# Overview of Task 1

- **Objective:**
  Maximize real power exported to mid-voltage distribution networks from coupled low-voltage microgrids.

- **Issues**:
  - Voltage-rise problem;
  - Weak network property;
  - Legacy control's compatibility.

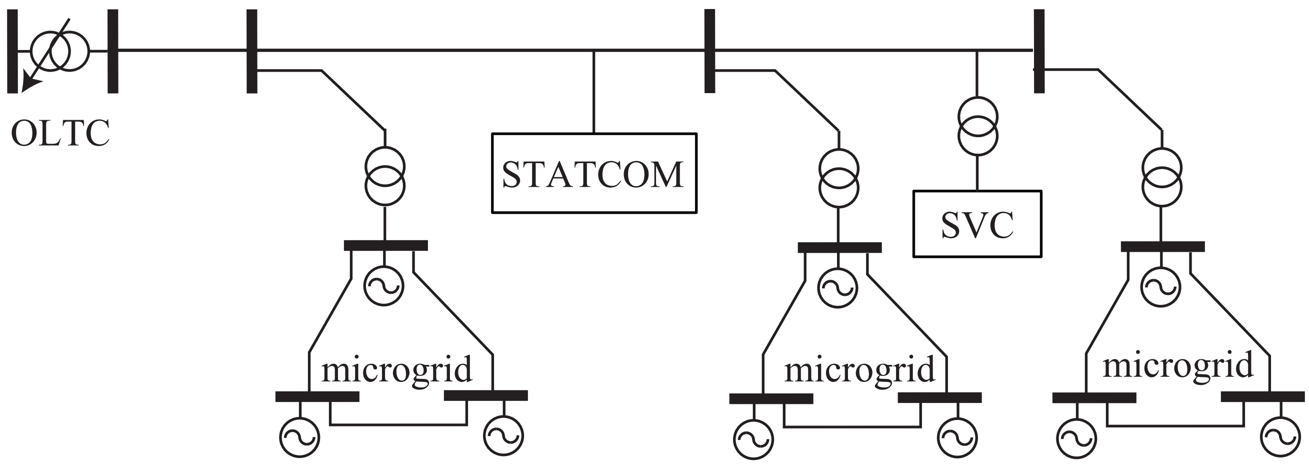


Fig. 1 Distribution Network with Legacy Controls

- **Approach**:
  - Reactive power dispatch;
  - Distributed optimal controller;
  - Simulation analysis.

- **Benefits**:
  - **Minimize** impact on existing voltage regulation policies;
  - **Maximize** real power exported back to distribution network.

# Task 1.1 Algorithm Development

- **Objective**

  Manage generations coordinatively to export **maximum real power** and maintain **voltage levels within limits**.

- **Results**

  - A **hierarchical control architecture** includes: Microgrid Consortium Manager (**MCM**), Microgrid Interface Controller (**MIC**), and CERTS droop controller.
  - Two levels of optimization problems in MICs: microgrid states are determined **locally**; set points of microsources are solved in a centralized manner.

