# Possibility of network voltage control using demand side management


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# Outline of presentation

- Network & Voltage controllability challenges
- Advanced demand profiling & management
- How it could be used for voltage control
- Summary

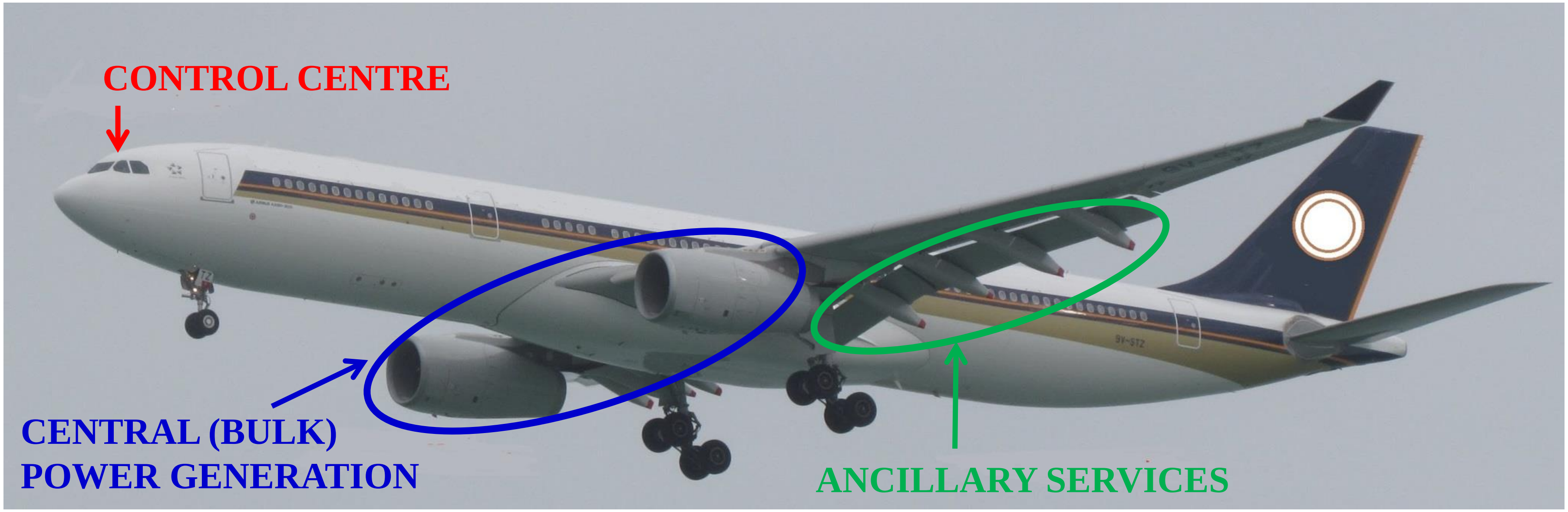
# Network & Voltage controllability challenges

# The drivers

- Evolving/new market structures and operation
  - Increasingly liberalised market
  - Increased cross-boarder bulk power transfers to facilitate effectiveness of market mechanisms
- The participation of controllable (that can be both, controlled and used for control) plant in generation mix is reducing
- The nature and behaviour of load has changed and is changing (e.g., spatial in addition to temporal variation)
- New transmission components (still insufficiently understood, compared to “old” technologies) are being added to the system

# Controllability challenge

- The complexity and vulnerability of the system is increasing
- The system control, stability and security are becoming increasingly important and much more time dependent than before




- "Every little helps" is becoming very important
  - Additional/Advanced controllability of RES
  - Deployment and control of energy storage
  - Efficient Demand Side Management (DSM)

# Advanced demand profiling & management

# (Advanced) Demand profiling

Identification/estimation and forecasting of static composition (in terms of load categories and load controllability) and dynamic response of demand

Why (or) Do we need to consider it ?

