OPTIMAL PLANNING OF RENEWABLE-BASED COMMUNITY ENERGY SYSTEM FOR ISLAND-MODE OPERATION DURING PROLONGED OUTAGES

Dr. Laiz Souto, University of Bristol, email: laiz.souto@bristol.ac.uk

University of BRISTOL

Supergen Energy Networks

Introduction

- **What?** Methodology for optimal planning of highly renewable community energy system resources for island-mode operation during prolonged outages.
- **Why?** To simultaneously improve power system resilience to extraordinary events and increase penetration of renewable generation at local level.
- **How?** Taking advantage of renewable distributed generation at local level to minimize the energy not supplied (ENS) when the external grid is not available.

Methodology

Mixed-integer quadratic programming formulation to minimize the projected ENS values subject to operating limits and available resources:

1) Load demand constraints by bus over time:

$$\underline{P}_{\mathrm{D}nt} \leq p_{\mathrm{D}nt} \leq \overline{P}_{\mathrm{D}nt}, \forall n \in \mathcal{N}, t \in \mathcal{T},$$
$$\underline{Q}_{\mathrm{D}nt} \leq q_{\mathrm{D}nt} \leq \overline{Q}_{\mathrm{D}nt}, \forall n \in \mathcal{N}, t \in \mathcal{T},$$

2) Generation constraints by bus over time (if present):

$$\alpha_n \underline{P}_{\mathrm{G}nt} \leq p_{\mathrm{G}nt} \leq \alpha_n \overline{P}_{\mathrm{G}nt}, \forall n \in \mathcal{N}, t \in \mathcal{T},$$
$$\alpha_n \underline{Q}_{\mathrm{G}nt} \leq q_{\mathrm{G}nt} \leq \alpha_n \overline{Q}_{\mathrm{G}nt}, \forall n \in \mathcal{N}, t \in \mathcal{T},$$

3) Storage constraints by bus over time (if present):

$$0 \leq p_{\mathrm{CH}nt} \leq \alpha_n P_{\mathrm{CH}n} \qquad 0 \leq p_{\mathrm{DCH}nt} \leq \alpha_n P_{\mathrm{DCH}n}, n \in \mathcal{N}, t \in \mathcal{T}.$$
$$e_{nt+1} = e_{nt} + \tau \left(p_{\mathrm{CH}nt}\eta_{\mathrm{CH}n} - \frac{p_{\mathrm{DCH}nt}}{\eta_{\mathrm{DCH}n}} \right)$$
$$\underline{E}_n \leq e_{nt} \leq \overline{E}_n, \forall n \in \mathcal{N}, t \in \mathcal{T}.$$

4) Maximum number of distributed generation units:

$$\sum_{n \in \mathcal{N}} \alpha_n \leq \overline{N}_{\mathrm{DG}}.$$

Objective function: minimize projected ENS values

$$\min \sum_{t \in \mathcal{T}} \sum_{n \in \mathcal{N}} \left(\overline{P}_{\mathrm{D}nt} - p_{\mathrm{D}nt} \right)^2$$

