Distribution Network Characterisation: Visibility and Operation

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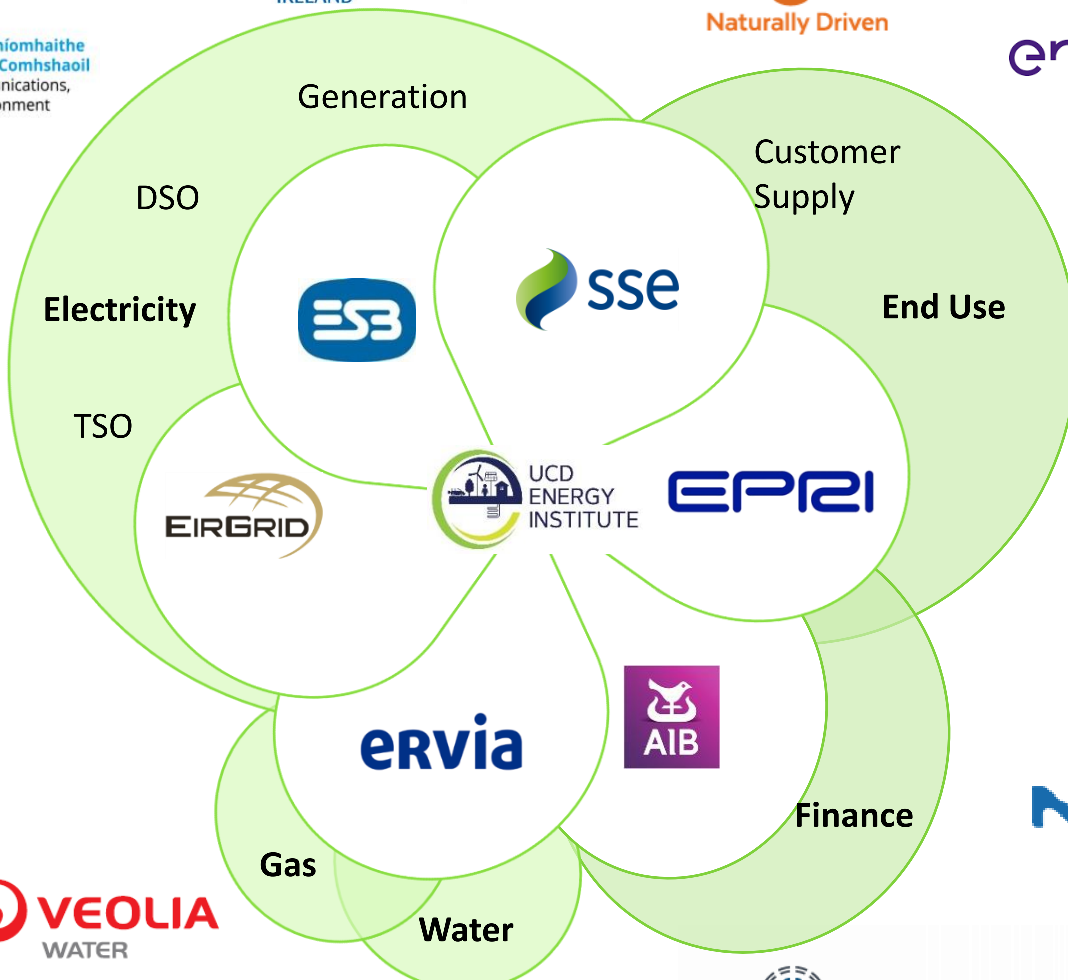
Energy Systems Integration Partnership



Glen Dimplex IRELAND

BORD NA MÓNA Naturally Driven

enel x

Roinn Cumarsáide, Gníomhaithe ar son na hAeráide & Comhshaoil
Department of Communications, Climate Action & Environment

