- ✓ Statistical approach for missing aspects:
  - Phase connectivity
  - Consumption patterns
- ✓ Scalable towards 100000's of feeders
- ✓ Profiles with timestep of 15 min
- ✓ Not 1 but more solutions:
  - ➔ stochastic loadflow using Monte Carlo sampling
  - ➔ Results in a *probability* a situation emerges with congestions

### ↔ Classic power flow tools

- balanced (1-phase calculations)
- Load estimated based on empirical factors
- 1 timestep in winter (evening peak) en 1 in summer (injection peak)



# Performance

*Flemish center city: **2162 feeders***

*1 day, 200 statistical samples / feeder, **41.5M power flows***

*Medium sized server = **21 minutes** calculation time*

***3 ms / power flow***

# Detailed results for all feeders

Example:



# Detailed results for all feeders

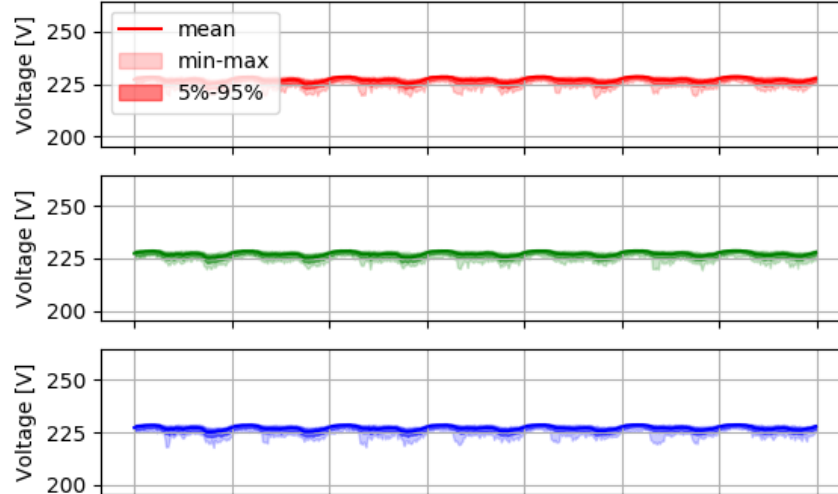
## Example:

3ph32A, 30% EVs

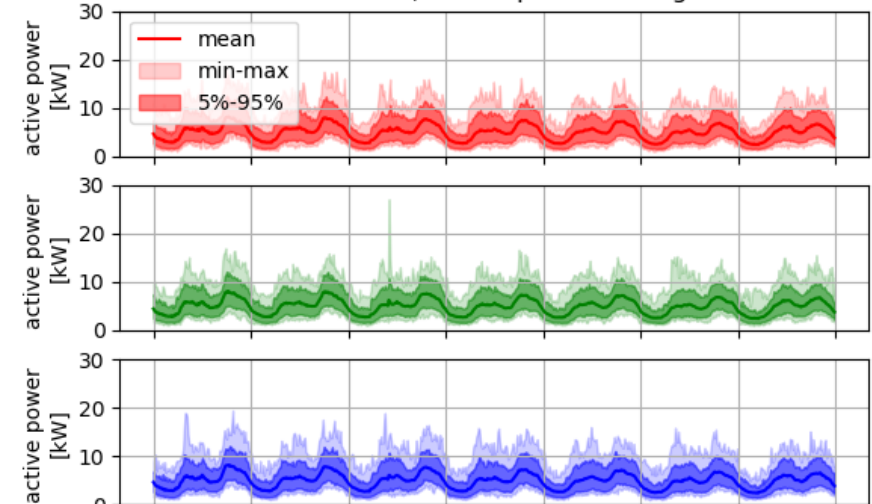
Congestion probability:

- Undervoltage: 20%
- Overcurrent: 75%

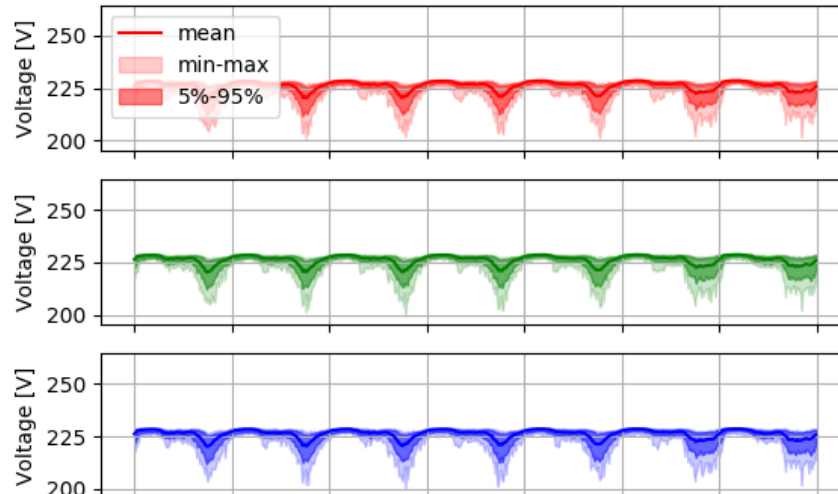
Voltage at the end of the 230V underground cable  
For one week, 0% EV penetration grade



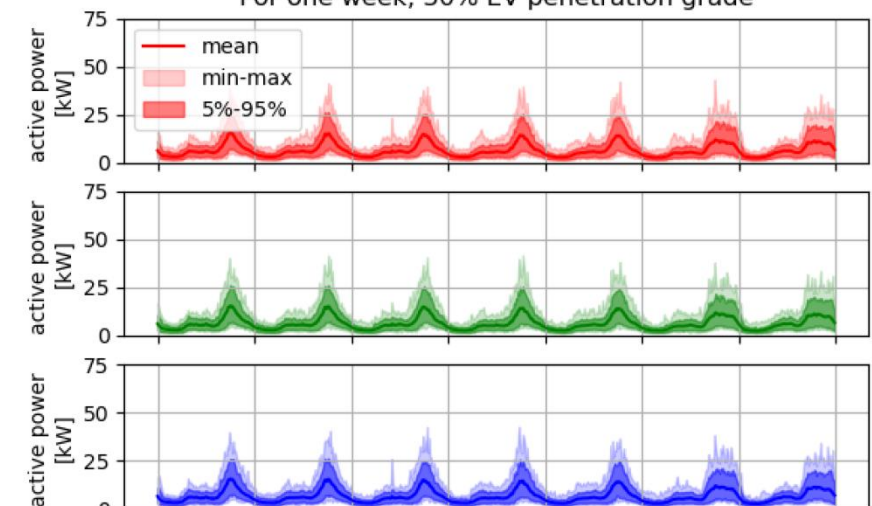
Power at the transformer for the 230V underground cable  
For one week, 0% EV penetration grade