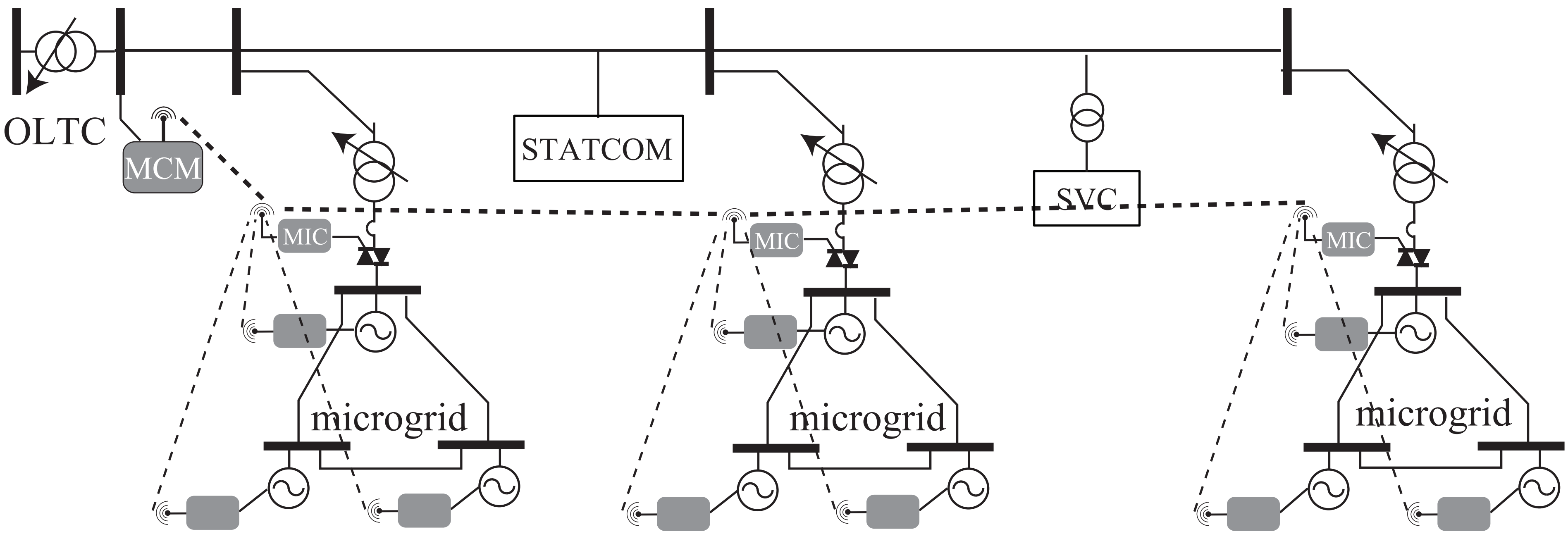


Fig. 2 Hierarchical Control Architecture

# Task 1.2 Simulation Development

- **Objective & Approach**

  **Performance** of the proposed controller is checked in distribution network simulation models. Simulations are built with simpower toolbox in matlab.

- **Result**

  - A complete simulation model of distribution network is formulated, including the proposed hierarchical control architecture.
  - Legacy control devices are individually integrated into the simulation model to check controller compatibility.