Cylon

seai

climote

economics for energy

retrofitenergy IRELAND LIMITED

MET éireann

MERCK

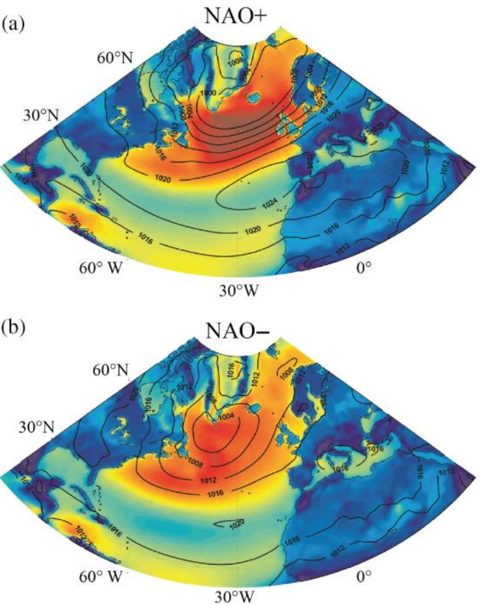
VEOLIA WATER

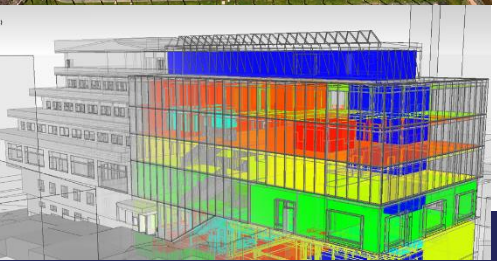
MOLLOY ENVIRONMENTAL SYSTEMS

ElectroRoute

sfi Science Foundation Ireland

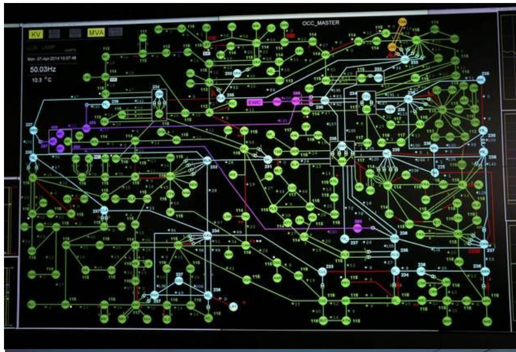
Areas of Research through ESIPP



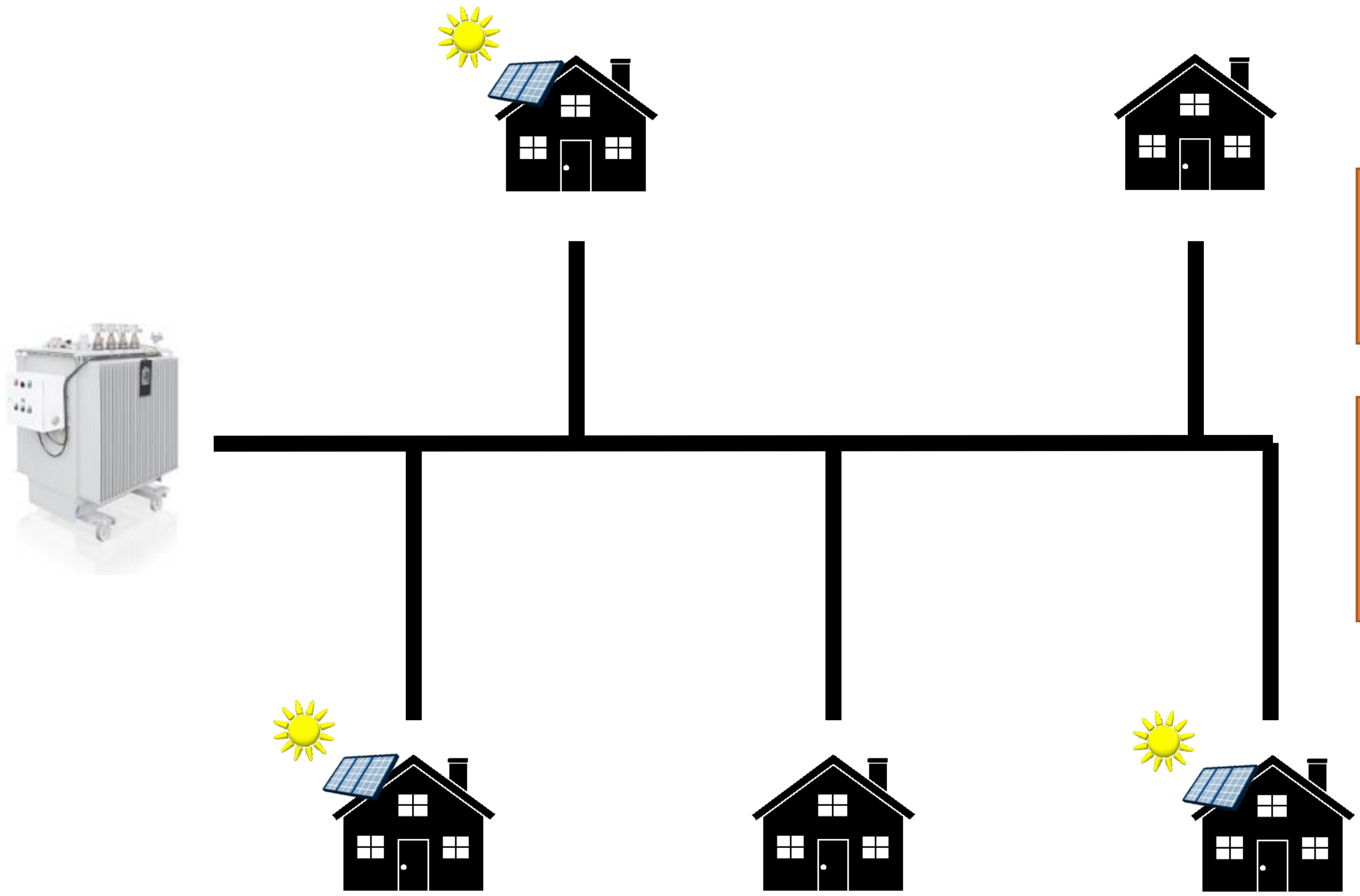


- Power System
- Gas Networks
- Climate and Weather
- Residential and Commercial Buildings
- Manufacturing
- Wastewater Treatment
- Data Centres
- Market structures – incentives and risks
- Consumer Behaviour

Integration and Optimisation!



How do DERs affect the distribution grid?