# Efficient DSM

- To apply efficiently Demand Side Management (shift load from the hours of high consumption to hours of low consumption) to facilitate required "change in paradigm" and enable load-follows-generation approach for efficient integration of RES we need to be able to forecast (reasonably accurately) the demand from 30 min (or less) to a day (or more) in advance and to control it.
  - At present only demand for real power at bulk supply points is forecasted
- Forecasting only total demand for real power (P) is not sufficient
  - the information about the available reactive power (Q) is required as well, e.g., for voltage regulation

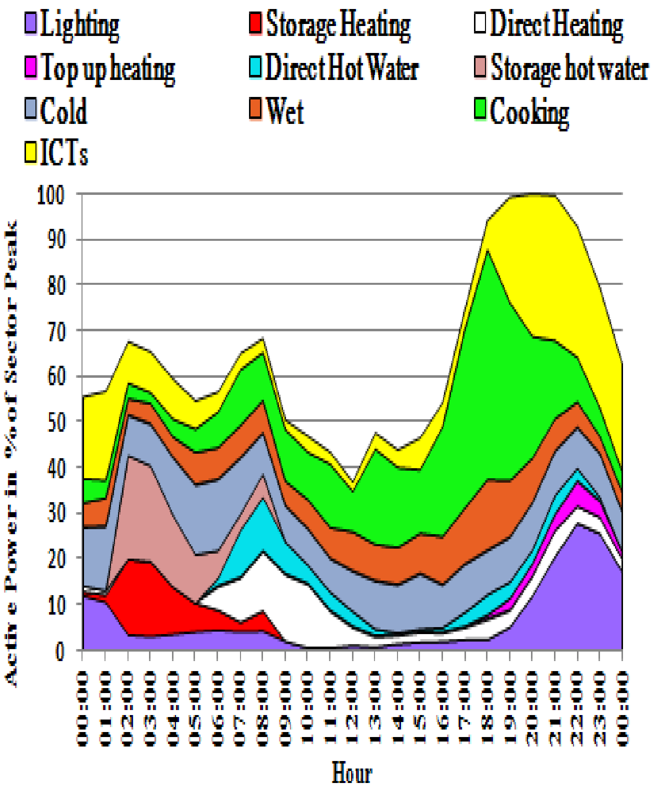
# Efficient DSM

- Knowledge of total demand (be it accurate and for both P and Q) is not sufficient
  - the information about demand composition in terms of controllable (that can be shifted from one hour to the next) and uncontrollable load is needed
- Knowledge of demand composition is not sufficient
  - the information about load category (based on dynamic response to system disturbances) mix in both controllable and uncontrollable part of demand is needed
- Knowledge of demand composition in terms of load category is not sufficient
  - the information about dynamic response of aggregate demand at bulk supply point before and after the shift of controllable load is needed