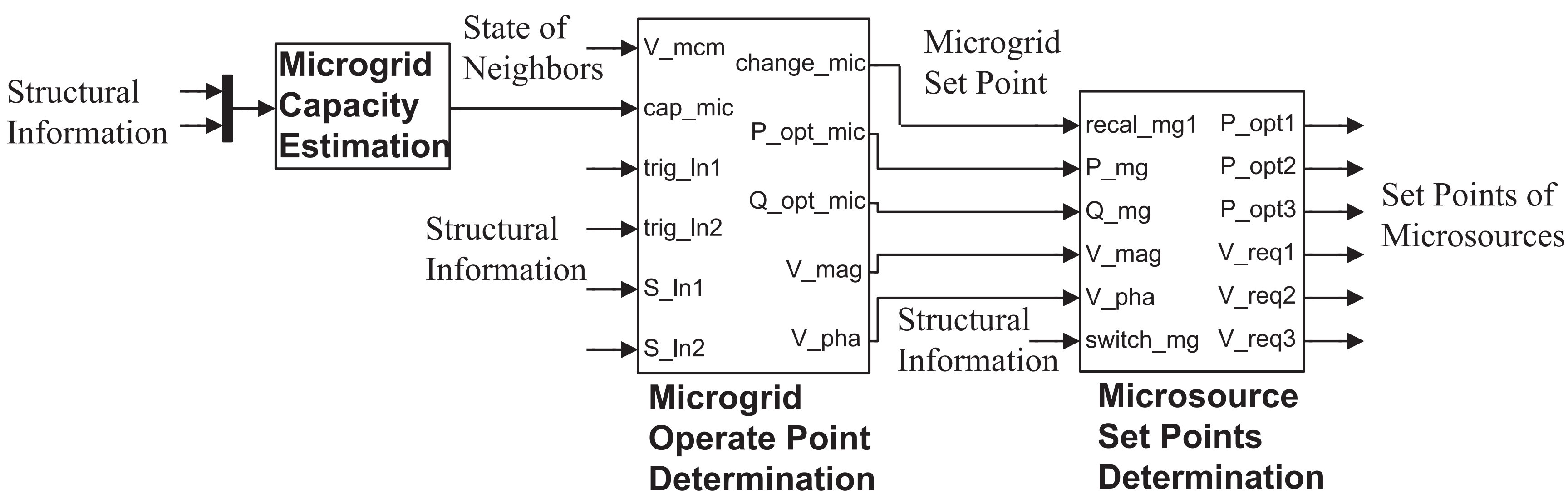


Fig. 3 Realization of MIC in the Simulation Model

# Task 1.3 Evaluation

- **Objective**

  Evaluating the compatibility of the controller with existing voltage control mechanisms in distribution networks.

- **Result**
  - In normal operation, system is **optimal** with respect to microgrid capacity estimation results.
  - After **load** or **structural** changes, stable operation is verified.
  - Control scheme compatible with legacy control devices, including **OLTC** and **SVC**.