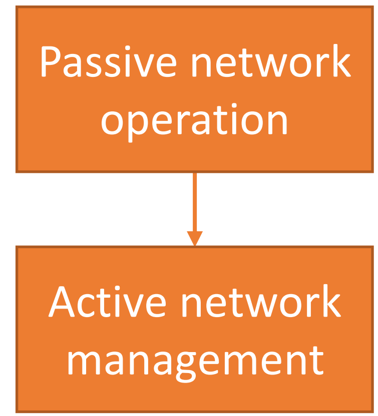
Secure integration

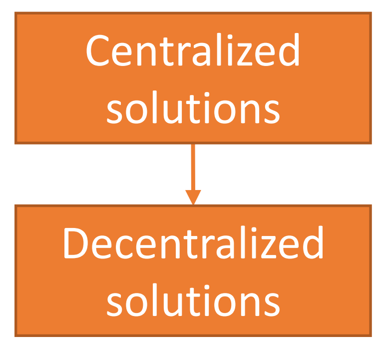
↓

Need for models that represent the grid state

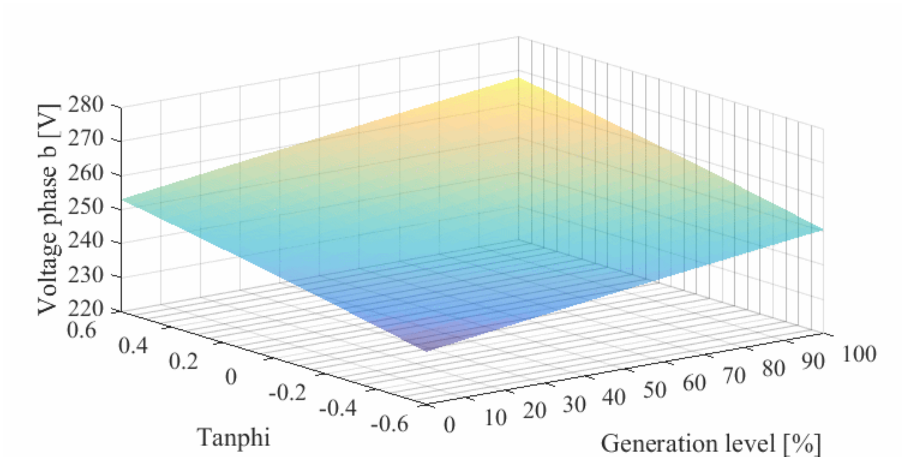
Context

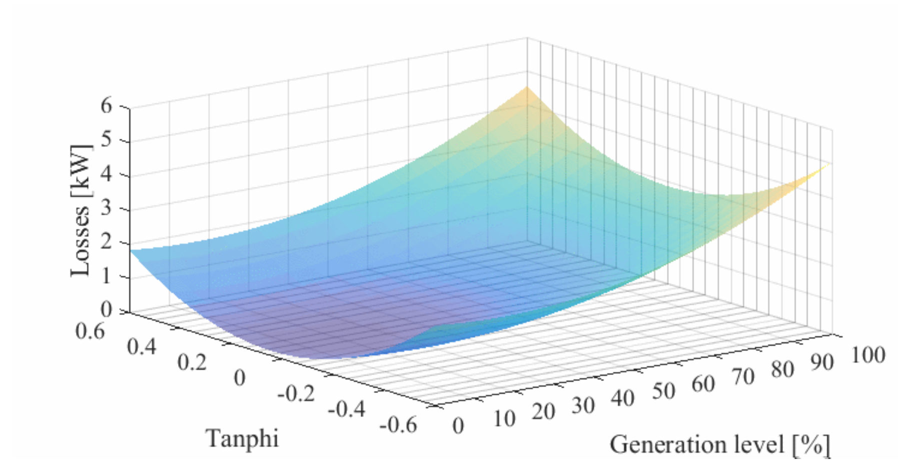
- Increasing penetration of distributed energy resources (DER) are transforming distribution system
  - Embedded generation
  - New electric loads (electric heating, EVs, etc.)
  - Demand response mechanisms
- Technical problems
  - Violation of voltage statutory limits
  - Overloading of network assets
- Need for cost-effective solutions
  - Limited monitoring and communication
  - Result in efficient network regulation
  - Implementable in near-term
  - Compatible with real-time operation
  - Consideration of network security and status