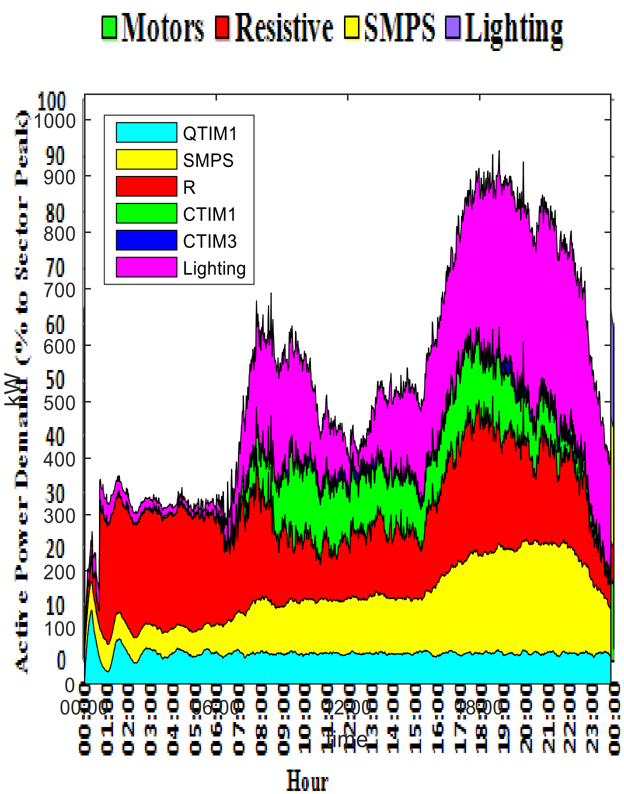
# Estimation of demand composition

**1. Assuming that we have online measurements from advanced smart meters installed at individual customer sites**

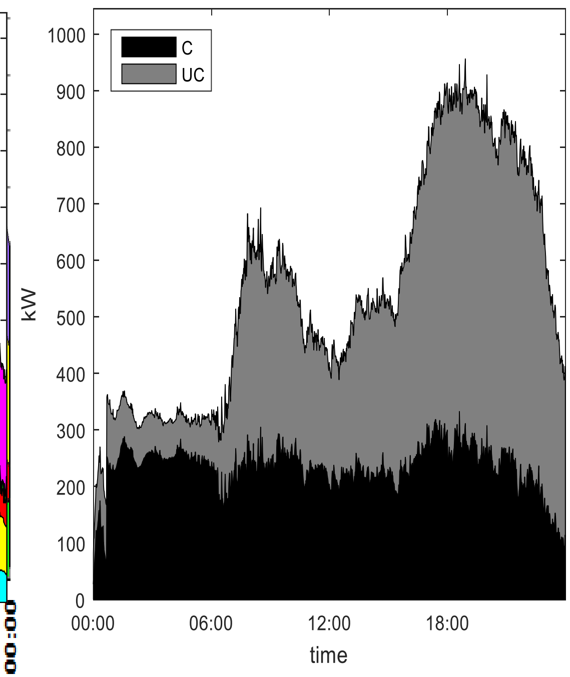
# Demand profile




Decomposed Load Curves based on Load Type

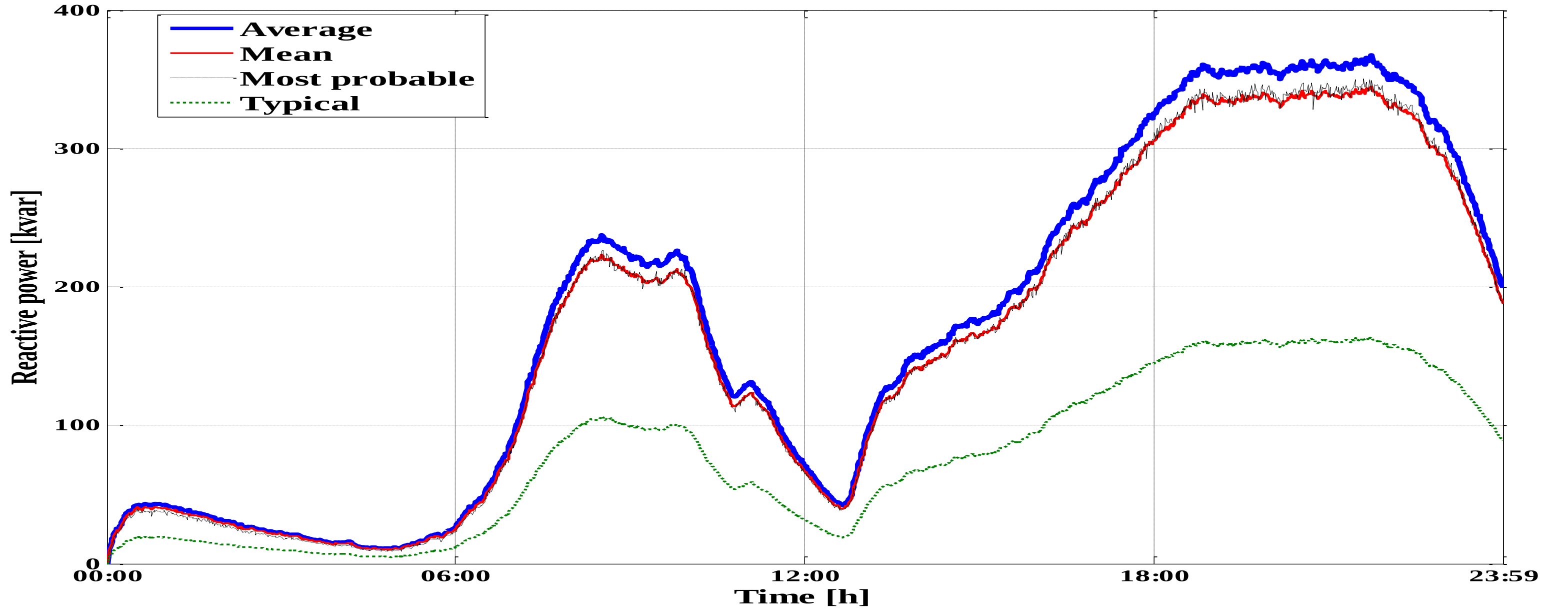


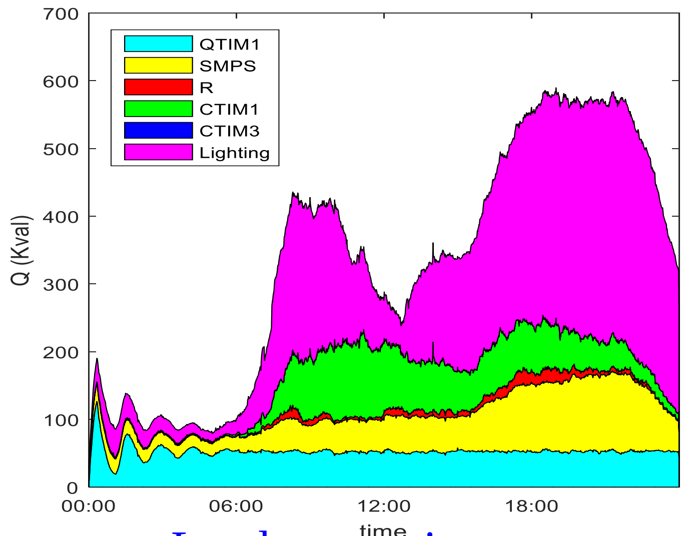

Decomposed Load Curves based on Load Categories



