THE UNIVERSITY OF MELBOURNE

Real-Time Optimisation of Distribution Networks Using Optimal Power Flow

Michael Z. Liu

PhD Student in Smart Grids

liumz@student.unimelb.edu.au

2nd October 2019

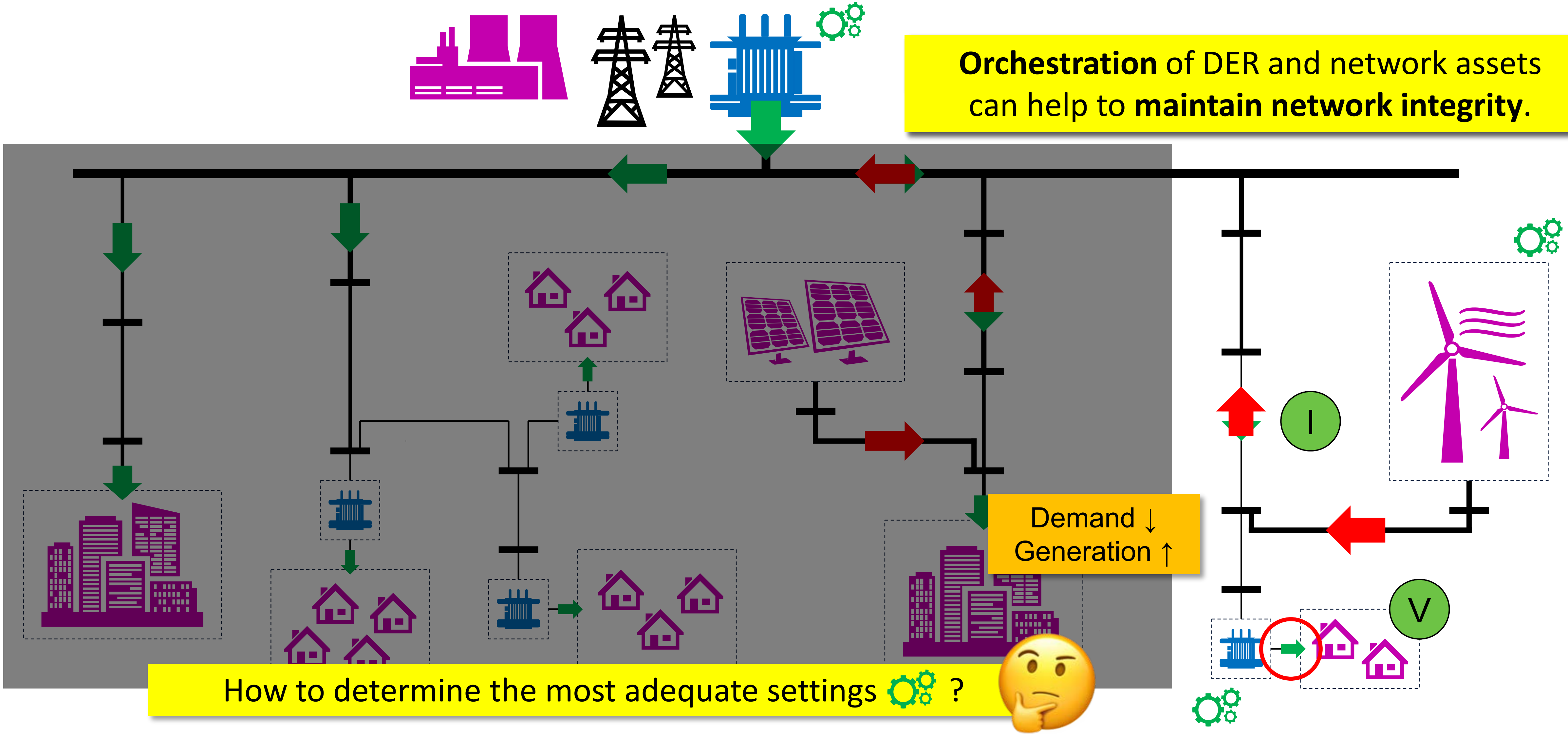
RTDS Australia User's Group Meeting

Outline

- Context
- Implemented Demonstration Platform
- Case Study
- Remarks
- Conclusions

Orchestration of DER and Network Assets

Orchestration of DER and network assets can help to **maintain network integrity**.



