1 THESIS SUMMARY

Modern power systems face massive integration of distributed energy resources, i. e., small and modular energy generation or storage, interfaced with electrical distribution networks through power electronic converters. Active distribution networks are the result of this integration, where the distribution network is no longer a passive load sink, but actively participates in the power system operation. Power converters are electronic devices that enable the integration of renewable energy resources in power systems by converting electrical energy from one form to another. The increased integration of these devices alter the power system dynamics; the fairly slow electromechanical phenomena driven by synchronous machines are now dominated by the complex fast-response of power converters. Traditional control strategies are not able to cope with the new dynamics, and may fail at guaranteeing the safe operation of the electrical network. Furthermore, power converters usually interface renewable energy production, or flexible loads with the grid, and their intermittent nature require new fast control strategies to continuously track the time-varying grid conditions.

In the first part of this thesis, we derive new modelling tools to represent the dynamic behavior of power converters. Based on the following observations:

- Detailed models of power converters may not be available due to data privacy,
- Even though detailed models are available, they are not appropriate to run system-level studies as they are computationally expensive,
- Generic models may not be able to represent specific dynamics, in particular, when we consider large-signal perturbations,

we seek to solve the following problem:

Problem 1.1. *Developing power electronic converters' models that (i) do not require a-priori knowledge about their internal structure, (ii) are computationally lightweight, and (iii) are valid for system-level studies.* □

The models developed in this thesis are based on a multimodel approach and are particularly well-adapted to system-level studies. There are designed to analyze the system's dynamics in different operating conditions. Also, they are computationally lightweight compared to detailed models, which allows for simulations of large systems with many different assets. Figure 1.1 illustrates the type of model we aim to develop; models of power converters that are ready to be installed in houses, and that are appropriate to perform system-level studies.

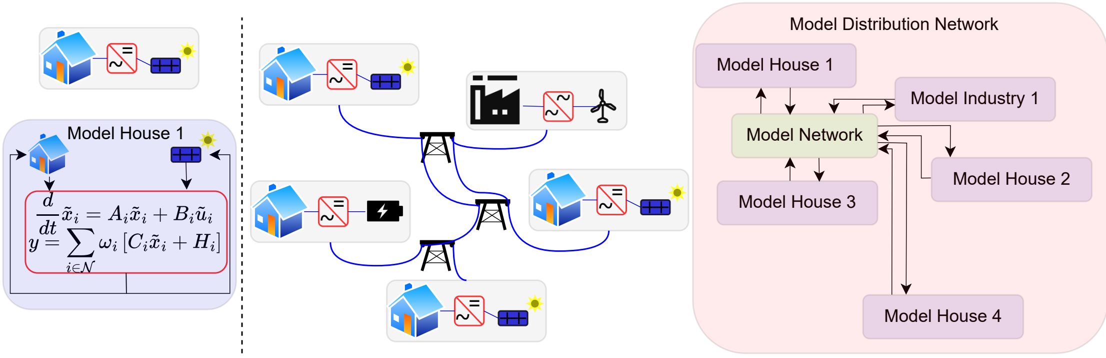

Figure 1.1: Illustration of component and system modelling.

In the second part, we consider the problem of controlling inverter-interfaced distributed energy resources (DERs) to ensure voltage regulation in a distribution network while minimizing resource usage. Voltage issues can occur due to the massive integration of renewable energy resources. In particular, excessive production of solar energy in residential low voltage networks can lead to overvoltages. Motivated by the following observations:

- Increased integration of renewable energy resources and load management strategies leads to operational and reliability challenges,
- Underlying dynamics of distribution networks are too fast to regulate power setpoints based on traditional AC optimal power flow techniques,
- Limited information is available at the distribution side, and there is a lack of communication infrastructure,

we seek to solve the following problem:

Problem 1.2. *Developing control algorithms that (i) leverage DERs' flexibility to ensure operational constraint satisfaction in distribution networks while minimizing the usage of resources, (ii) operate in real-time to ensure proper operation of the network, (iii) does not require extensive monitoring of the distribution network.* □

In Figure 1.2, we illustrate the voltage regulation problem in distribution networks with increased penetration of DERs, and how DERs' flexibility can mitigate these issues.

We first propose a centralized online feedback optimization method that drives controllable power setpoints to a solution of an optimization problem, while ensuring anytime satisfaction of voltage constraints. We then propose a decentralized incremental Volt/-Var control strategy, where the gains are derived in order to minimize resource usage and satisfy voltage constraints with a prescribed probability. The optimization problem centrally, but the method requires only occasional communication. Finally, we propose a

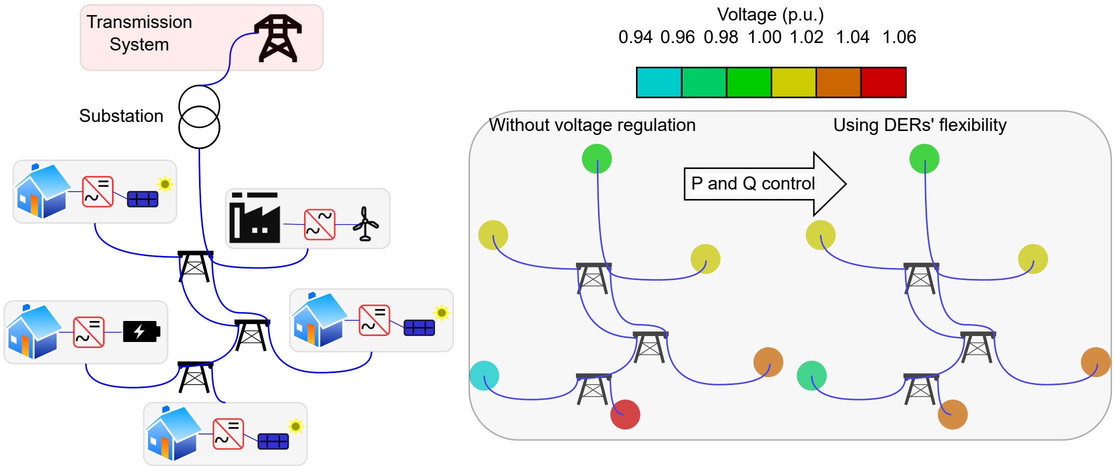

Figure 1.2: Illustration of voltage issues in distribution networks with high penetration of DERs, and how DERs flexibility can mitigate them.

distributed controller where an optimization problem is decomposed and solved node by node, with only local communication between neighboring nodes.

Finally, we conclude this manuscript with a discussion on why modelling tools are crucial to validate new control strategies for active distribution networks. In particular, we comment on how the first and second part of this manuscript are related and how they can be used together to validate and test new control strategies.