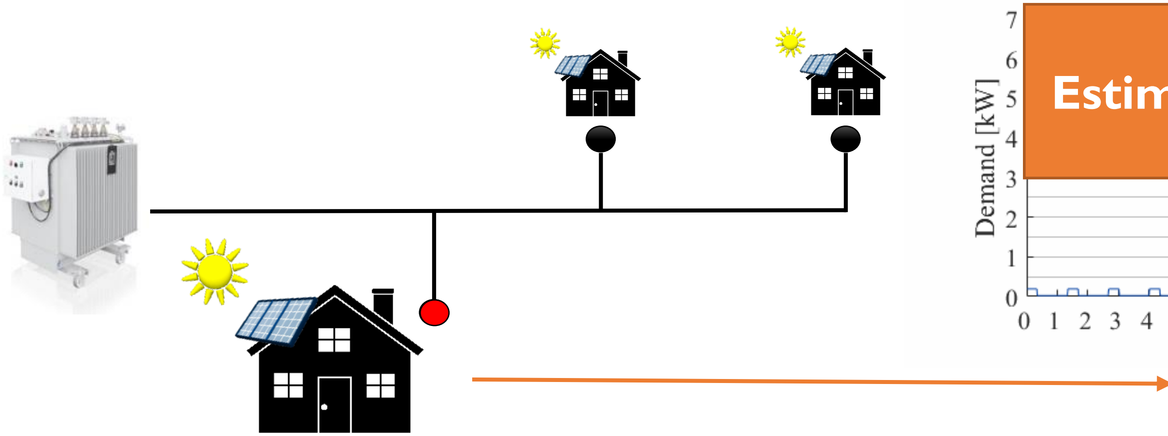


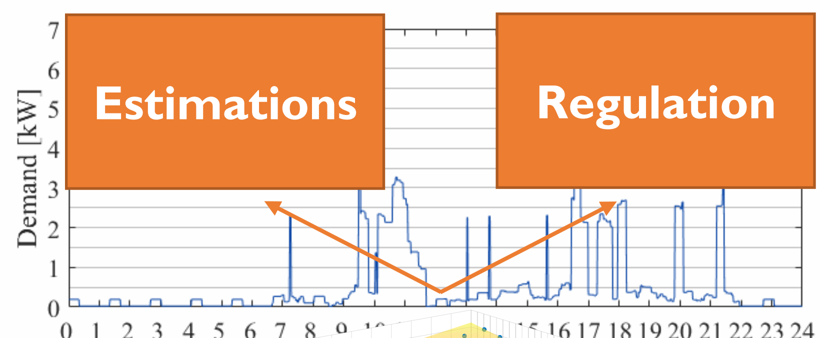


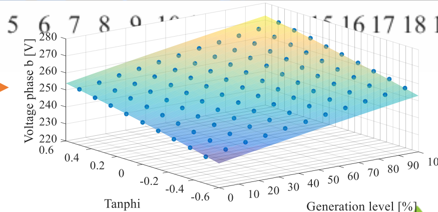
Curve fitting in distribution systems





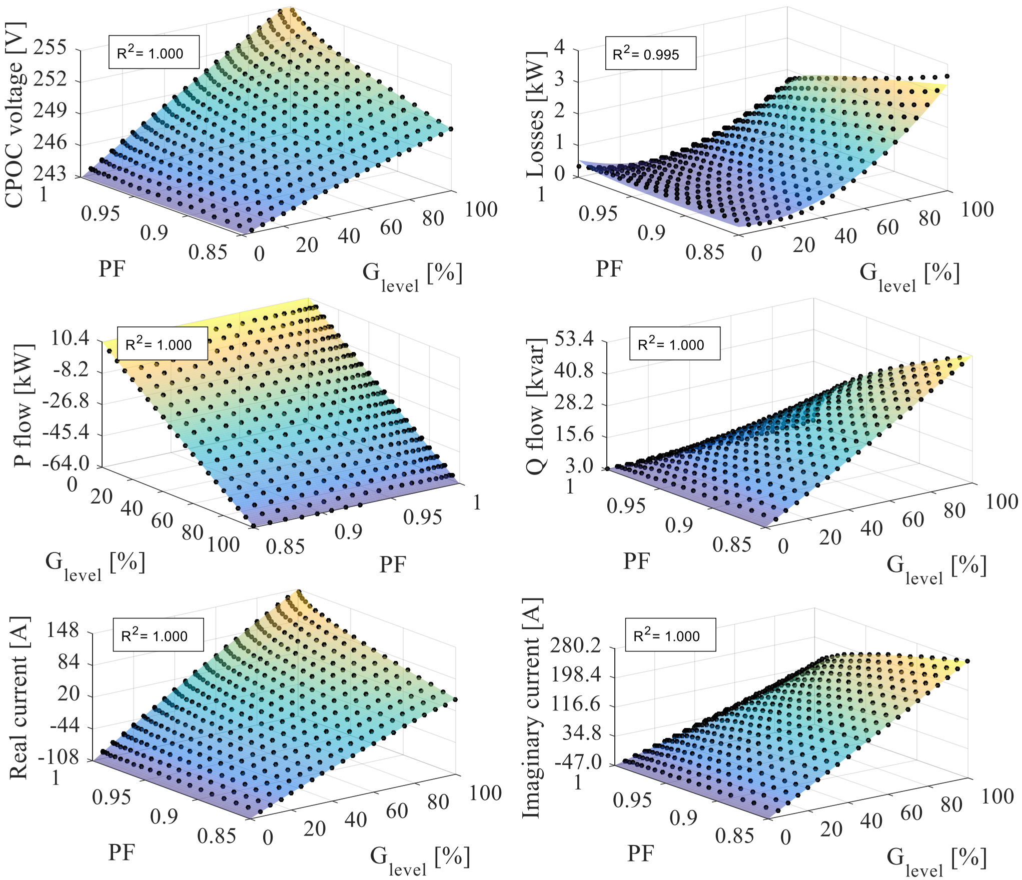


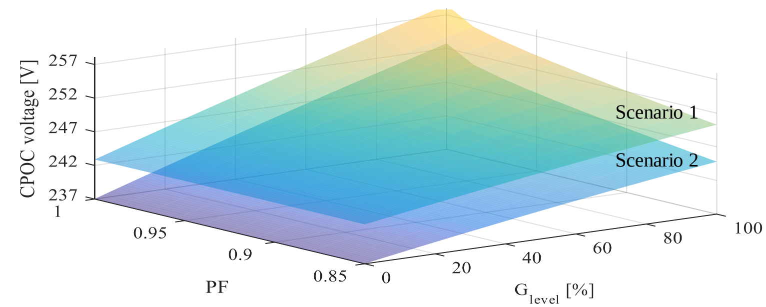




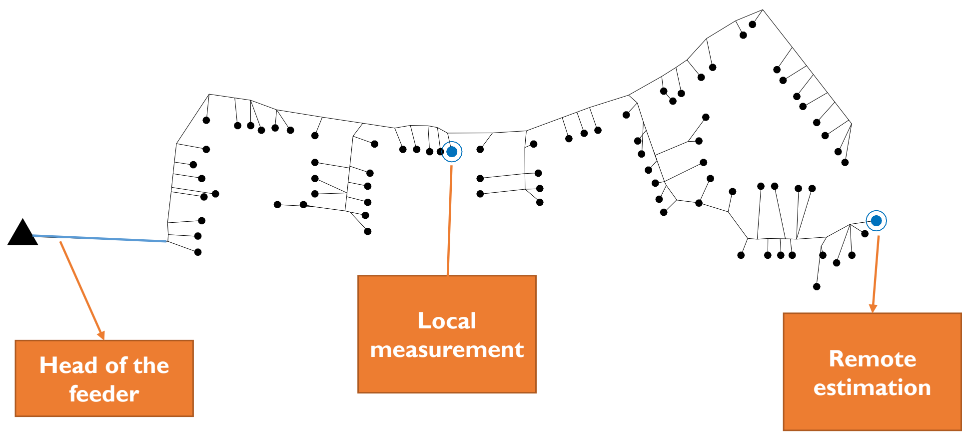
[*] V. Rigoni, A. Soroudi and A. Keane, “Use of fitted polynomials for the decentralized estimation of network variables in unbalanced radial LV feeders”, IET Generation Transmission & Distribution, 2020

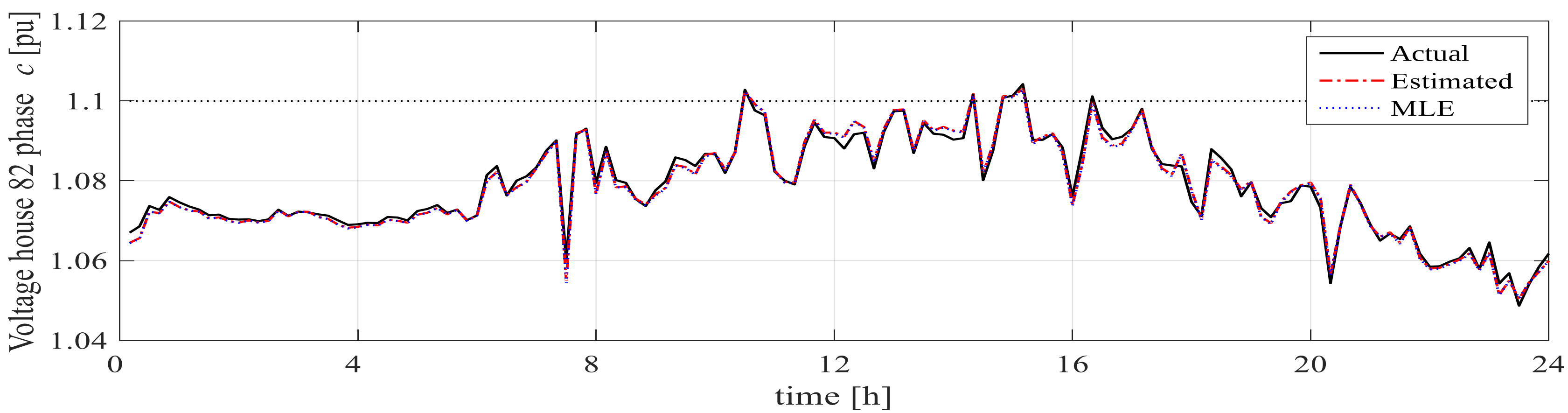
Polynomic characterization of the system variables