How to determine the most adequate settings ?

Optimal Power Flow (OPF)

- One way of formulating the problem
  - Often used in transmission (**1ϕ DC**) … starting to enter distribution (**1ϕ AC**)

- Three-phase OPF for distribution networks

Max/Min Objective Function

Subject to:

'Basic' AC OPF
- 3ϕ parameters (Z, P, Q, etc.)
- 3ϕ variables (V, I, etc.)
- 3ϕ equality constraints (KCL, KVL)
- 3ϕ inequality constraints (network V and I limits)

DER and Network Assets
- Controllable DER
- Non-controllable DER
- Controllable network assets (OLTCs)
- Non-controllable network assets
- etc., etc.

→ The most **adequate settings** for DER and network assets.

Towards an Active Distribution Network

- Thanks to …
  - Deployment of **communication** and **metering** infrastructure
  - Advancement in **computing power** and **problem formulations**

- Concepts such as **network-level optimisation** and **orchestration of DER and network assets** are increasingly becoming plausible
  - E.g., using Optimal Power Flow-based schemes to control DER and network assets

However, before such concepts are readily adopted by industry, their **technical feasibility must be demonstrated**.

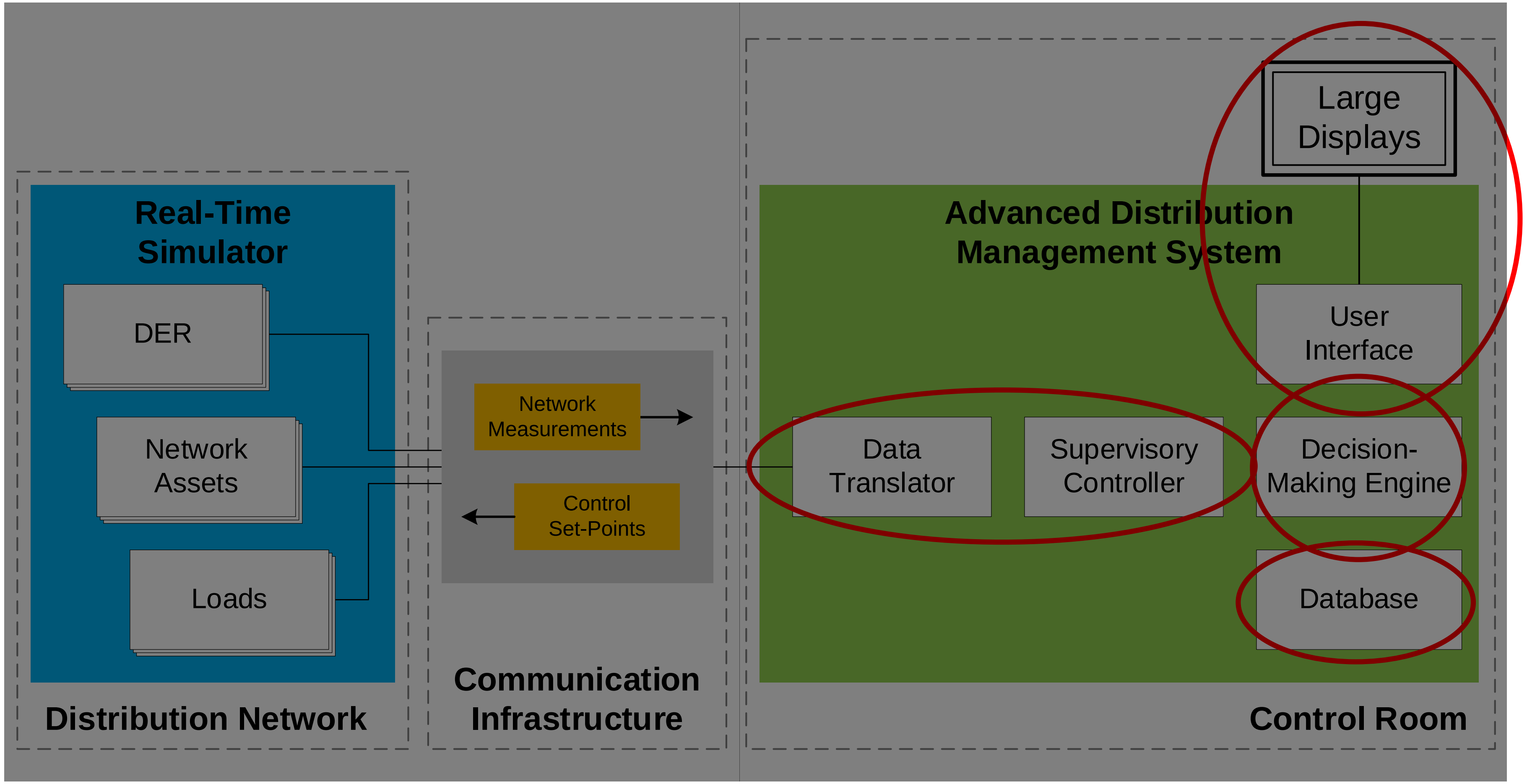
Distribution Network Studies

- (Conventionally) **Offline analysis** with PC-based software
  - Limited external interfaces to other hardware and software
  - Not designed for real-time testing of control schemes
  - Less realistic, not suitable for live demonstrations

- **Online analysis** with hardware-in-the-loop (HIL) simulation
  - Simulated network can interact with **external hardware and software**
  - **Realistic environment** for evaluation and demonstration purposes