Case study

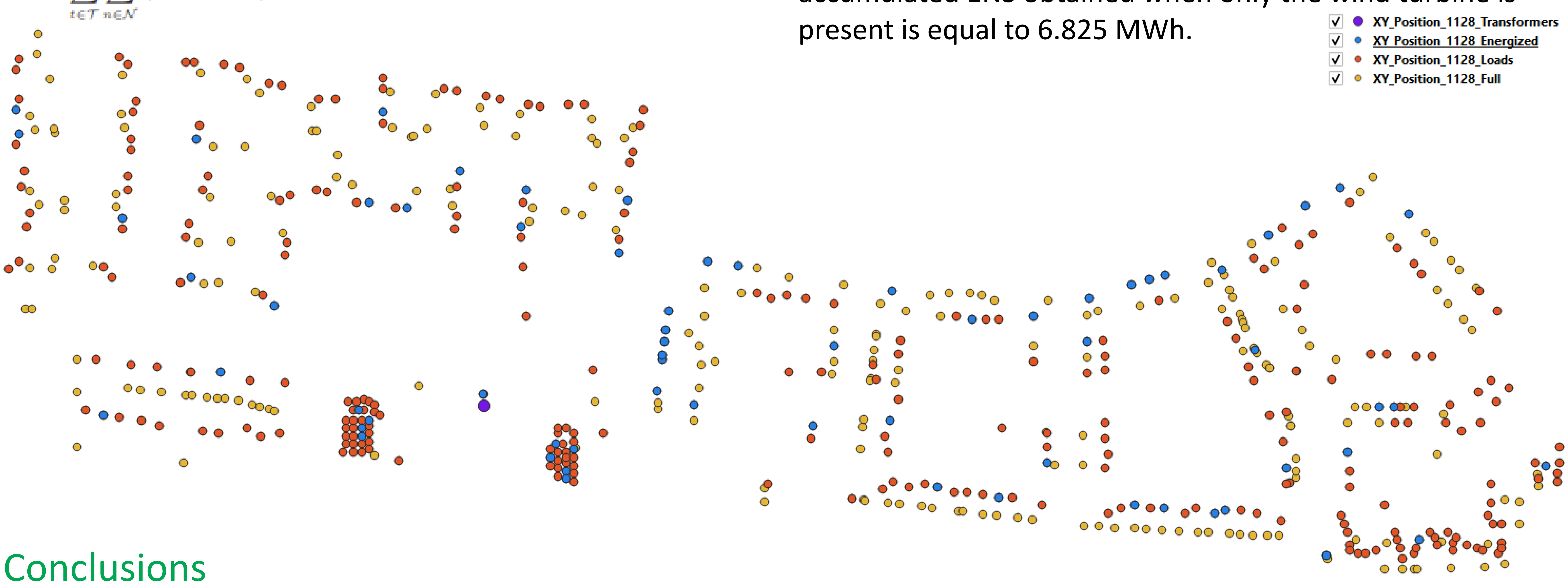
- Real-world three-phase unbalanced LV network in the UK with 330 single-phase loads and a 0.5 MW onshore wind turbine connected to the substation transformer.
- 3-day power outage during which supply from the external grid becomes unavailable
- Realistic load demand plus wind and solar energy profiles obtained with hourly resolution from 6 to 8 July 2019 at a selected neighborhood in Bristol, UK (lowest wind speeds in 2019).
- Assumption: up to 66 sets of solar photovoltaic panels plus battery storage units will be deployed in the LV network (i.e., 20% of households)
- Wind turbine specifications: Enercon E40/500, 65 m hub height, 0.25 MW maximum reactive support.
- Solar panel specifications: 2 kWp peak power, 10% system losses, 2-axis tracking, 35° tilt, 180° azimuth.
- Battery specifications: 30 kWh storage capacity, 3 kW dis/charging power, 0.98 dis/charging efficiency, 2.5%/97.5% minimum/maximum state of charge.

Results

The methodology determines:

1. the **energy not supplied (ENS)**,
2. the **optimal locations** in which sets of distributed generation units should be installed to minimize the ENS values (see diagram), and
3. relevant **electrical quantities** given by the optimal operating conditions.

The accumulated ENS obtained when the wind turbine plus sets of solar photovoltaic panels plus battery storage units are present is equal to 4.968 MWh. In comparison, the accumulated ENS obtained when only the wind turbine is present is equal to 6.825 MWh.



Conclusions

The results indicate that the proposed methodology can help communities to increase energy self-sufficiency and improve resilience to extraordinary events through local renewable energy supply. Therefore, it can be effectively used by local and regional energy system planners and renewable project developers to boost renewable community energy initiatives, given resource constraints, and accelerate decarbonization.