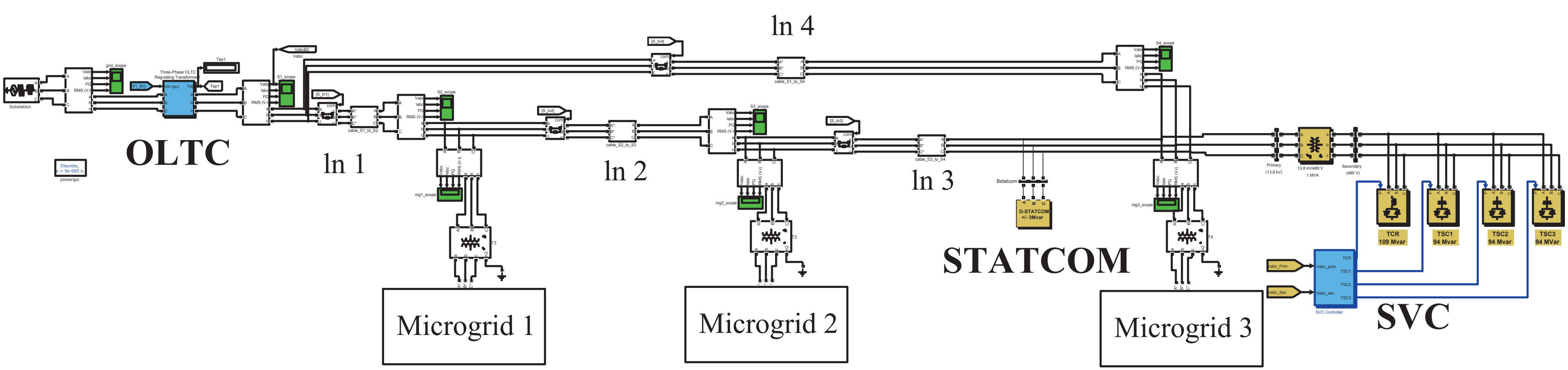


Fig. 4 Complete Simulink Simpower Model for Evaluation

# Task 1 Simulation Result with OLTC

## System with structural changes inside and outside of microgrids

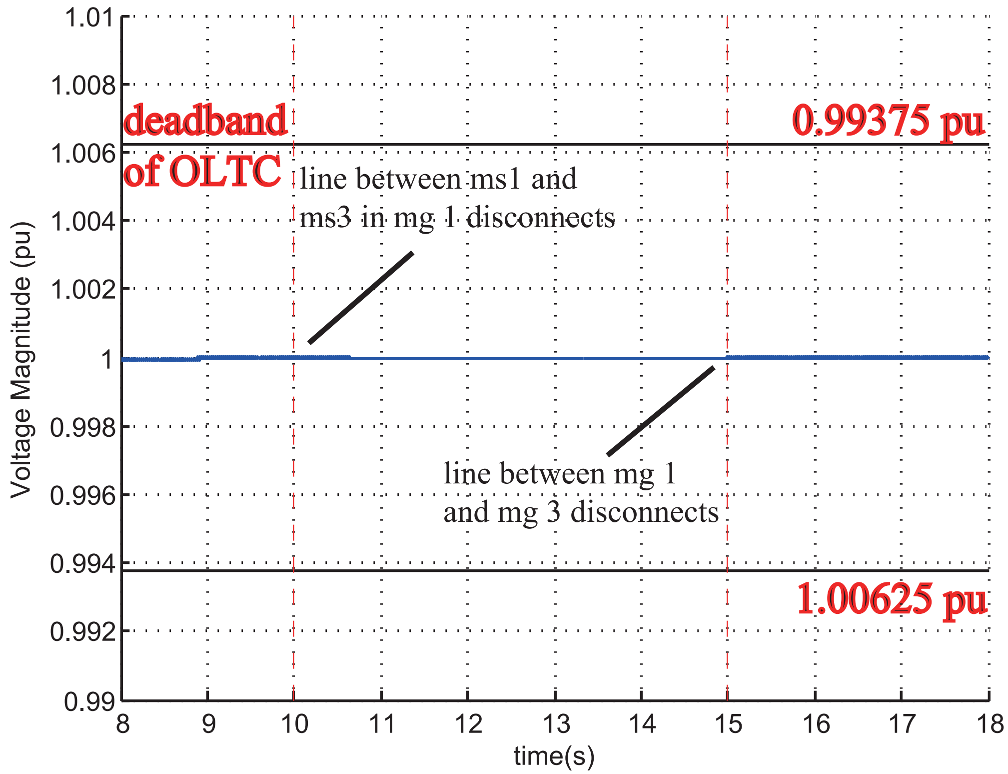


Fig. 5 Response of Voltage at the PCC of mg 1

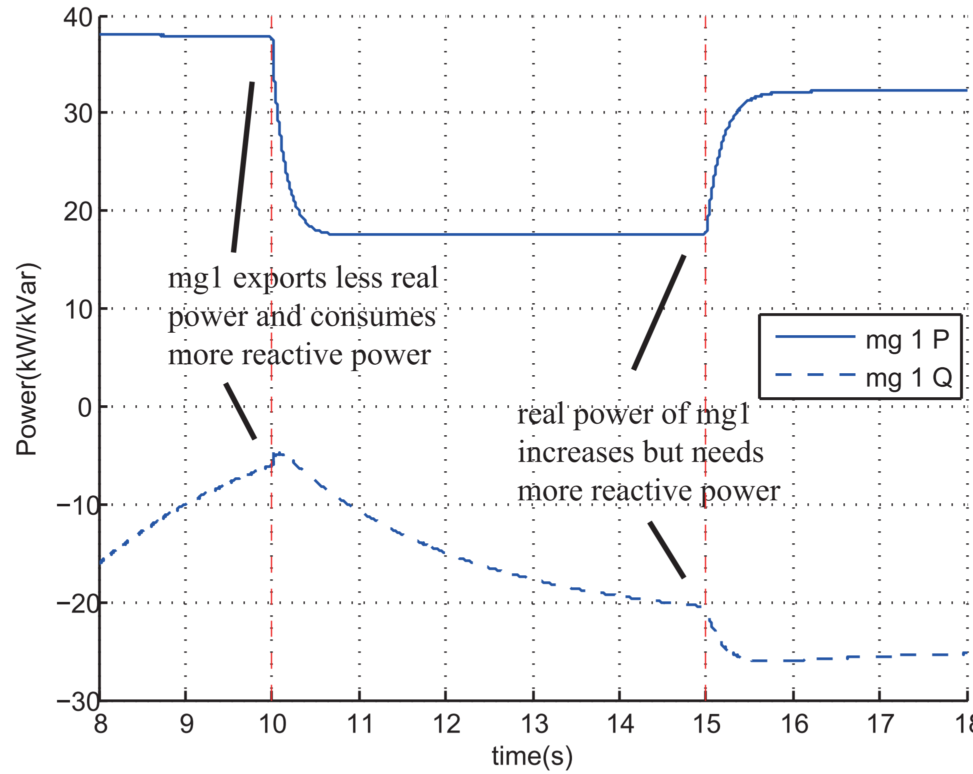


Fig. 6 Power Outputs of Microgrid 1

- Optimal set points solved by the distributed controller have voltages at 1.0 pu;
- **OLTC** tap is kept at **0** throughout the simulation, since the feedback voltage stays within **OLTC**'s deadband.