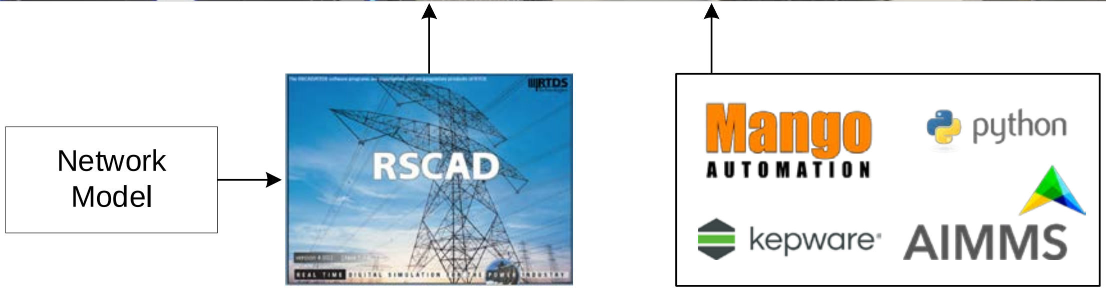
Proposed HIL Architecture

- A realistic representation of an active distribution network



HIL Demonstration Platform

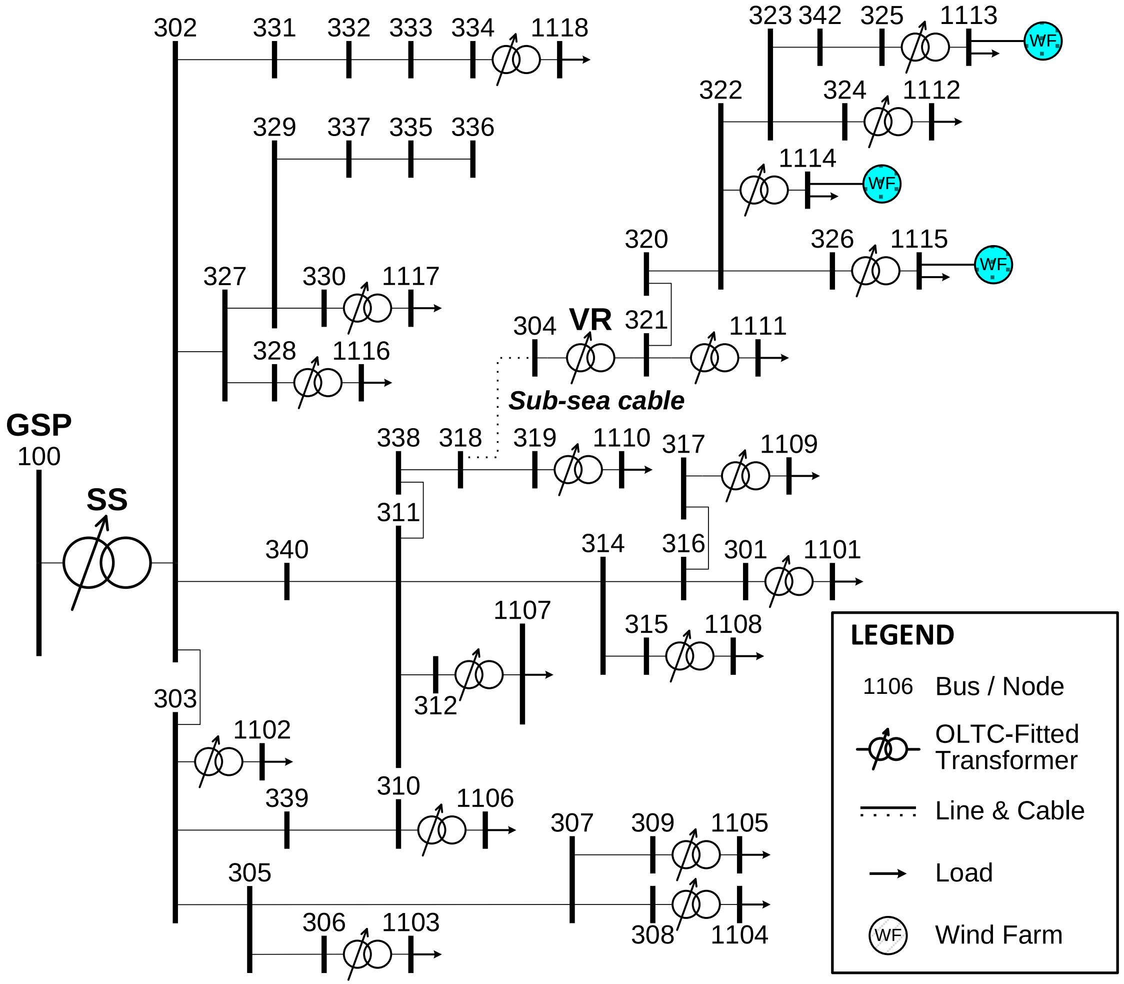
- Implemented at the Smart Grid Lab (The University of Melbourne)
- Network simulator
  - RTDS / Novacor in **distribution mode**
- SCADA platform
  - Mango Automation