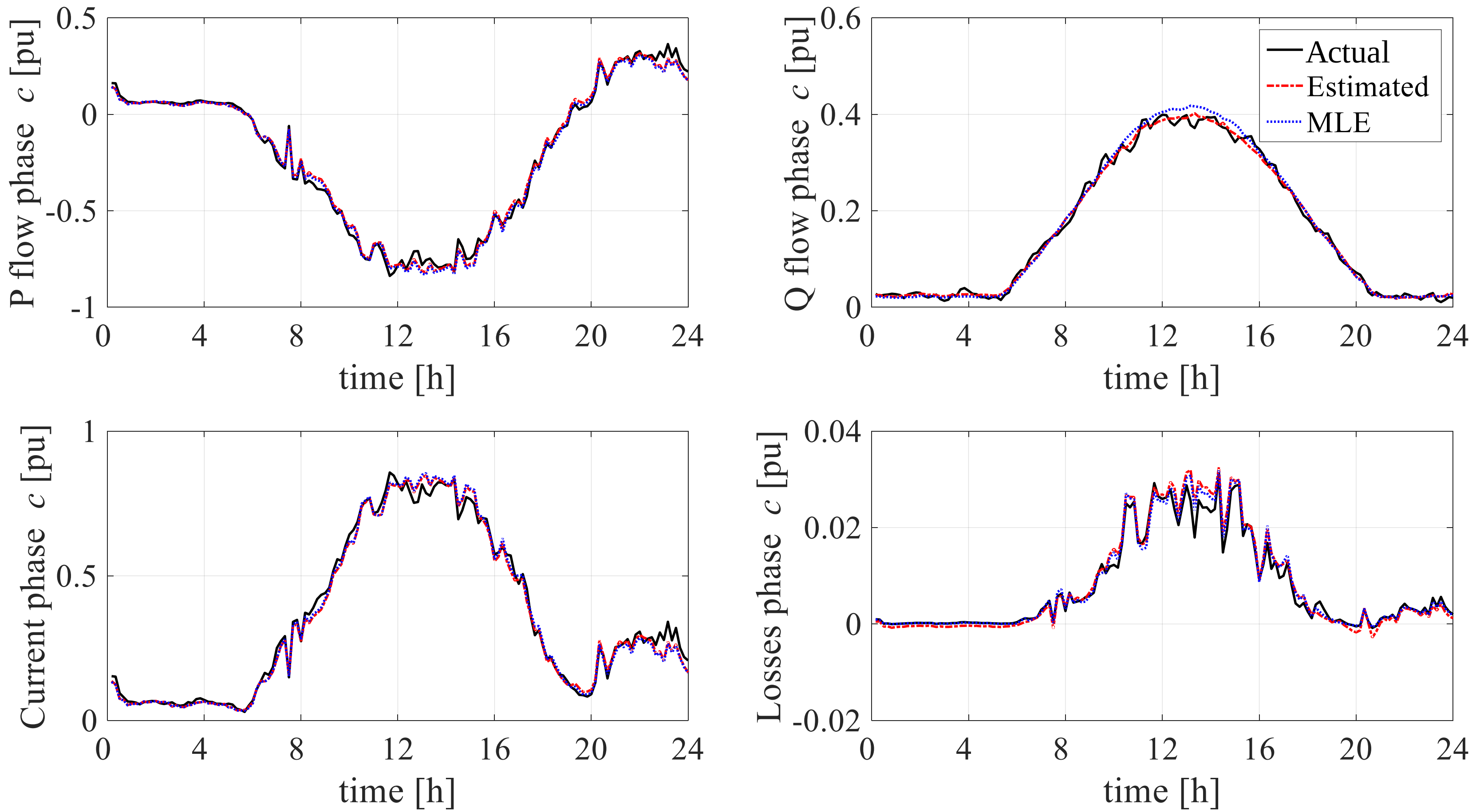
Test case and results: estimating remote variables based on local voltage measurement