# Task 1 Simulation Result with SVC

## System with structural changes inside and outside of microgrids

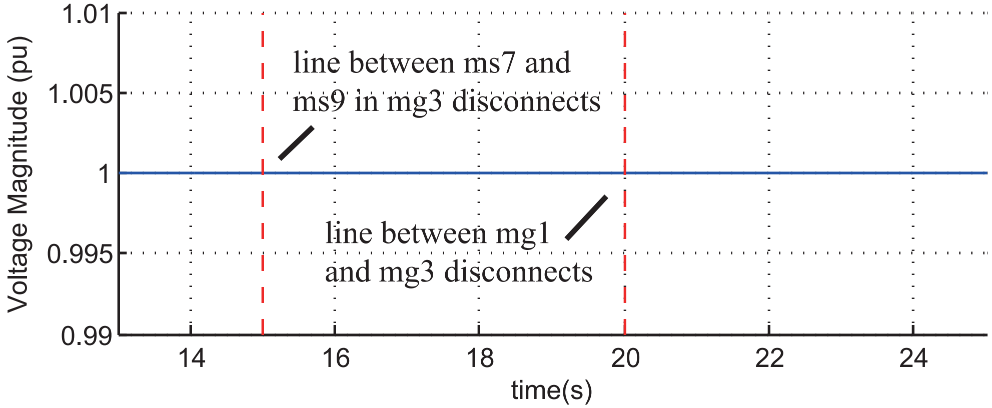


Fig. 7 Response of Voltage at the PCC of mg3

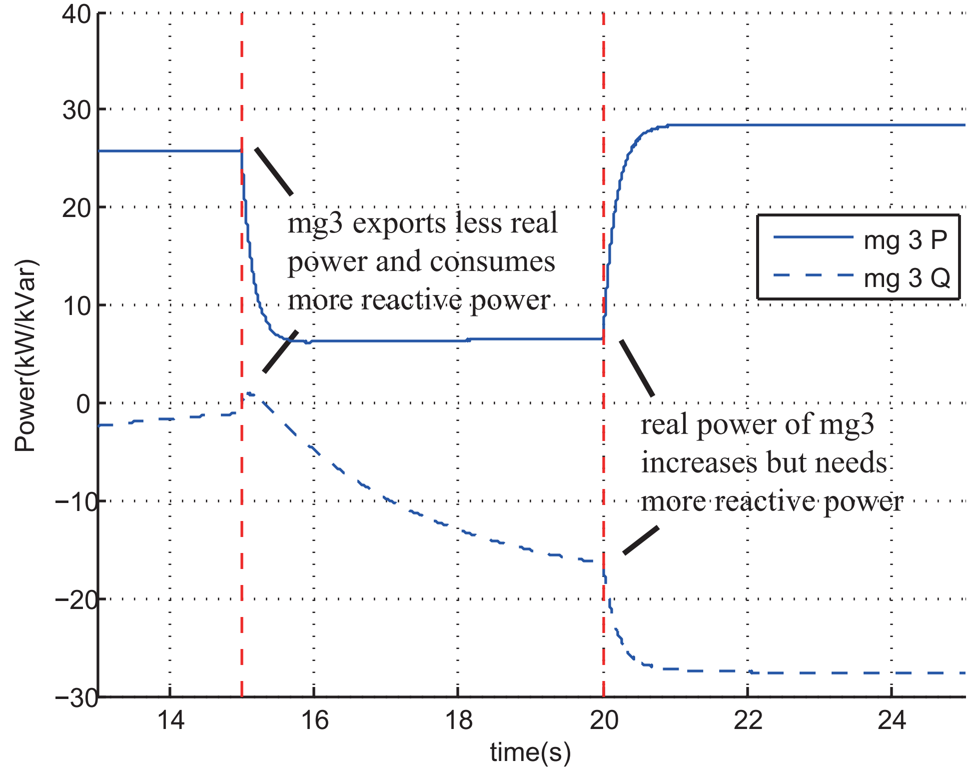


Fig. 9 Power Outputs of Microgrid 3

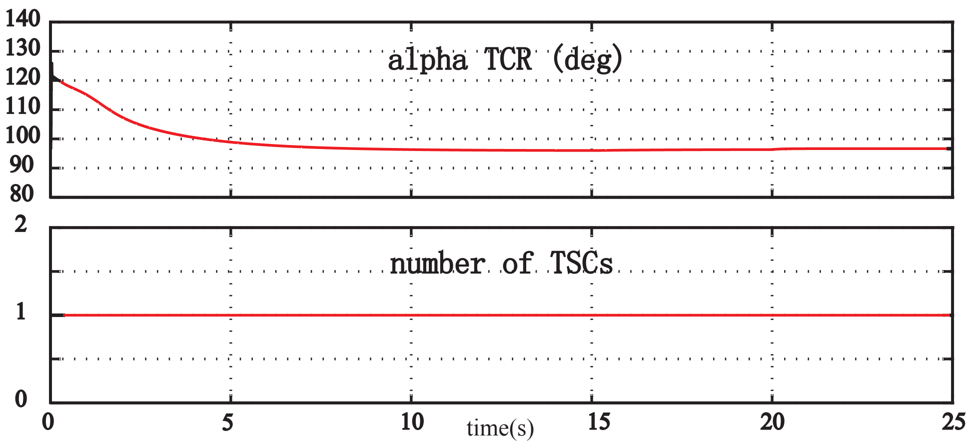


Fig. 8 Operation of SVC

- Voltage feedback of **SVC** is kept close to 1.0 pu, so there is no switching;
- The reactive power absorbed by **SVC** is constant around 2 kVar.

# Task 1 Conclusion

- **The hierarchical controller proposed does not interfere with legacy voltage control devices, such as OLTC and SVC.**
  - During structural changes inside and outside of microgrids, the operation of legacy control devices is **not** influenced by microgrids;
  - Distributed optimal controller reconfigures coupled microgrids to export **maximum** real power and maintain PCC voltages close to 1.0 pu;
  - Proposed controller is realizable in **microgrid controllers from GE**, and it will not interfere with existing distribution network control mechanisms.
- **If cooperation with DSO is available, voltage control devices being set according to the connected microgrids, then at least 20% more real power is expected to be provided by coupled microgrids.**

# Task 1 Recommendation I

- **Operate Microgrids Close to the Nominal Voltage**
  - Keep voltage of microgrid within deadbands of **OLTCs** to prevent tap change.
  - Keep microgrid voltages close to the nominal value to reduce reactive power support required from **SVC** ~~and **STATCOM**~~.

- **Benefit**