  - Kepware KEPServerEX
  - AIMMS + Python
- DNP3 protocol
  - Ethernet connection



Case Study: Test Network

- UK-style rural distribution network
  - UKGDS EHV1
  - 132 kV to 11 kV
  - 38 MW peak demand
  - 3 wind farms (20.5 MW installed capacity)

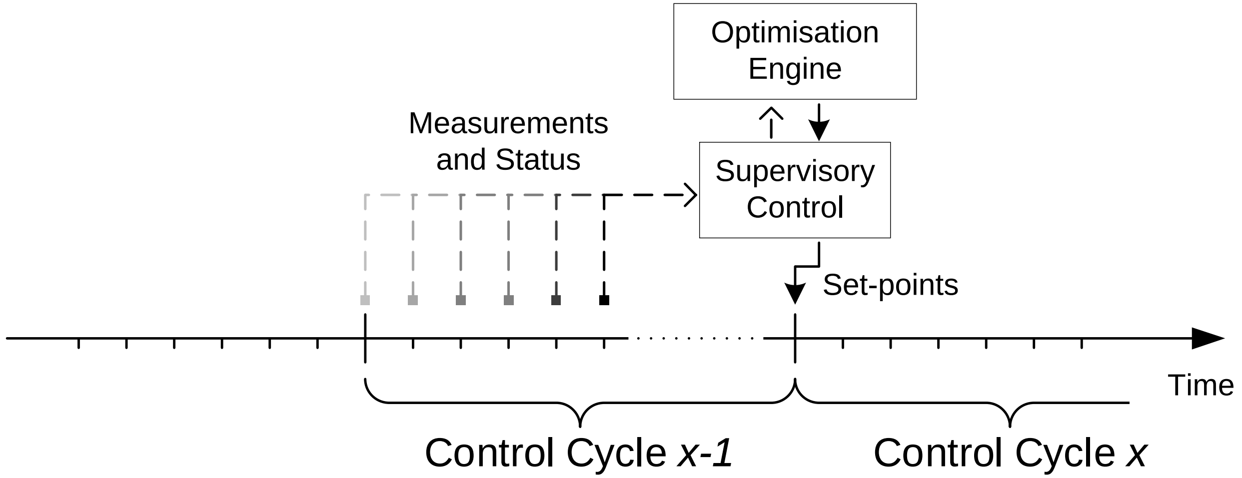
- Controllable elements
  - 3 wind farms (P and Q)
  - 20 OLTCs (tap position)