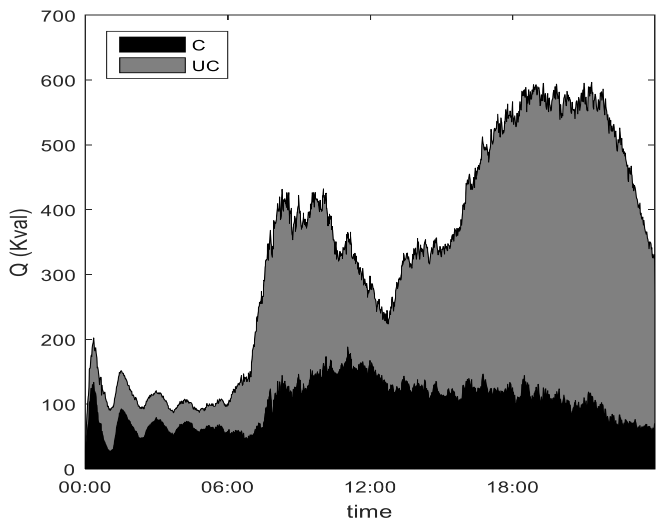

Decomposed Load Curves based on Load Catrollability

# Probabilistic estimation of Q




Load categories




Controllable/uncontrollable load

## 2. Assuming that we don’t have any online measurements from individual customers

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# Probabilistic estimation of demand profile & controllability

