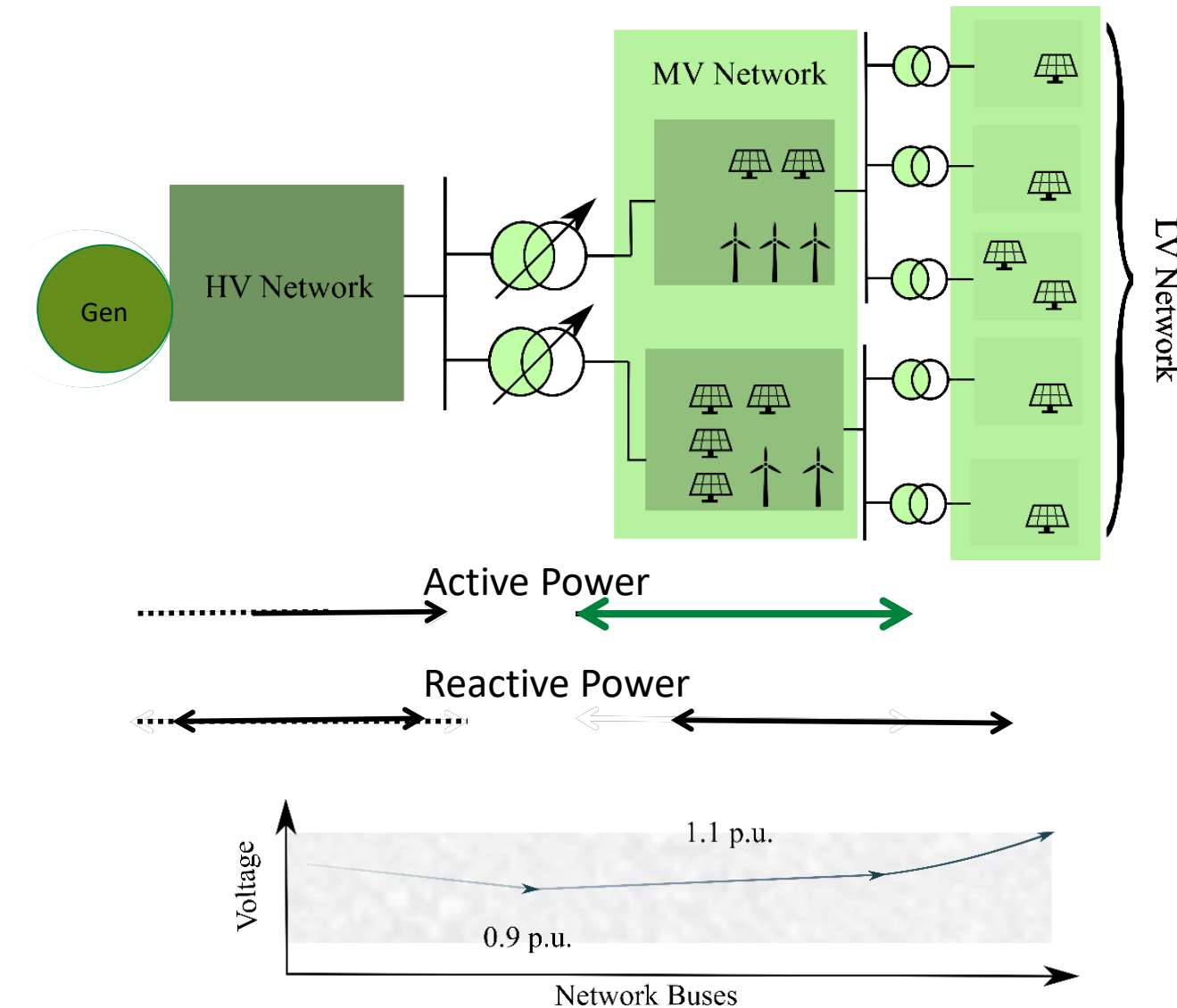




Effects of Weather-dependent Uncertainty in Distribution Grids with Large Share of Wind Power Plants