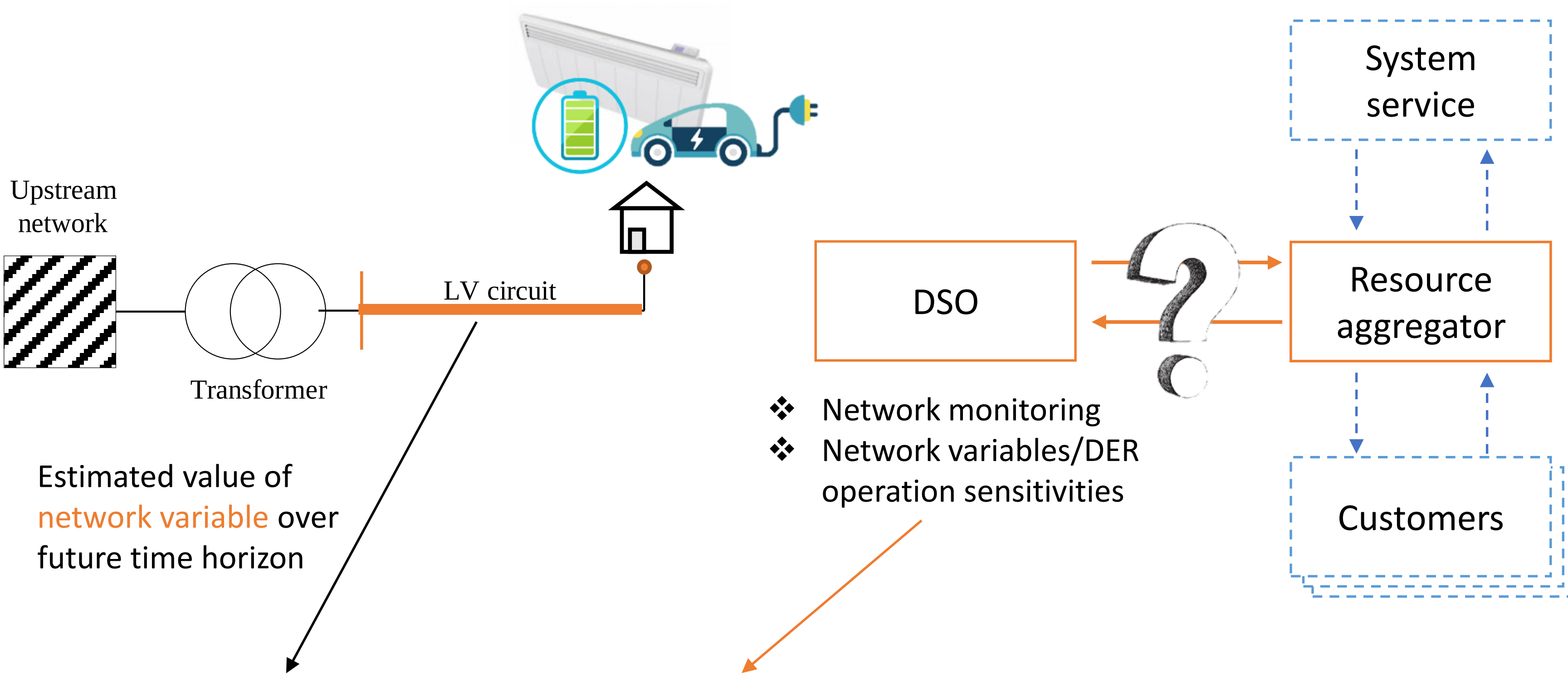


Voltage estimations

Estimations



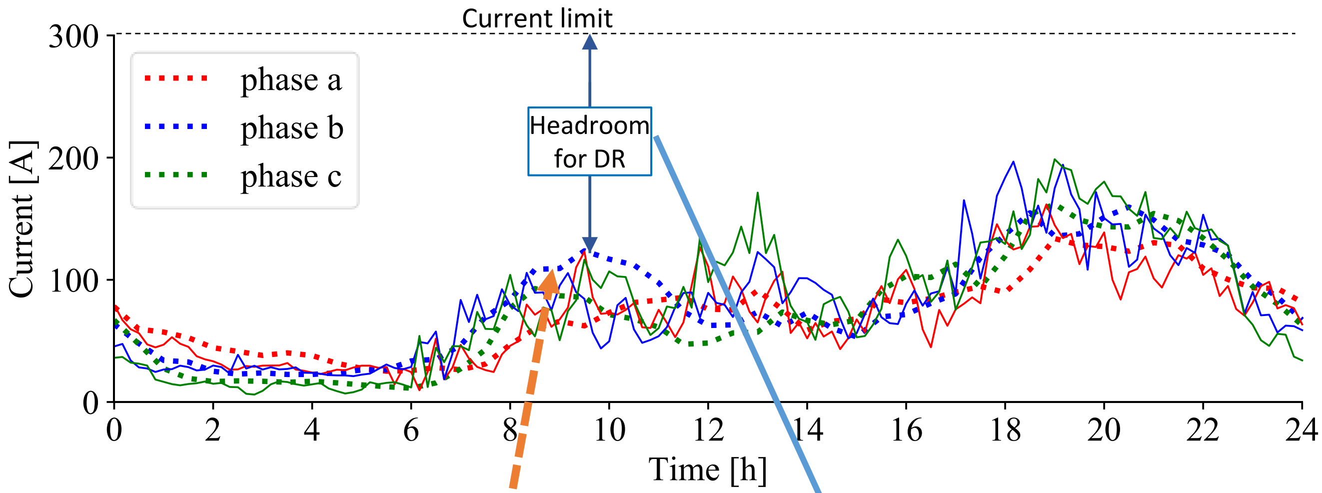
Coordinating demand response services with network operational constraints



$$estimate\ value = \boxed{forecast\ + effects\ from\ DER}$$

[*] V. Rigoni, D. Flynn and A. Keane "Coordinating Demand Response Aggregation with LV Networks Operational Constraints", IEEE Transactions on Power Systems, 2020

Characterising network sensitivities with polynomial fitting



$$\Upsilon_i^{min} \leq \Upsilon_{i,t} \leq \Upsilon_i^{max}$$

$$\Upsilon_{i,t} = \Upsilon^*_{forecast\,i,t} + \sum_h^H c_t^{\Upsilon_i, P_h} P_{h,t}$$

DR allocation

Network sensitivities

Estimated value of network variable over future time horizon

Day ahead scheduling and real-time operation problem

$$\min \sum_{t_{init}^{schedule}}^{T} \left(\sigma_{P_t} P_{total_t} + \sigma_{Q_t} Q_{total_t}\right)$$

subject to:

$$\Upsilon_{min_i} \leq \Upsilon_{i,t} \leq \Upsilon_{max_i} \; with \; i = 1, \ldots, k$$

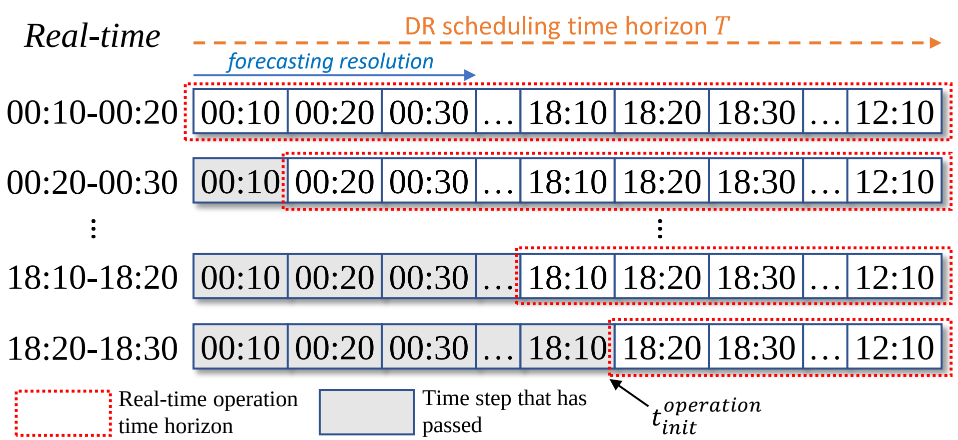
$$g_j(\boldsymbol{x}) = y_j \quad with \; j = 1, \ldots, q$$