Metering Data

Customer Surveys

General Knowledge of Demand Composition

DDLC Based on Load Classes

Participation of Load Categories in Different Load Classes

DDLC Based on Load Categories & Controlability

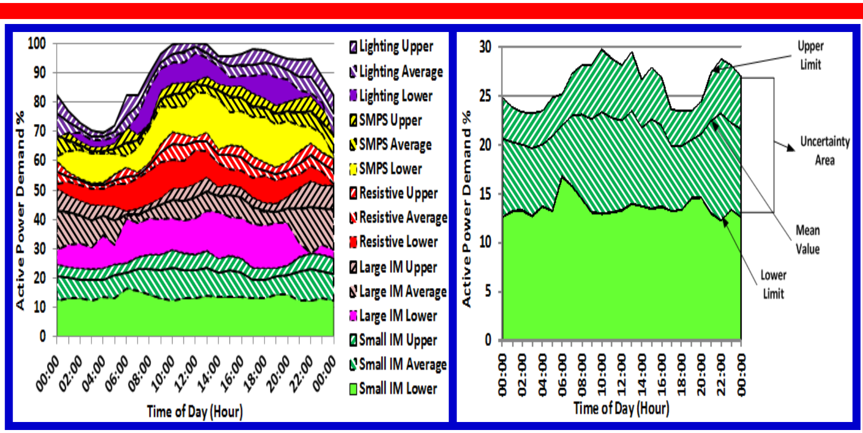
Data Processing with Parameter Uncertainty

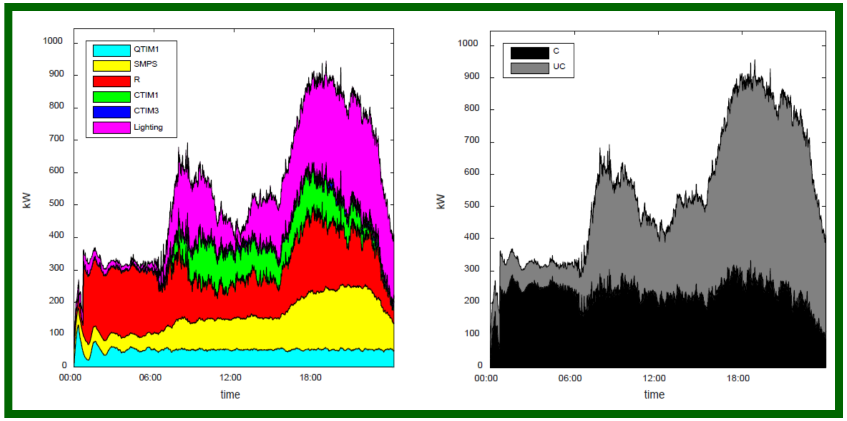
Probabilistic DDLC **Based on Categories & Controlability**

**On-line measurement using Smart Meters**

**Data processing & Aggregation based on Load categories & controlability**

**Deterministic** DDLC **Based on Categories & Controlability**



# Is this all we need?

- **Demand composition** affects demand (load) dynamic response following small or large voltage (predominantly) or frequency disturbance in the network
  - Changing of transformer tap position
  - Fault in the system

- Different **dynamic response of the load** will affect overall dynamic response of the system (voltage, frequency or angular stability of the system)
  - The contribution of the load (with given composition) to system dynamic response depends on
    - The size of the load
    - The location of the load