Voltage at the end of the 230V underground cable  
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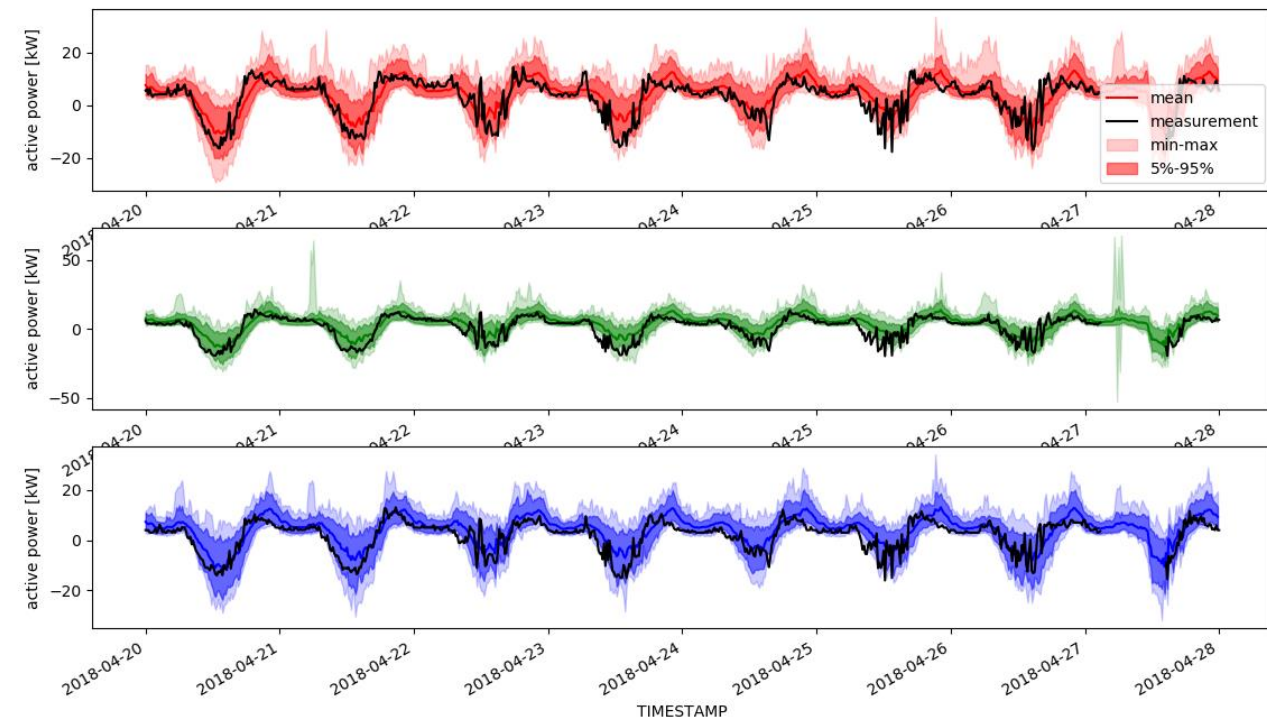


Power at the transformer for the 230V underground cable  
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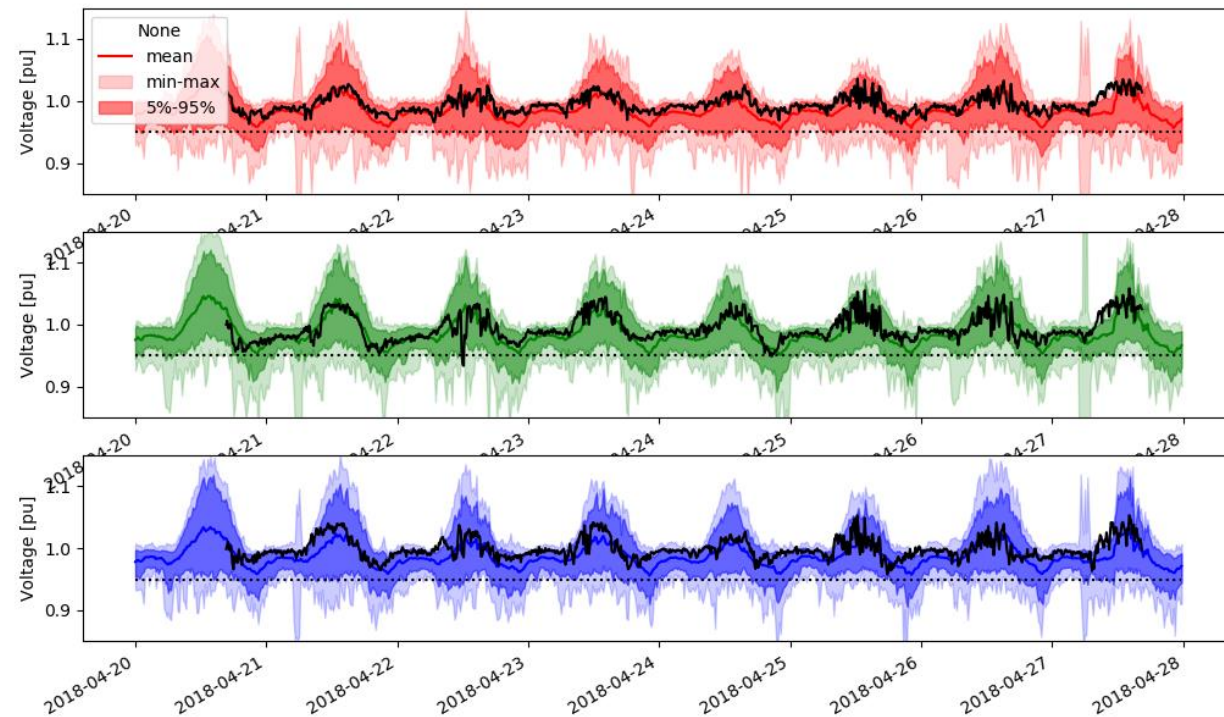


# Validated

## Feeder with 45 EANs



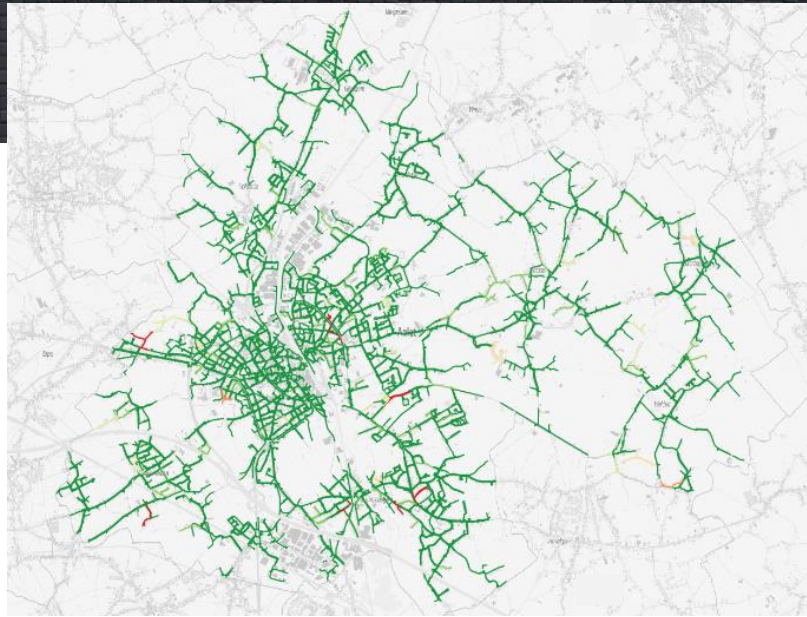
Measurement (black line) versus probabilistic prediction (coloured lines) of active power flow in the feeder at the substation.



Measurement (black line) versus probabilistic forecast of voltage at the feeder end.