$$f_u(\boldsymbol{x}) \geq d_u \quad with \; u = 1, \ldots, w$$

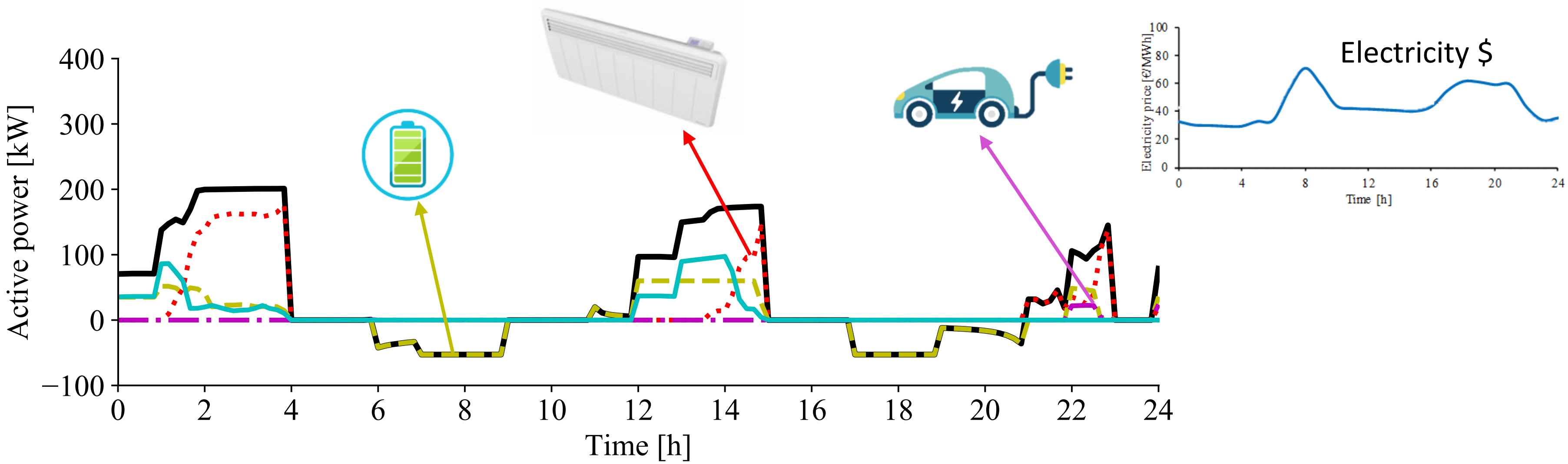
where

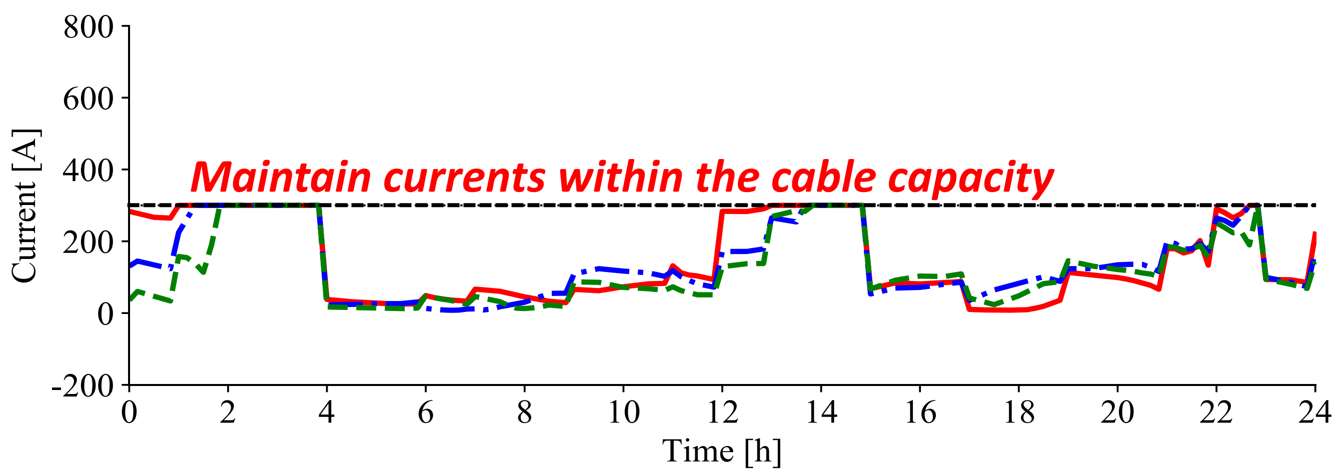
$$P_{total_t} = \sum_h^H P_{h,t}, \; Q_{total_t} = \sum_h^H Q_{h,t}$$