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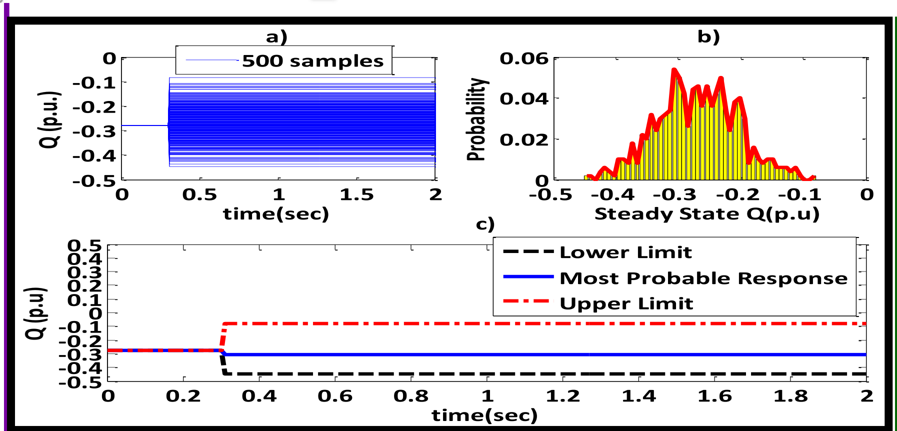
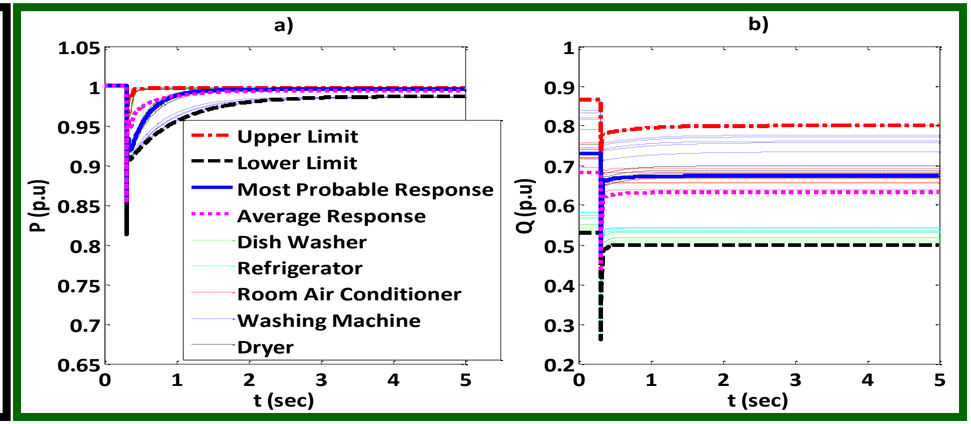
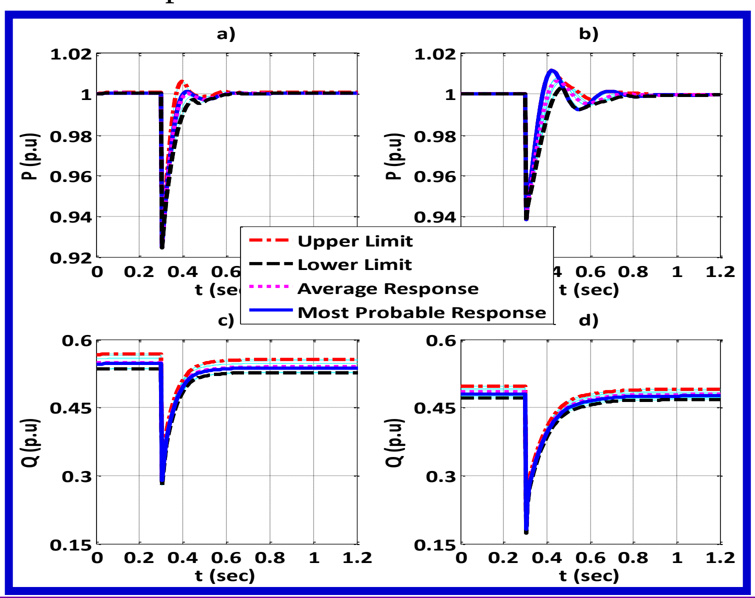
# Responses of different load categories



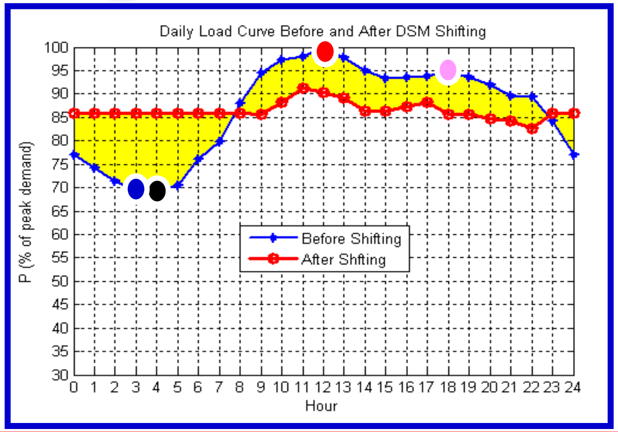

Real power responses to a step reduction in voltage for SMPS: a) responses obtained from 500 MC simulations; b) probability histogram of steady-state power after voltage drop; c) upper and lower limit of the responses and the most probable response