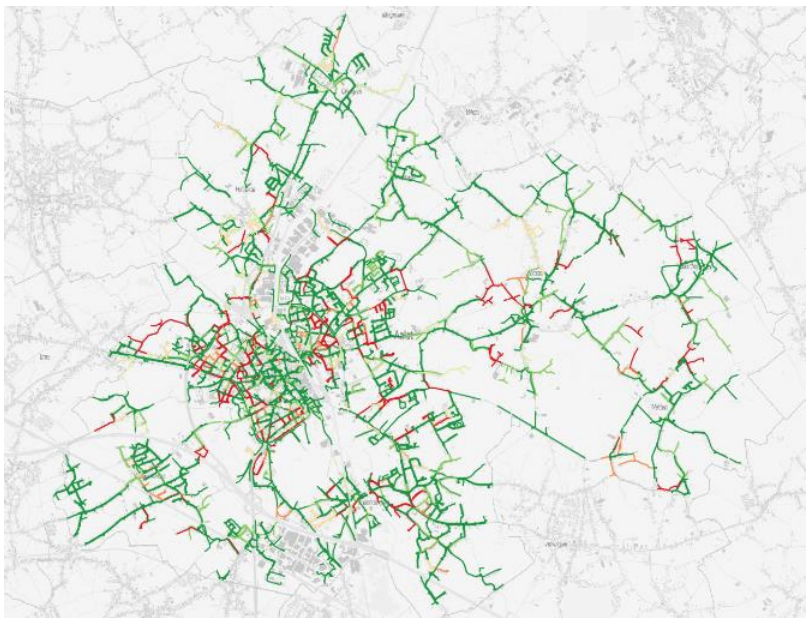


50% EV, mono 16A

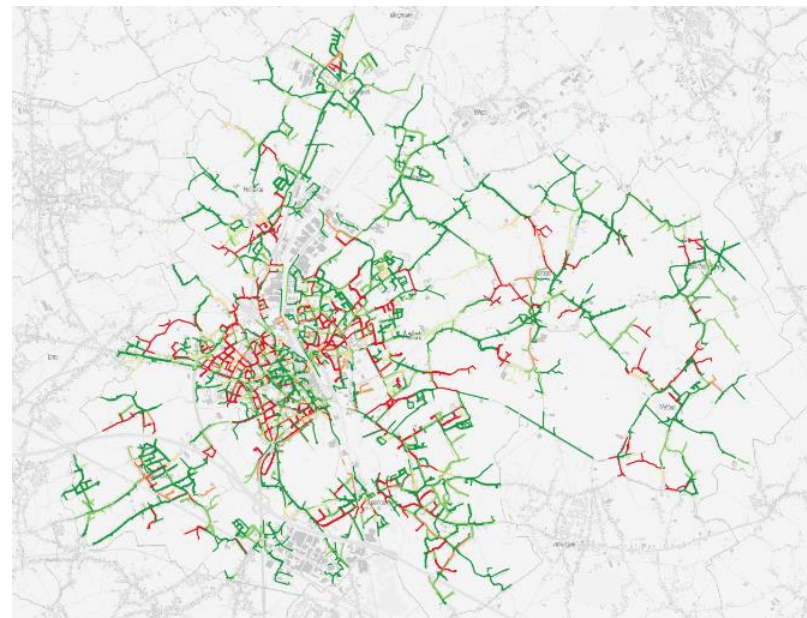


0% EV

Flemish centre city  
 421 transfo's  
 2162 feeders  
 44452 connections



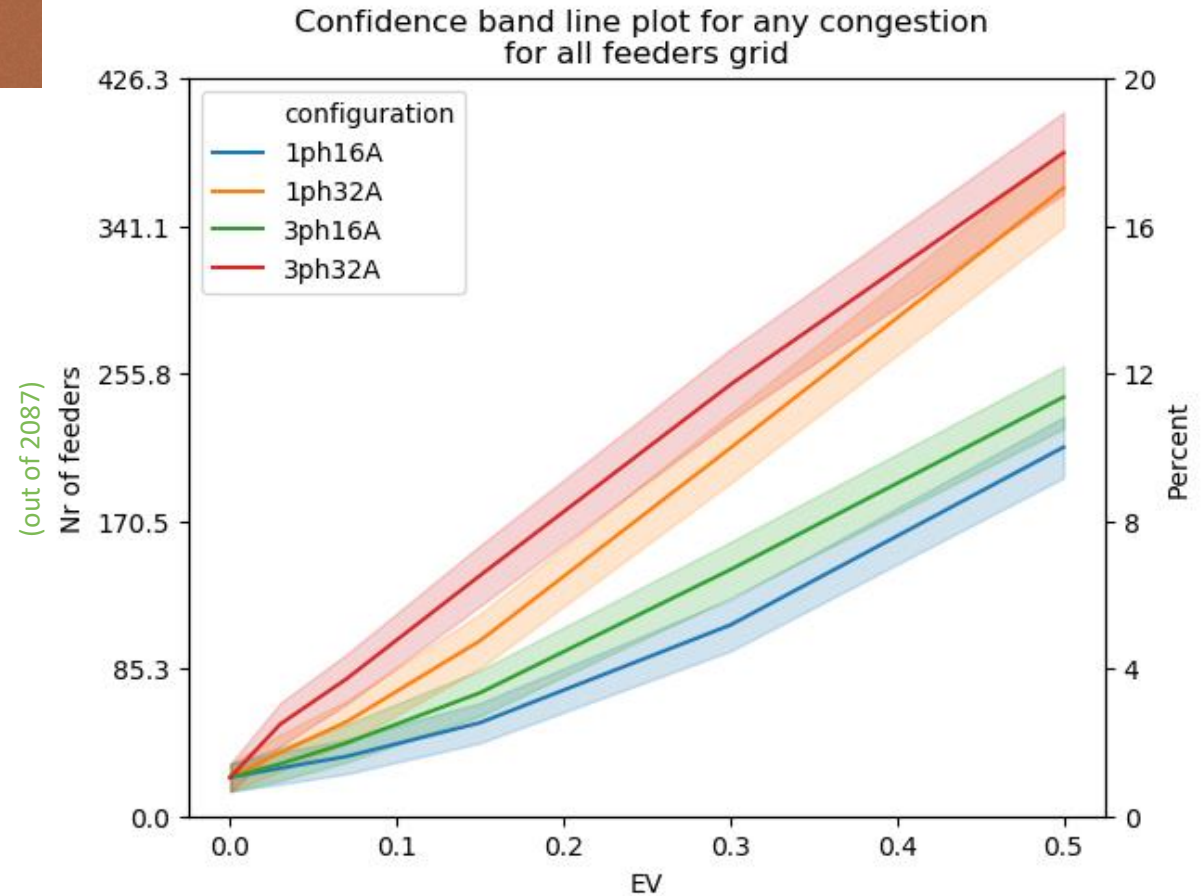
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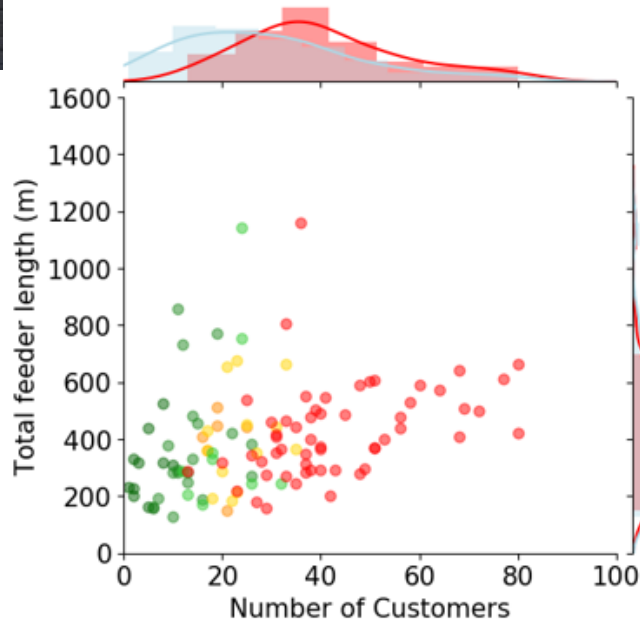
50% EV, 3phase 32A