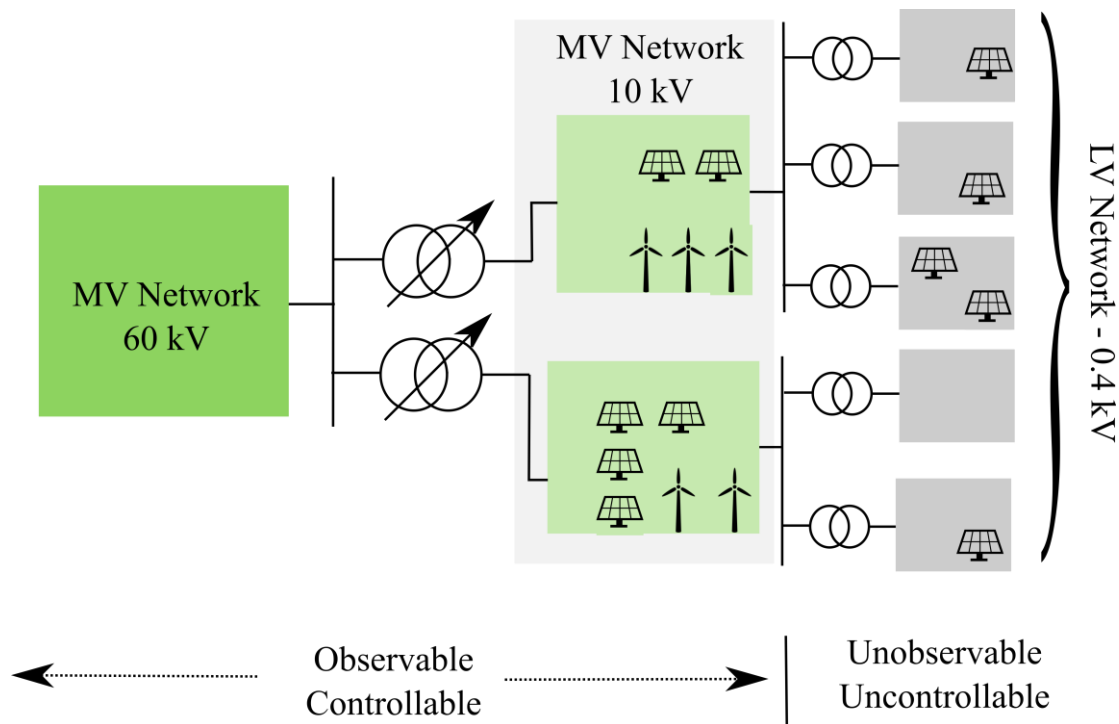
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Motivation



- The distribution networks are undergoing a major transformation from being passive consumers to actively generating power
- Decommissioning of large synchronous generators and introducing decentralized generation causes an imbalance in the system
- The traditional design of the distribution network is not optimal for the distributed generation
- Challenges for distribution network operators include,
 - Increasing active power losses
 - Power Quality
 - Harmonics

