Distribution Network Characterisation: Visibility and Operation

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generation

DSO

TSO

Electricity

Customer Supply

End Use

Finance

Gas

Water

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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

Diagram:
- Passive network operation
- Active network management
- Centralized solutions
- Decentralized solutions
Curve fitting in distribution systems

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

\[
\text{estimate value} = \text{forecast} + \text{effects from DER}
\]

Characterising network sensitivities with polynomial fitting

\[ \gamma_{i,t} = \gamma^*_\text{forecast}_{i,t} + \sum_{h}^{H} c_t \gamma_{i,P_h} P_{h,t} \]

DR allocation

Network sensitivities

Estimated value of network variable over future time horizon

\[ \gamma_{i,\min} \leq \gamma_{i,t} \leq \gamma_{i,\max} \]
Day ahead scheduling and real-time operation problem

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

subject to:

\[Y_{\text{min}_i} \leq Y_{i,t} \leq Y_{\text{max}_i} \text{ with } i = 1, ..., k\]

\[g_j(x) = y_j \text{ with } j = 1, ..., q\]

\[f_u(x) \geq d_u \text{ with } u = 1, ..., w\]

where

\[P_{total_t} = \sum_{h}^{H} P_{h,t}, \quad Q_{total_t} = \sum_{h}^{H} Q_{h,t}\]

Integrated DR Headroom into Aggregator Operations
Results

Maintain currents within the cable capacity

Electricity $
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 multivariate Gaussian distribution
  - Using maximum likelihood approach

- Bayes’ likelihood ratio
  - To detect anomalous measurements

- 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

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

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