# Conclusions EV impact

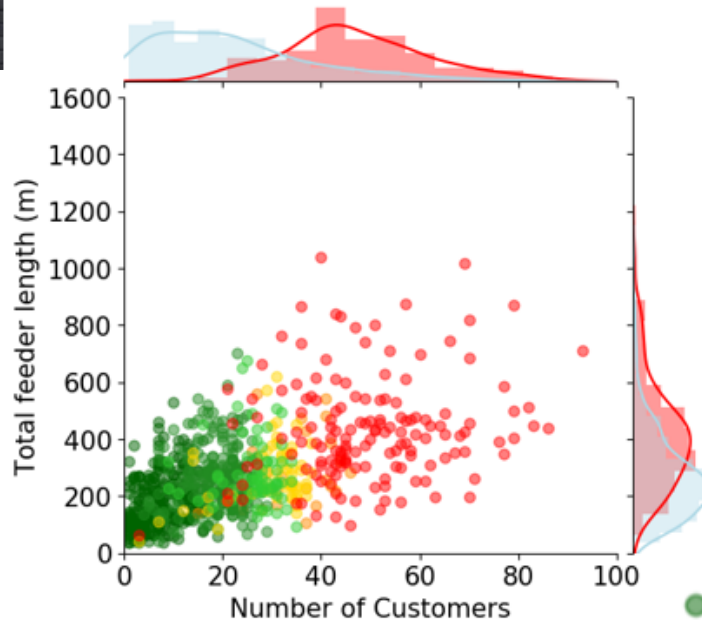
- 16A charging is preferred to 32A charging
- 32A charging doubles the #feeders with high congestion risk
- Fast charging at home:
  - always prefer 3ph16A to 1ph32A
    - 3ph16A is the faster of the two
    - 1ph32A is the tendency in automotive (Nissan, BMW, Ford, Mercedes, Jaguar, ...)



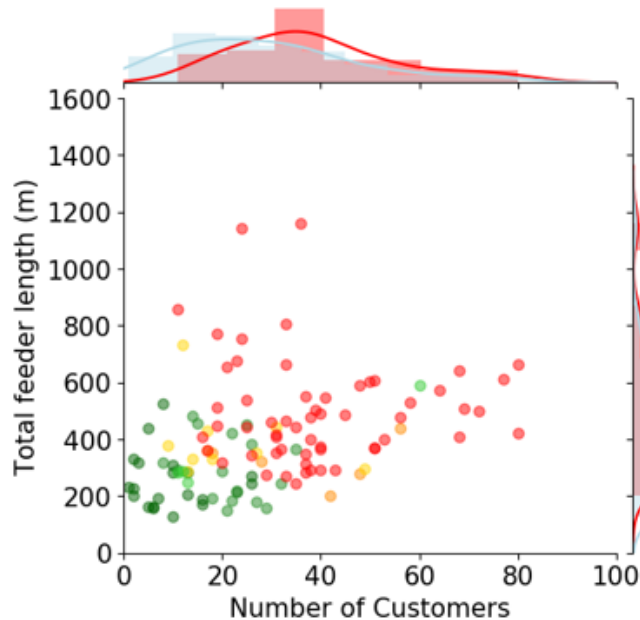
3ph32A 230V overhead lines  
60% PoF for overcurrent



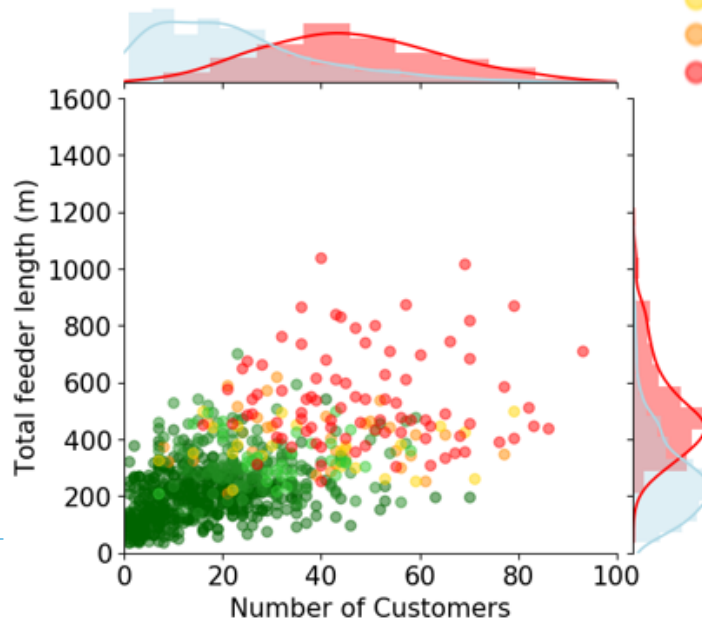
3ph32A 230V underground cables  
60% PoF for overcurrent



3ph32A 230V overhead lines  
60% PoF for undervoltage



3ph32A 230V underground cables  
60% PoF for undervoltage



- impossible
- very unlikely
- unlikely
- possibly
- likely
- very likely

Long feeders  
=  
higher risk for undervoltage

Many connections  
=  
higher risk for overcurrents

# Mitigating measures

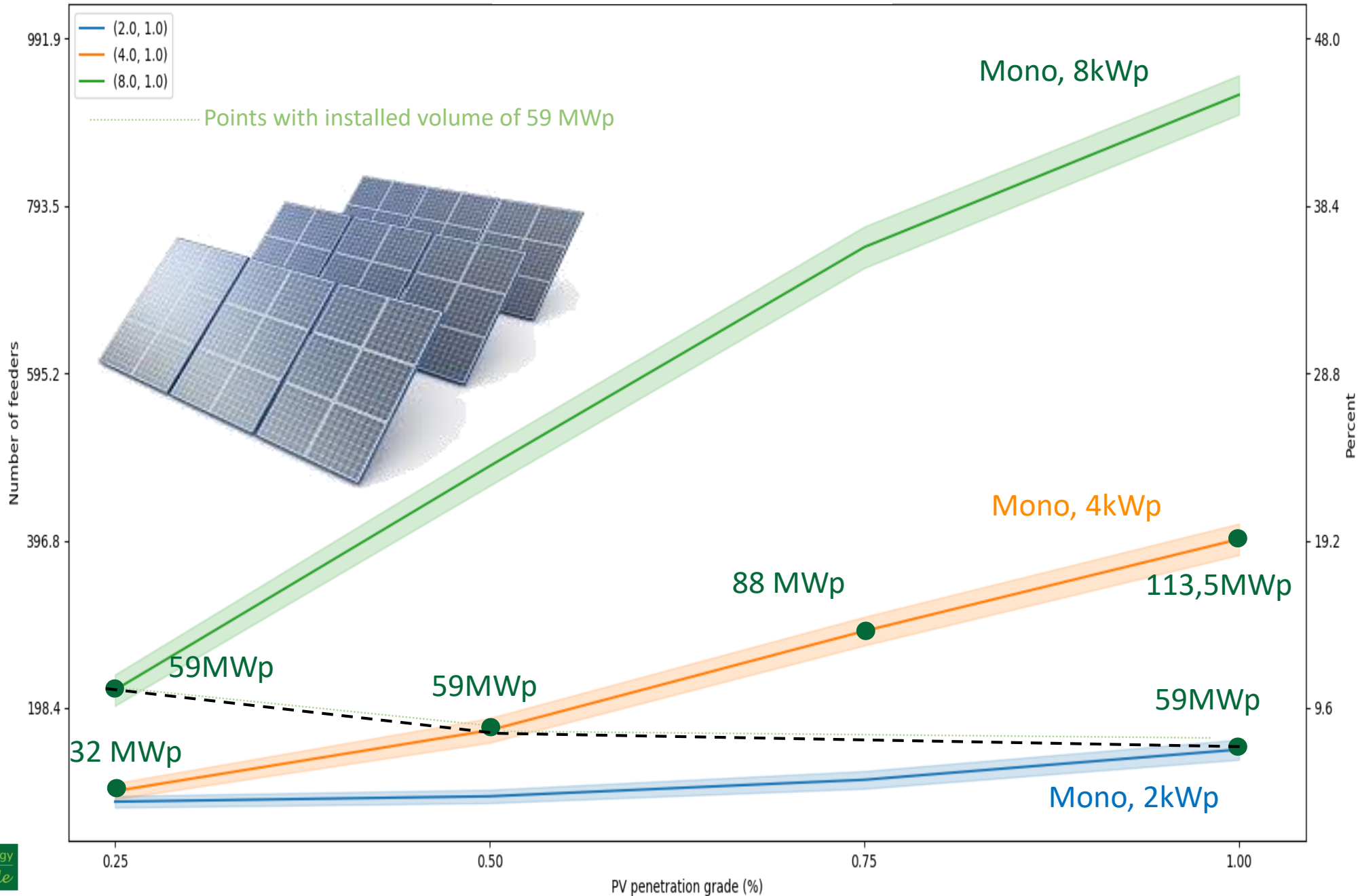
- 🌿 Promote slow charging at home (support 16A, discourage 32A)
  - ✂ Esp. 1ph32A is to be avoided, given the 3ph16A alternative
  - ✂ Automotive evolves to 1ph32A
  - ✂ Requires fast charging backup infrastructure
  - ✂ Adapted grid tariffs (e.g., capacity component)
- 🌿 Reporting duty for EV chargers is to be considered  
(allows targeted pro-active measures by the DSO)
- 🌿 Avoid charging during the evening peak, avoid synchronized charging
  - ✂ Support charging at work
  - ✂ Support shift charging beyond evening peak & spread charging in time
    - 🏠 Adapted grid tariffs (e.g., capacity component)
    - 🏠 Demand response