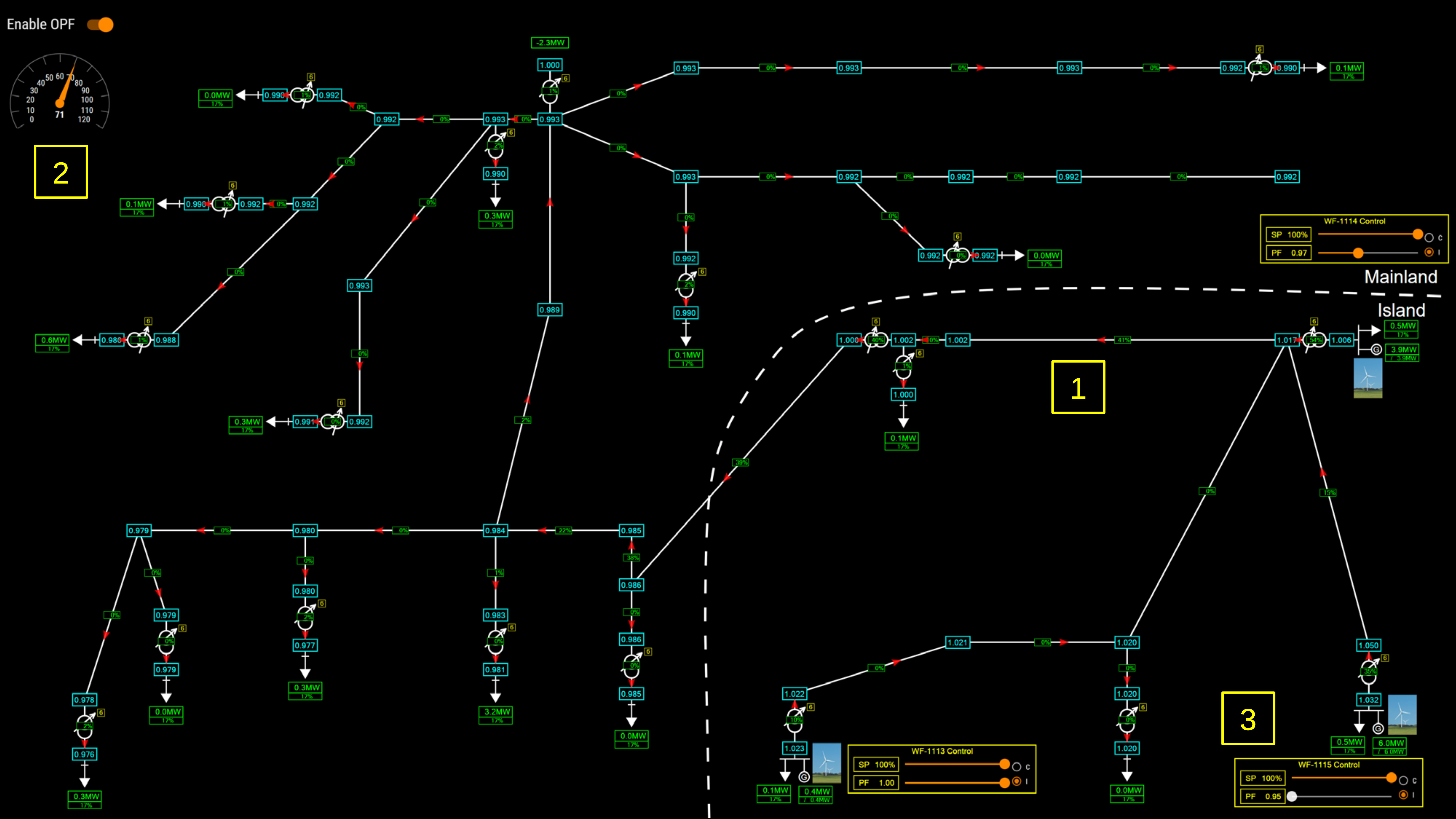
Case Study: Control Scheme

- Based on a linearised, three-phase OPF[1]
  - Maximise renewable energy harvesting
  - Minimise control actions