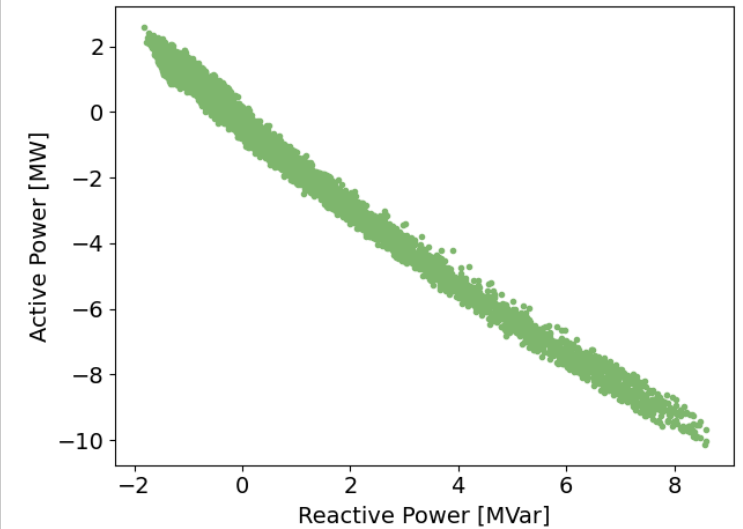
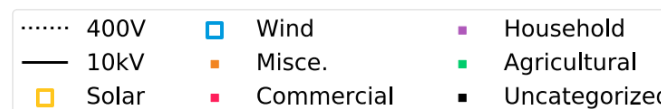
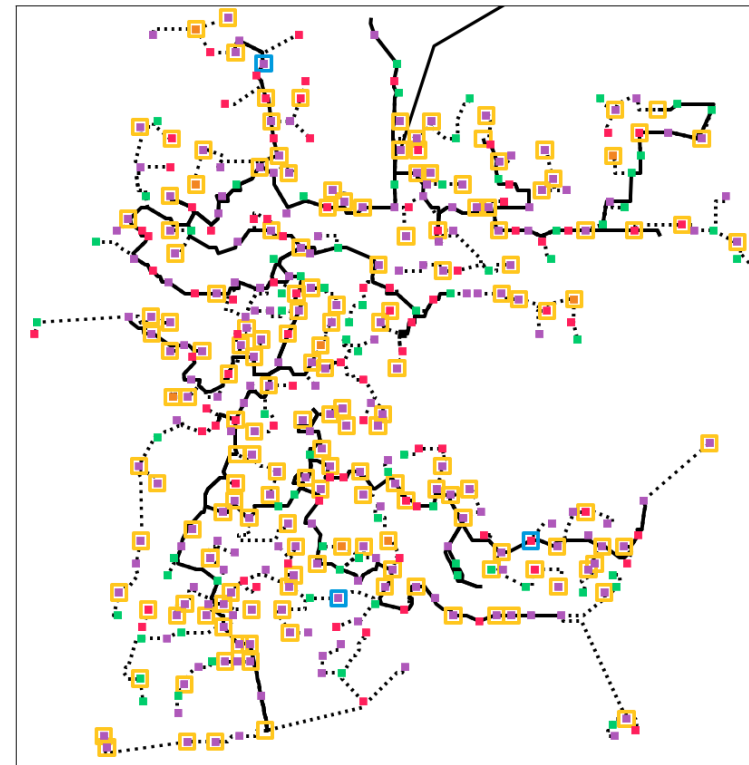
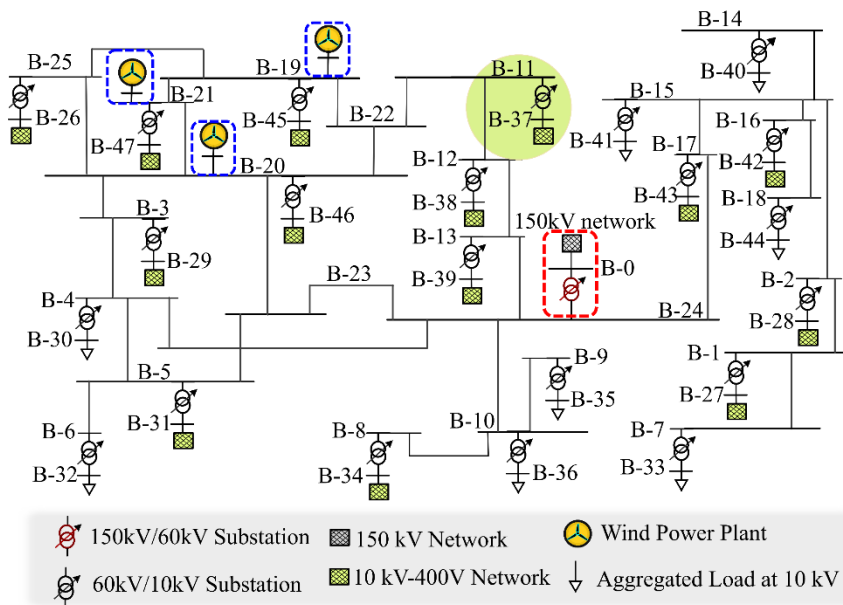
Unobservability in the Distribution Network



- The lower voltage level distribution networks are not always real-time observable due to a lack of measurement devices
- Lack of accurate data
 - Real-time update of network topology
 - Historical detailed load profile data for accurate predictions
- Due to the increasing share of renewable generation like solar PVs and wind power plants, the aggregated load profiles are becoming more weather-dependent

How does controlling assets in the medium voltage distribution affect the medium and low voltage networks considering uncertainty?

DTU-7k Bus Active Distribution Network (DTU-ADN)



[1] A. Baviskar, A. D. Hansen, K. Das, and M. Koivisto, "DTU 7k-Bus Active Distribution Network," *Dataset*. 2021, doi: 10.11583/DTU.c.5389910.