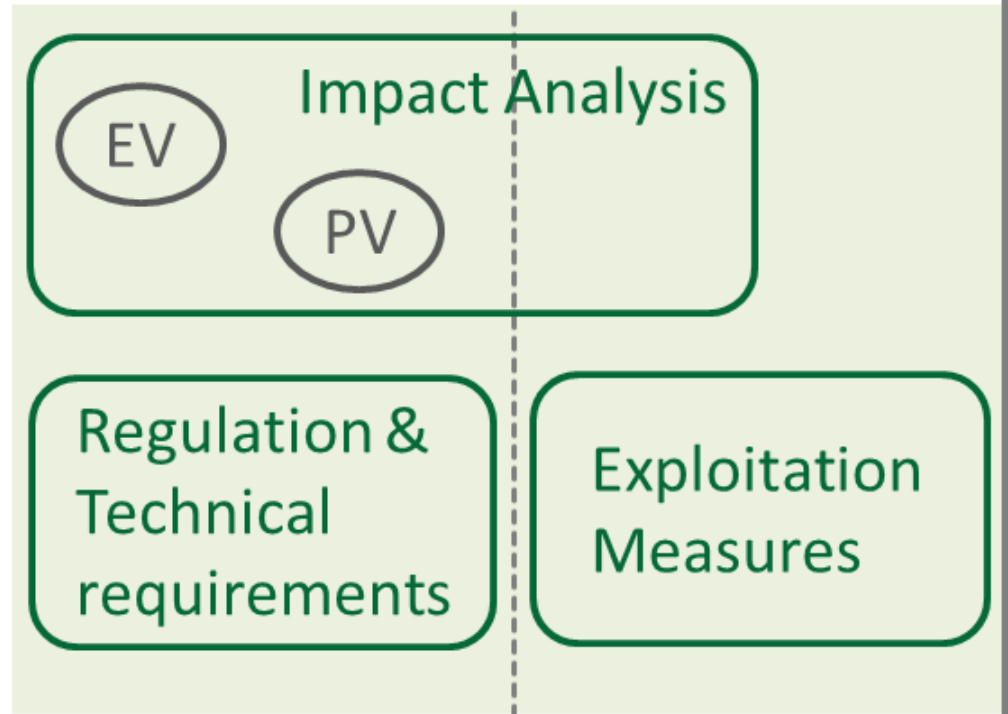
# *Impact massive rollout PV*



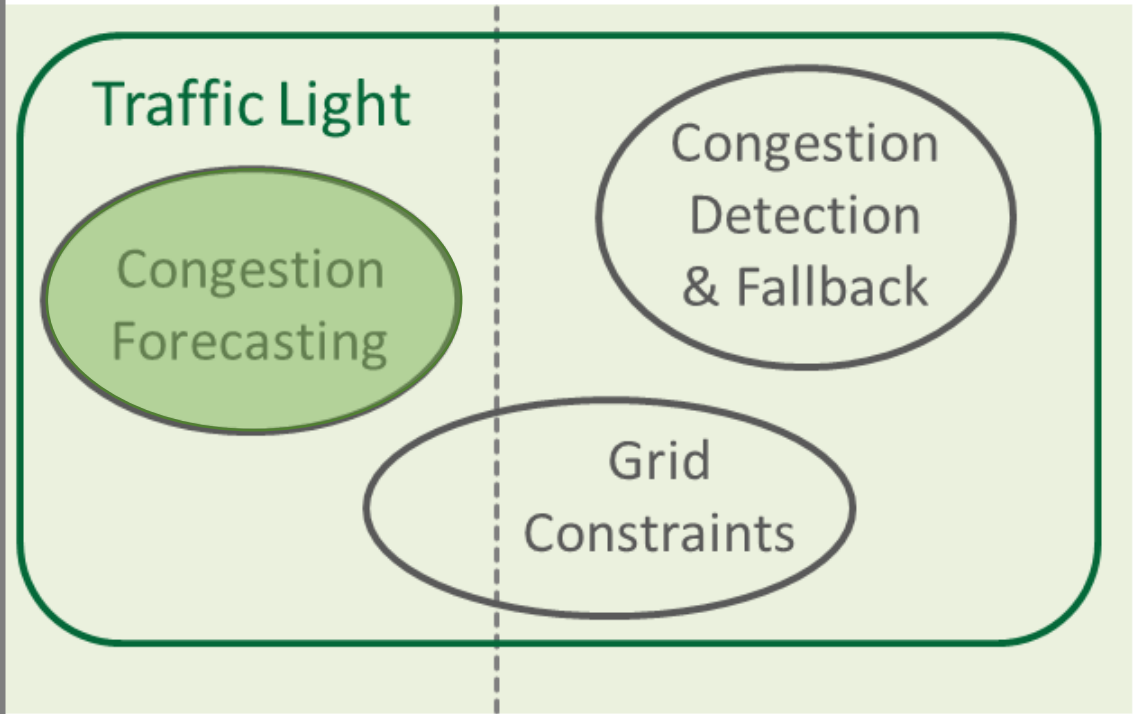
# 99% confidence band for # of feeders with congestions



# Planning



# Operations



## Active Distribution Networks

*Maximize the grid utilization*

# Stakeholders



Buys/sells energy from a reliable network connection  
Provides flexibility for the system