  - Existing distribution networks and voltage control mechanisms need **no modification**.
  - Microgrids operate like **good customers**, making it easier for DSOs to accept.

- **Cost**
  - Capacities of the coupled microgrids are **under-utilized** because voltages of microgrids are fixed.
  - If voltages of microgrids are allowed to change, **more real power export** is possible, but voltage control devices will switch frequently.

Without the DSO's coordination, this is the best we can do to integrate microgrids into distribution networks.

# Task 1 Recommendation II

- **Configure Voltage Control Devices According to Microgrid Set Point**
  - Modify the nominal voltage and deadband of **OLTCs** according to the set points of directly connected microgrids;
  - Keep the nominal voltage of **SVCs** ~~and STATCOMs~~ close to the set points of microgrids connected.

- **Benefit**
  - Switching frequencies of legacy control devices **decrease** as they are dynamically regulated.
  - Network voltage profile is more flexible, hence the required reactive power support is **reduced**.

- **Cost**
  - DSOs are required to coordinate with the microgrid hierarchical controller;
  - Communication structure is necessary to enable information exchange.

With **DSO**'s coordination, the coupled microgrids are able to export more real power in a flexible voltage profile without sacrificing legacy control devices. Reactive power dispatch in the network is controlled by the **coupled microgrids**, hence **legacy control devices** are saved to respond to emergencies.