Aggregated Load Profile at 60kV

Modelling uncertainty in weather-dependent aggregated load-generation

ARMA Model:

$$y(t|t-1, t-2, t-3, \omega, X) = \alpha_1 y(t-1) + \alpha_2 y(t-2) + \alpha_3 y(t-3) + \beta \omega + \gamma X + \epsilon(t) + \epsilon_\omega(t)$$

Where,

y : aggregated load-gen profile

ω : Wind Speed

X : Exogenous Factors

α_i : Coefficient for past data

β : Coefficient for wind speed

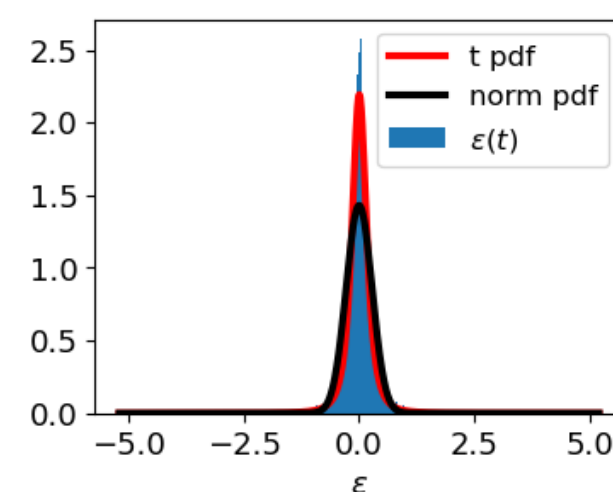
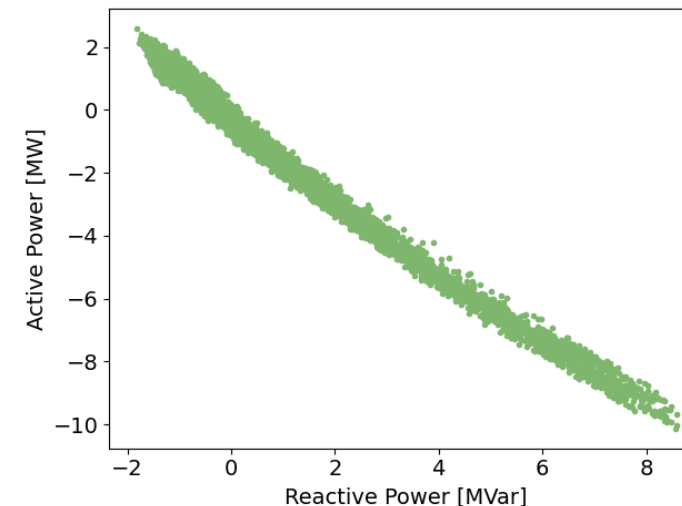
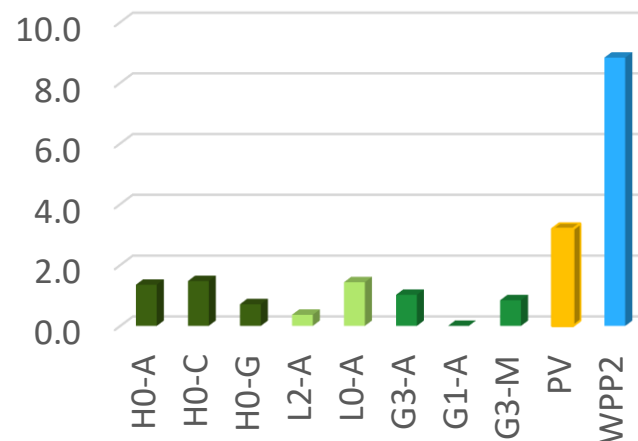
γ : Coefficient for exogenous factors