Prosumer



Ensures a reliable network connection

DSO



Combines flexibility and provides services to the system

Aggregator

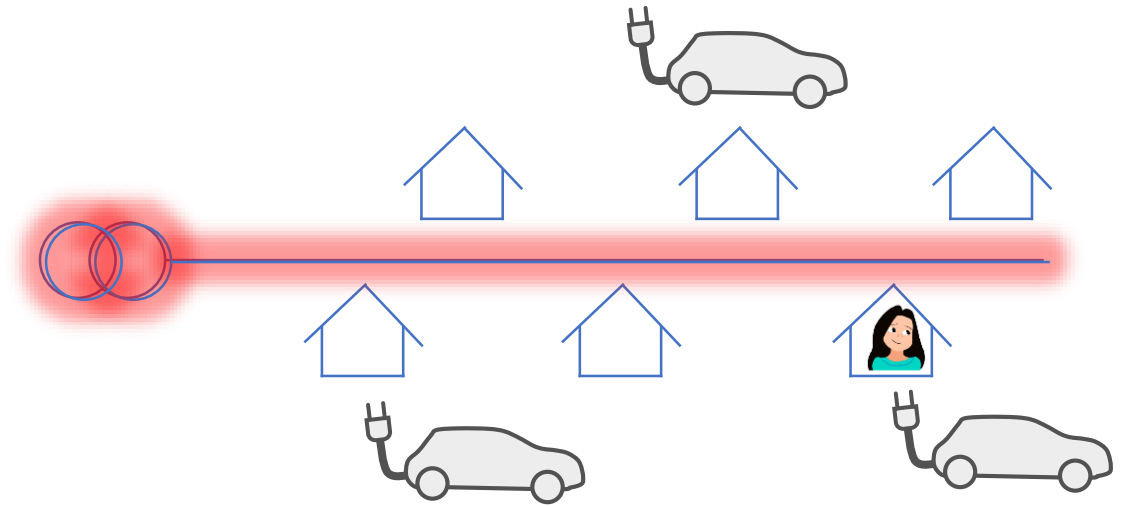


Provides a stable system in balance

TSO

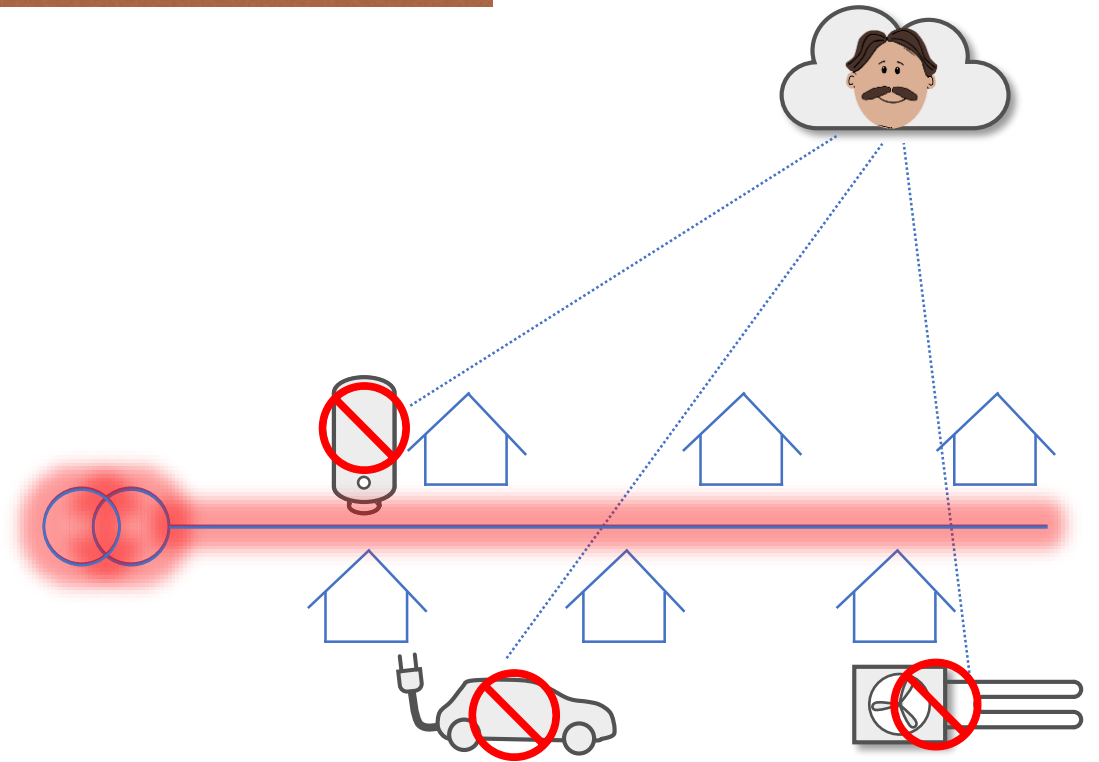
# The EV owner: Sara's tale

- Sara lives in a house
- Some of her neighbours buy an electric vehicle
- When Sara wants to connect her EV, the grid becomes congested



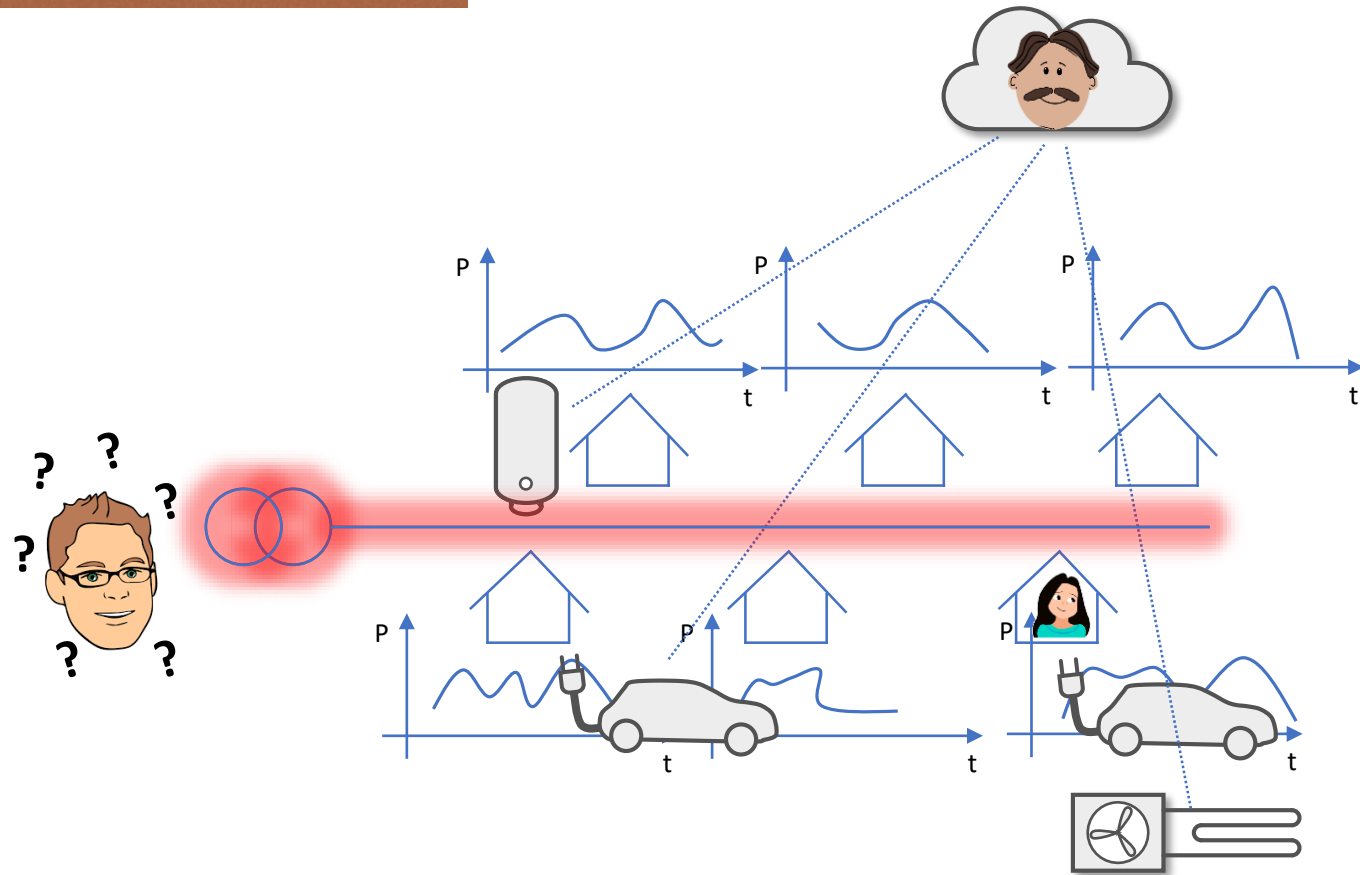
# The aggregator: Bert's tale

- Bert provides grid services
- He contracts customers with batteries, EVs and heating devices
- When the grid is congested, he cannot use the contracted flexibility