- Two-minute control cycle



[1] L. Gutierrez-Lagos, M. Z. Liu, and L. F. Ochoa, "Implementable Three-Phase OPF Formulations for MV-LV Distribution Networks: MILP and MIQCP," in *Proc. 2019 IEEE PES Innovative Smart Grid Technologies Conference - Latin America (ISGT Latin America)*, pp. 1-6.



Enable OPF
71
2
1
3
Mainland
Island
WF-1114 Control
SP 100%
PF 0.97
WF-1113 Control
SP 100%
PF 1.00
WF-1115 Control
SP 100%
PF 0.95
-2.3MW
3.2MW
3.9MW
6.0MW

Network Summary

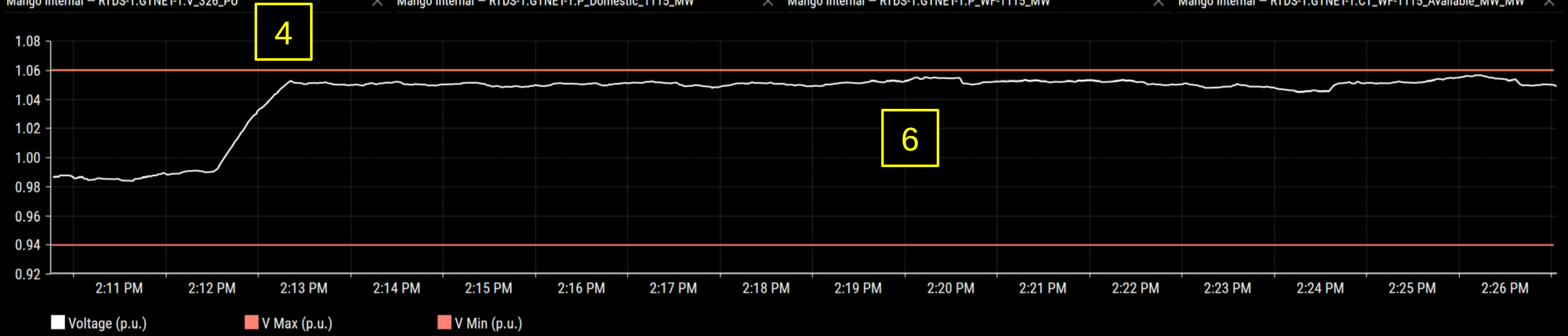
Total Demand 6.841 MW

Total Generation 10.272 MW

7

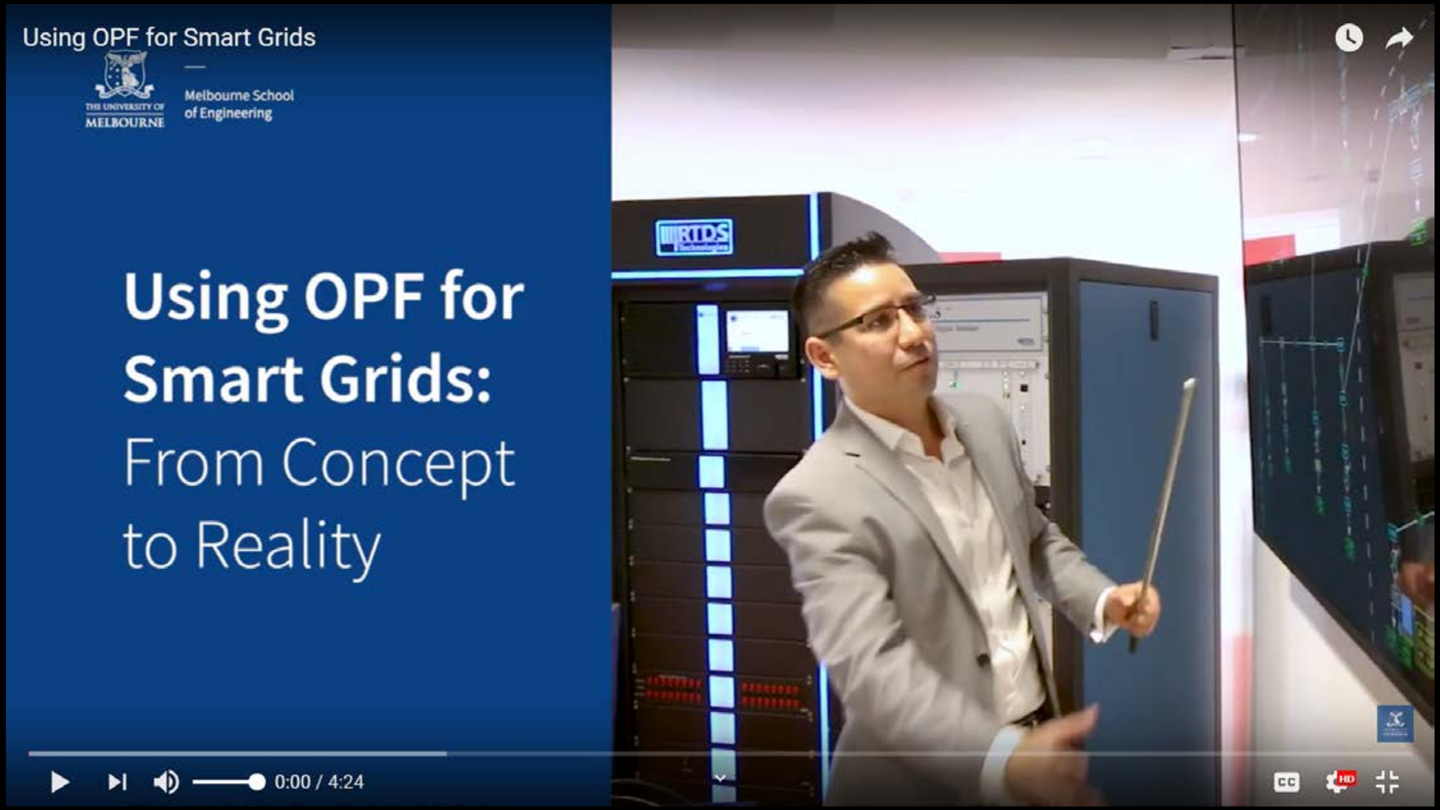
Real-Time Profiles

Choose bus voltage (hint: *V_XXXX*)	Choose local demand (hint: *P_Domestic*)	Choose wind power captured (hint: *P_WF*)	Choose wind power available (hint: *Available*)
Mango Internal — RTDS-1.GTNET-1.V_326_PU	Mango Internal — RTDS-1.GTNET-1.P_Domestic_1115_MW	Mango Internal — RTDS-1.GTNET-1.P_WF-1115_MW	Mango Internal — RTDS-1.GTNET-1.CT_WF-1115_Available_MW_MW



“Using OPF for Smart Grids: From Concept to Reality”

https://youtu.be/1TxaNIqTno4



Challenges Faced & Opportunities

- Distribution network-oriented models
  - Dynamic PQ source, stretchable components, etc.

- Communication interfaces
  - DNP3 variations (ints vs floats)

- **Scalability** to model larger distribution networks
  - E.g., thousands of buses across multiple voltage levels
  - From **creating models** in RSCAD to **visualisation**
  - ➢ *Automated Process*: GIS data → model + interface

Conclusions

- **Orchestrating DER and network assets** in real-time using optimisation-based schemes is increasingly **becoming plausible**.
- **Hardware-in-the-loop simulations** is a powerful technique to demonstrate these concepts in an extremely realistic environment.
- Ultimately, these efforts will help to **boost the industry's confidence** in adopting more advanced approaches.

Thank you ☺

Acknowledgement

Prof Luis(Nando) Ochoa
Professor of Smart Grids and Power Systems

THE UNIVERSITY OF MELBOURNE

Real-Time Optimisation of Distribution Networks Using Optimal Power Flow

Michael Z. Liu

PhD Student in Smart Grids

liumz@student.unimelb.edu.au

2nd October 2019

RTDS Australia User’s Group Meeting