$\epsilon(t)$: Modelling error of the ARMA model

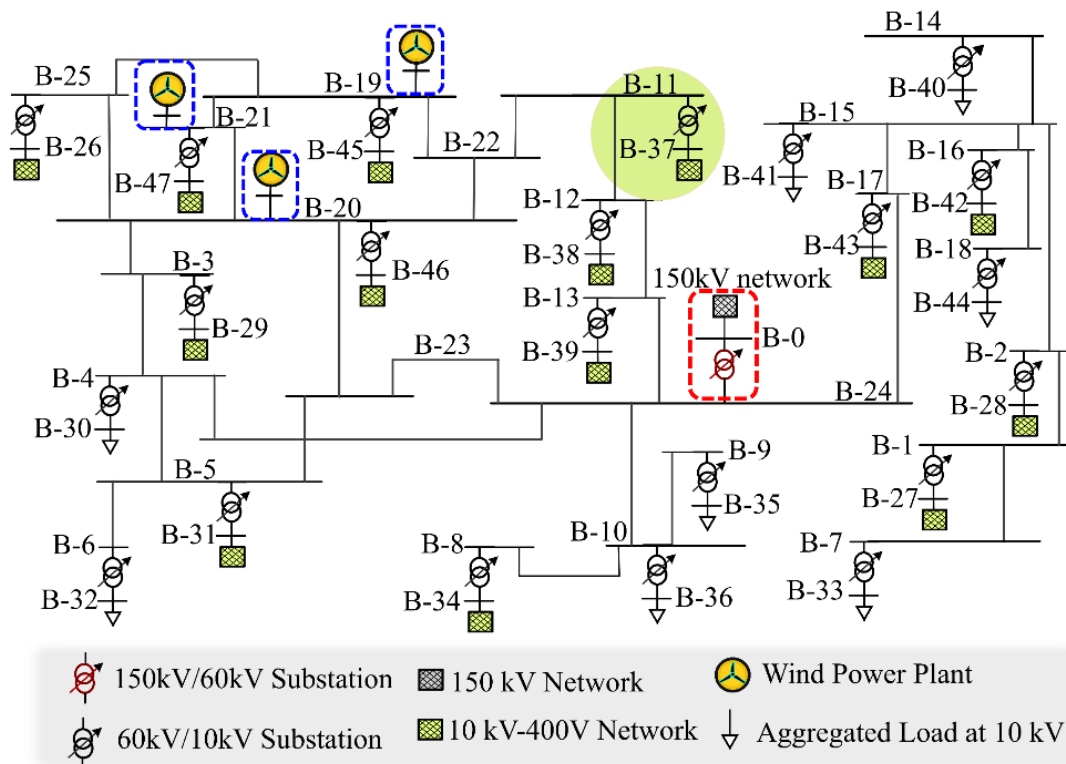
$\epsilon_\omega(t)$: Wind speed forecast error

Exogenous Factors Used:

1. Time of Day
2. Day of the Week
3. Temperature
4. Solar Irradiation
5. Public Holiday
6. Precipitation
7. Humidity



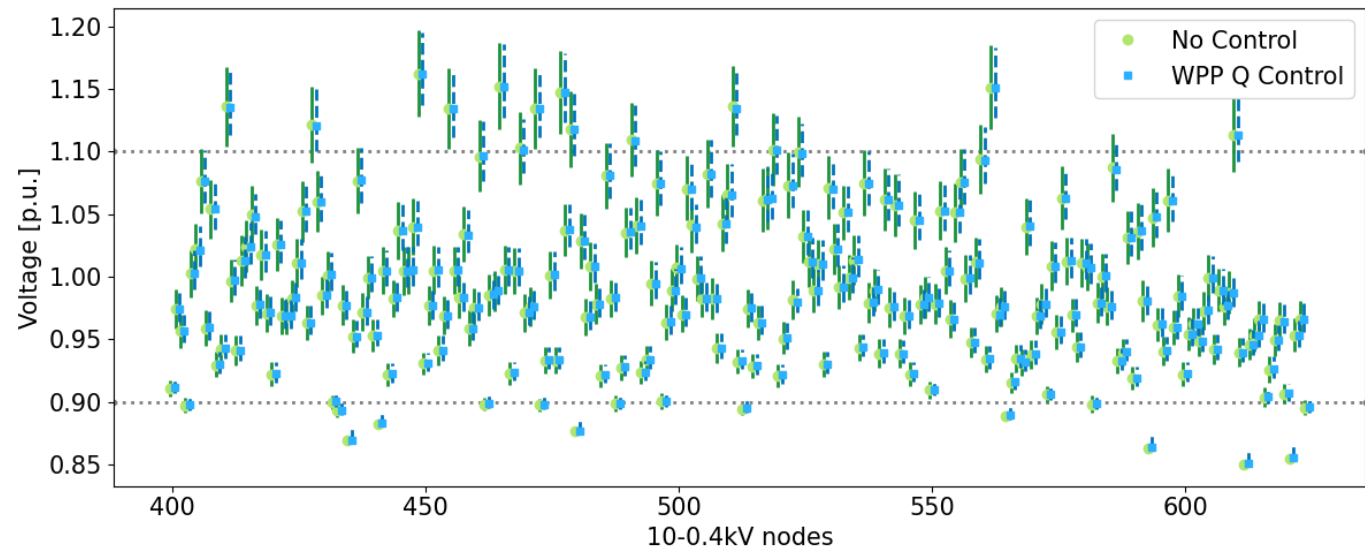
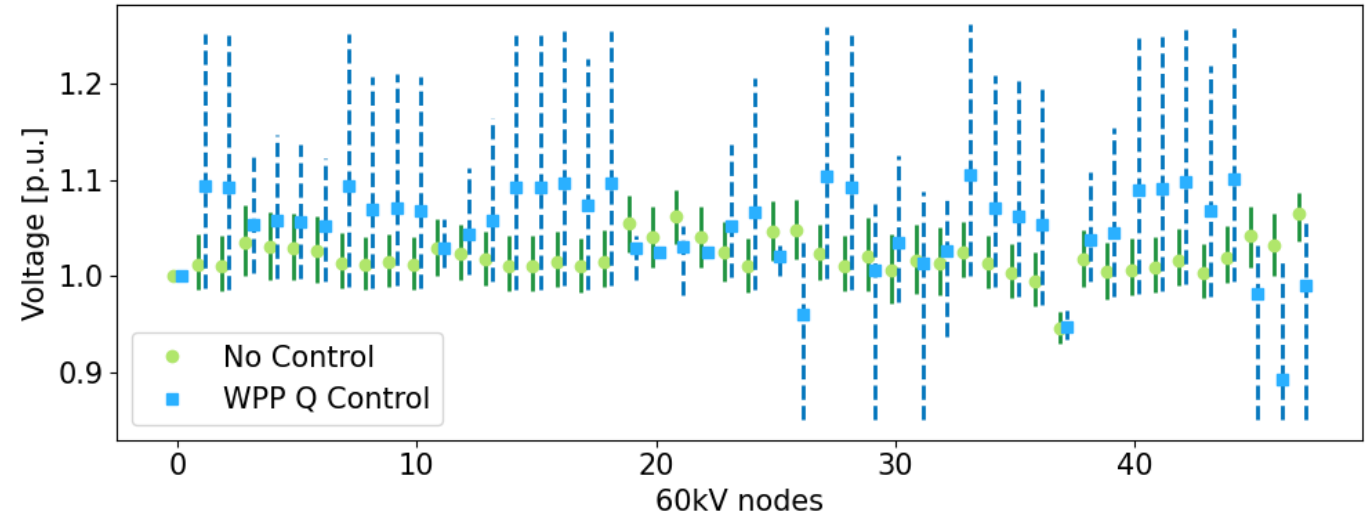
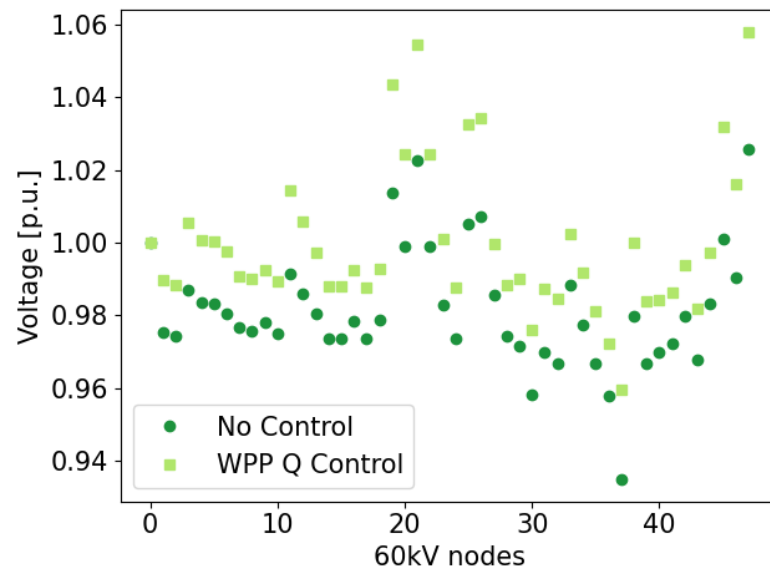
Sources of Uncertainty in a Distribution Network



- Modelling Error for the prediction of the aggregated load profile
- Uncertainty in aggregated load due to human interaction
- Weather-forecast errors, extreme weather events
- Uncertainty in power output for weather-dependent generation
- Uncertainty in the amount of online generation in the un-observable network

Voltage Profiles in the observable network

- The reactive power from wind power plants is considered controllable
- The objective is to minimize active power losses in the distribution network
- Results from the deterministic optimization show a better voltage profile!



Conclusion

- Increasing the share of weather-dependent generation induces an additional layer of uncertainty in the distribution networks
- The uncertainty, along with the un-observability in low voltage networks, can be detrimental to the power quality in the distribution networks
- There is a growing need to accurately model the stochasticity in the distribution network
- Stochastic optimization and control methods will be required to optimally operate future weather-driven active distribution networks

**Thank you for your
attention!**

Questions?

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