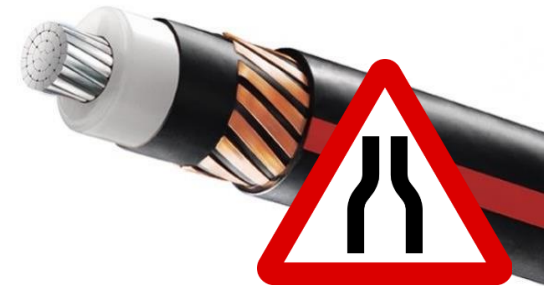


# The DSO: Stephan's tale

- Stephan works at the DSO
- In the past Stephan could design his system knowing that a simultaneity factor of 30% is sufficient
- With all the new services and loads, this does not work anymore



# Problem



**Today:** fit & forget approach and guaranteed fixed connection capacity

Increasing demand, and higher synchronicity: 3x impact

## DSO:

- Increase of fit & forget safety margins
- More capacity is needed to guarantee connection capacity
- Increased investments

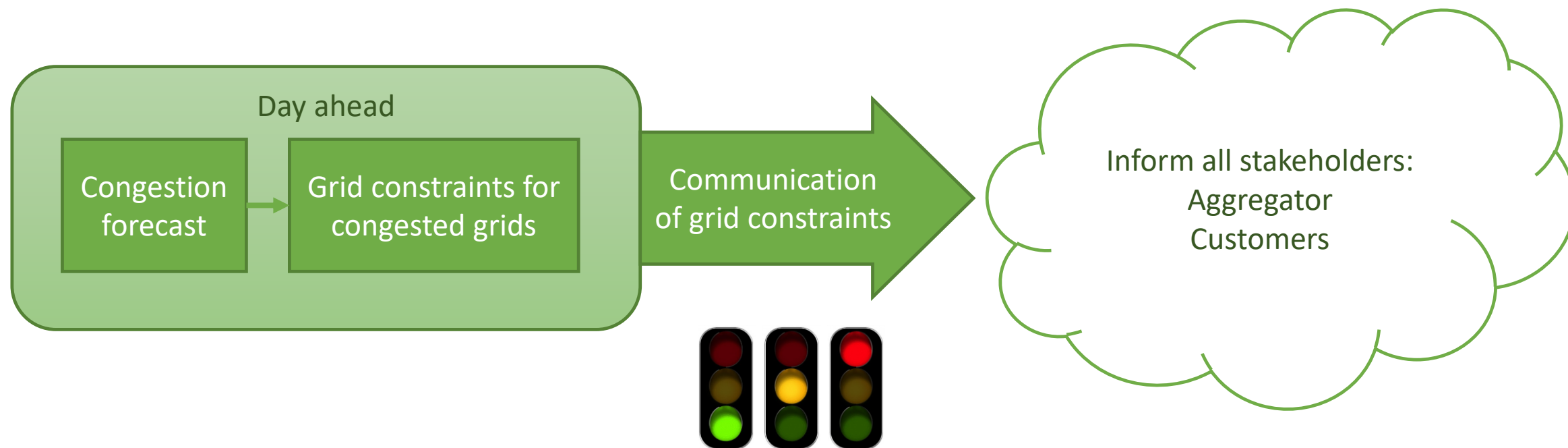
## Customer:

- Indirect: impact on distribution tariffs due to increased investments
- Direct: grid reinforcement after explicit demand for extra capacity

## Aggregator

- Cumbersome and static prequalification procedure (for a lot of small assets)
- access denied when congestion risk

# Solution



# Congestion forecasting

**Predict in which grids there is a high risk for congestions.  
at what hour tomorrow**

## Available data?

- ✓ Digital meter: limited number of customers, 15-min. data until yesterday
- ✓ (if available) transformer/feeder measurements
- ✓ Exogenous data: weather forecast (temperature, irradiance), calendar information

## Prediction quality?

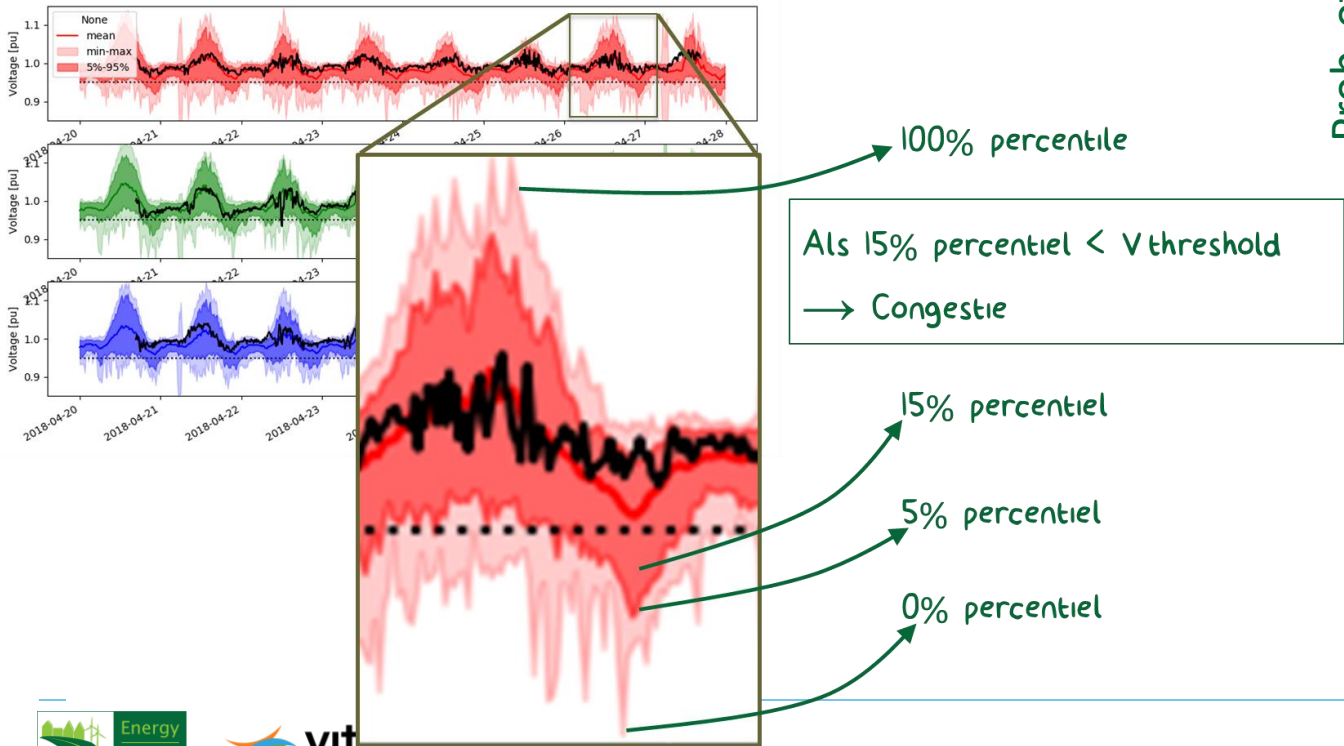
- ✓ as accurately as possible → no false negatives
- ✓ as little as possible false reports → limited false positives