Integrated DR Headroom into Aggregator Operations



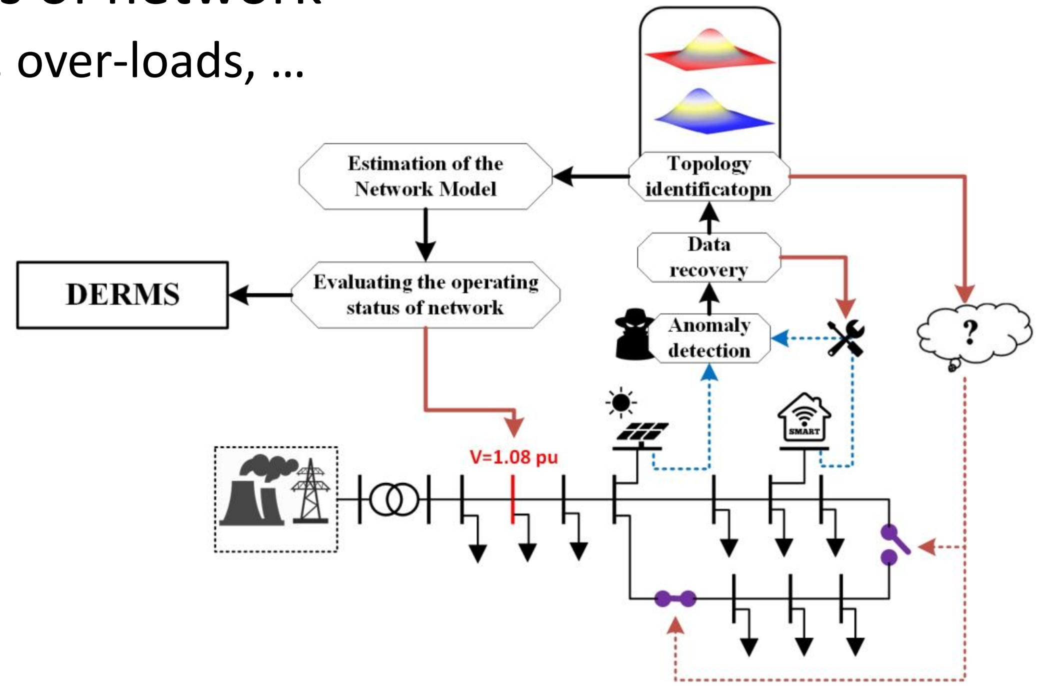
Results


Active power [kW]
Time [h]
Electricity $
Electricity price [€/MWh]
Time [h]


Maintain currents within the cable capacity
Current [A]
Time [h]

Enabling the application of DERMS

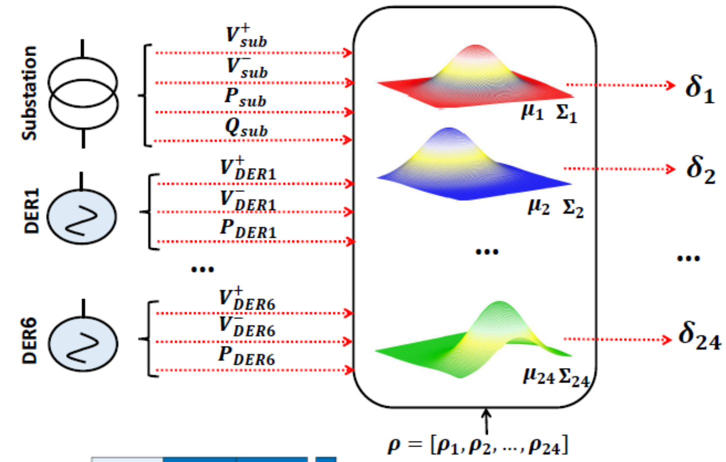
- Topology identification
  - Cyber-security
  - Loss of communication
- Operating status of network
  - Over-voltages, over-loads, …
- DERMS
  - Coordinated management of DERs



Resilient topology identification

Discriminant Analysis for topology identification

- Each topology is modelled as a multi-variate Gaussian distribution
- Using maximum likelihood approach



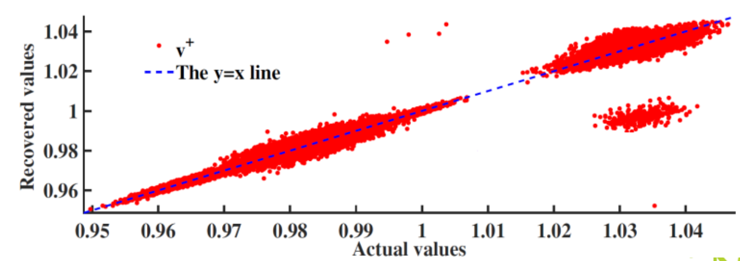
Bayes' likelihood ratio

- To detect anomalous measurements

	Normal	- Bias	+ Bias
$1000 \leq \alpha$	1.0	84.3	82.9
$100 \leq \alpha < 1000$	2.9	10.7	10.4
$60 \leq \alpha < 100$	1.8	1.3	1.7
$20 \leq \alpha < 60$	6.8	2.0	2.6
$10 \leq \alpha < 20$	8.2	0.9	1.1
$0 \leq \alpha < 10$	79.2	0.7	1.3

Quadratic optimization data recovery approach

- To recover the lost measurements



Closing Thoughts

- Many exciting new techniques emerging for network management and demand side services
- Consideration of network security and integrity is required
  - What is the real time topology?
  - Is data correct?
  - What if communications fail?
- These can be solved but do require attention

Closing Thoughts

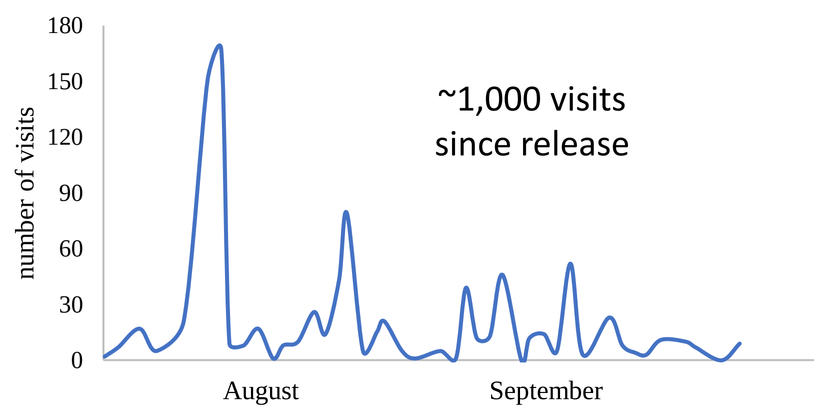
- High potential in characterisation of feeders
  - Polynomials can provide direct solution
  - Near instantaneous computation time
  - No iterations
  - Utilise local measurements, minimise communications

- Can drive local network management but also support new actors to participate in market/supply system services
  - Can support decentralised, centralised, cloud based approaches

Open-DSOPF: a platform for DER optimization in distribution grids

GitHub

https://github.com/ValentinRigoni/Open-DSOPF



[*] V. Rigoni and A. Keane, "Open-DSOPF: an open-source optimal power flow formulation integrated with OpenDSS", IEEE PES General Meeting, 2020