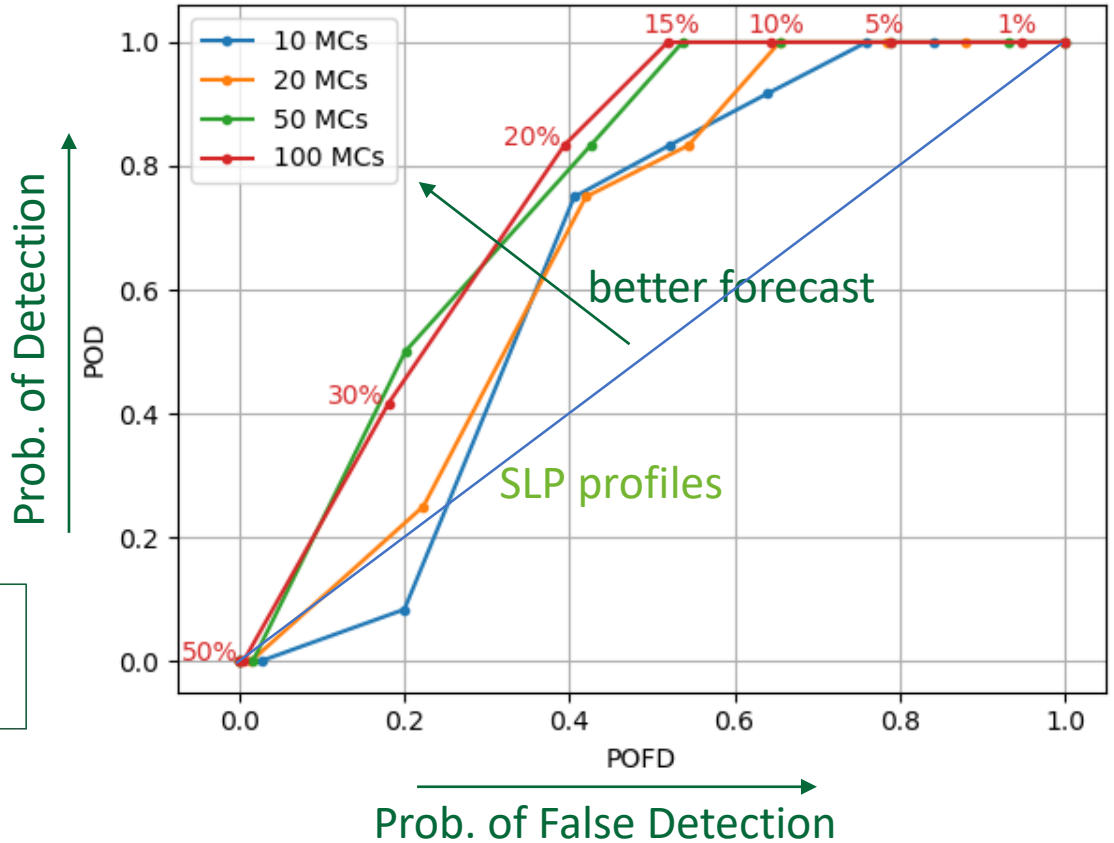
# Work in progress

15% threshold:

- All voltage congestions found
- +-half of the detections are false

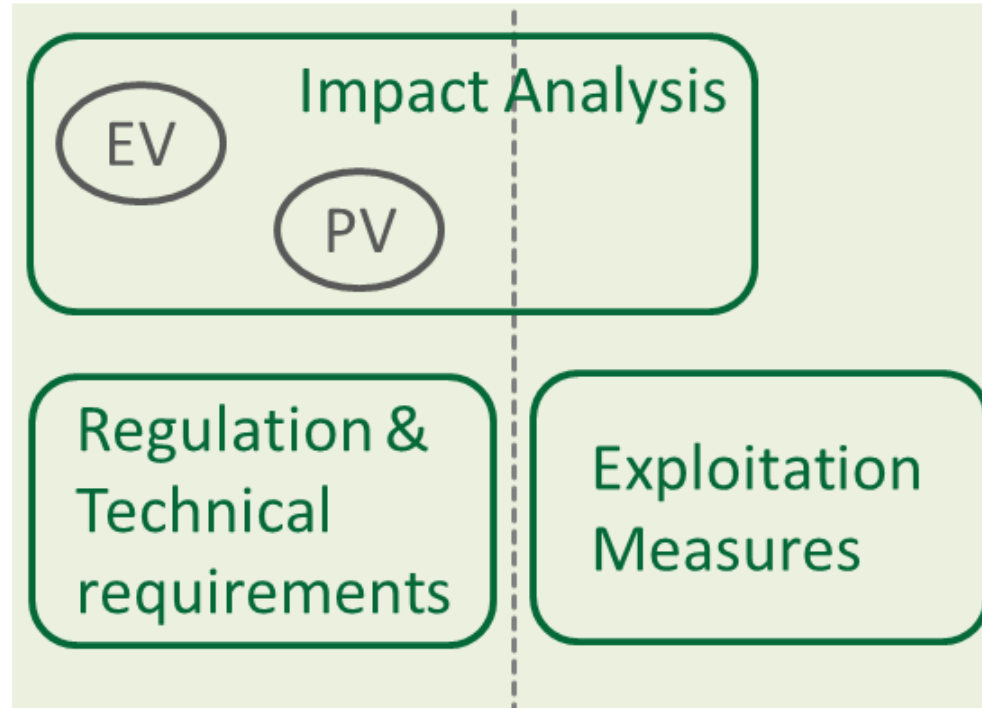


## ROC curve (Receiver Operator Characteristic)

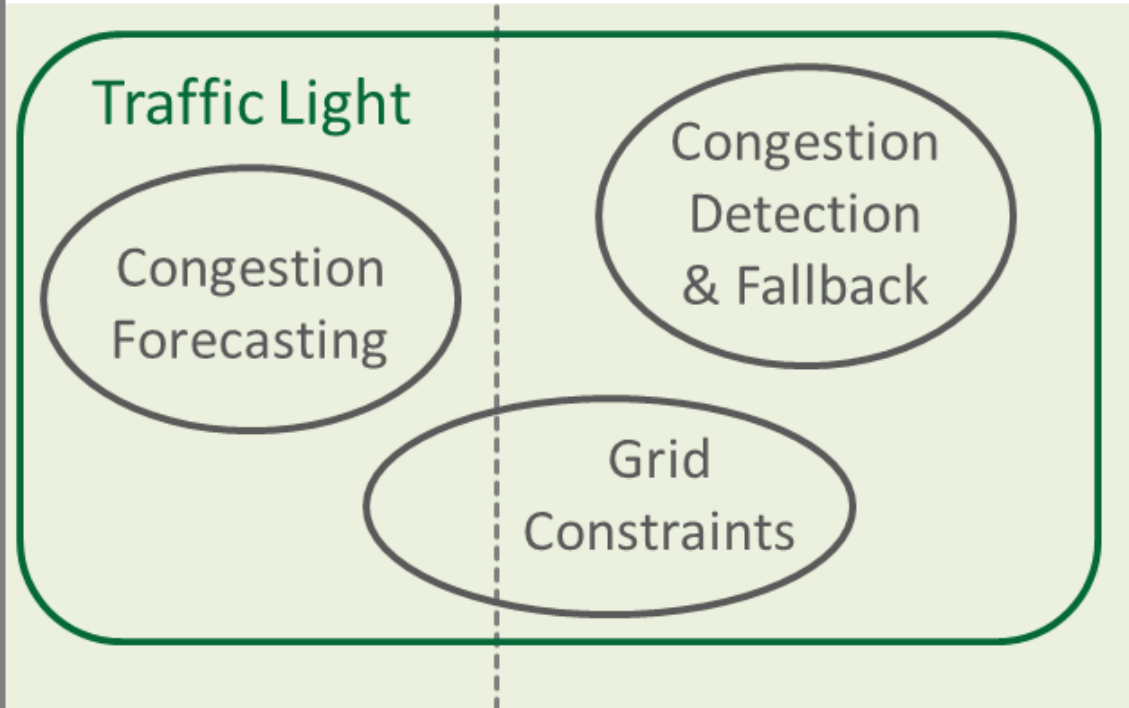


# Conclusion

## Planning



## Operations



## Active Distribution Networks

*Maximize the grid utilization*

Thank You 4

Feedback and  
Interest Survey 4



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