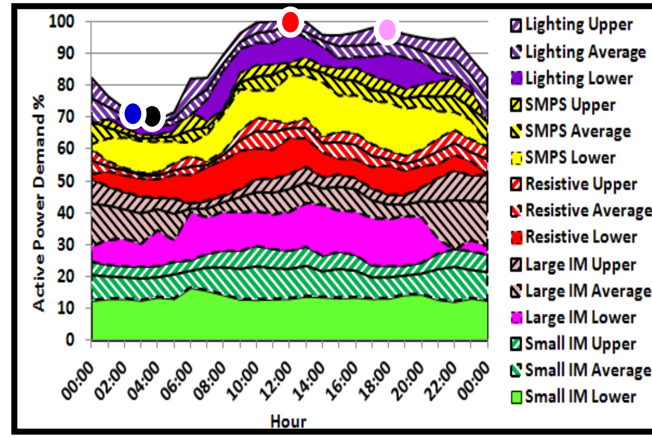
a) real power responses, and b) reactive power response for residential and commercial motors with most probable and average response specified

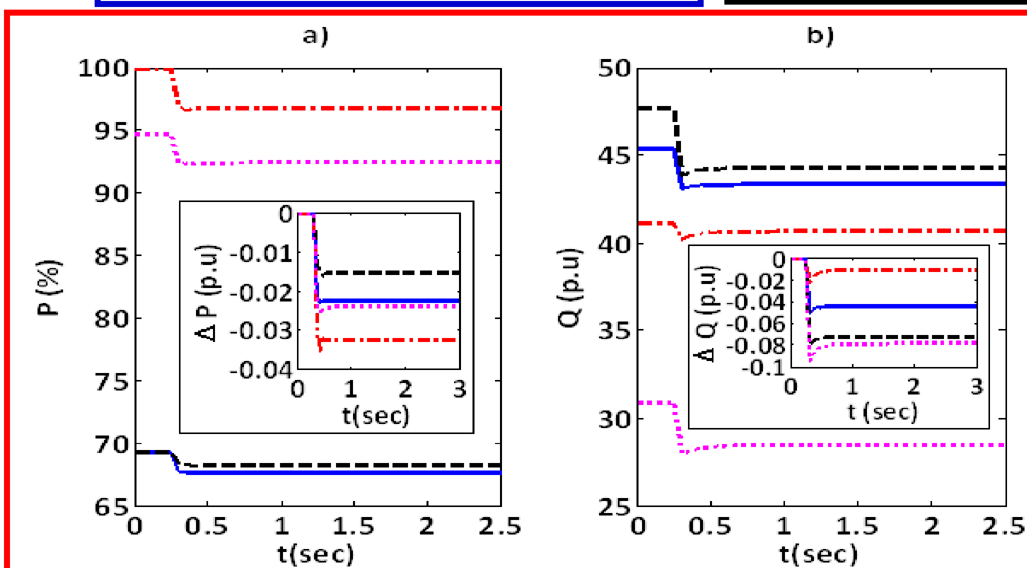



a) small industrial IM P response, and b) large industrial IM P response to step down voltage; c) small industrial IM Q response, and d) large industrial IM Q response to step down voltage. (The upper and lower limit and the average responses are also shown.)

# The effect of demand profile on dynamic response of the load




Comparison of different a) P and b) Q responses at different times of day (solid line: 03:00; dashed line: 04:00; dash-dot line: 12:00; dotted line: 18:00)

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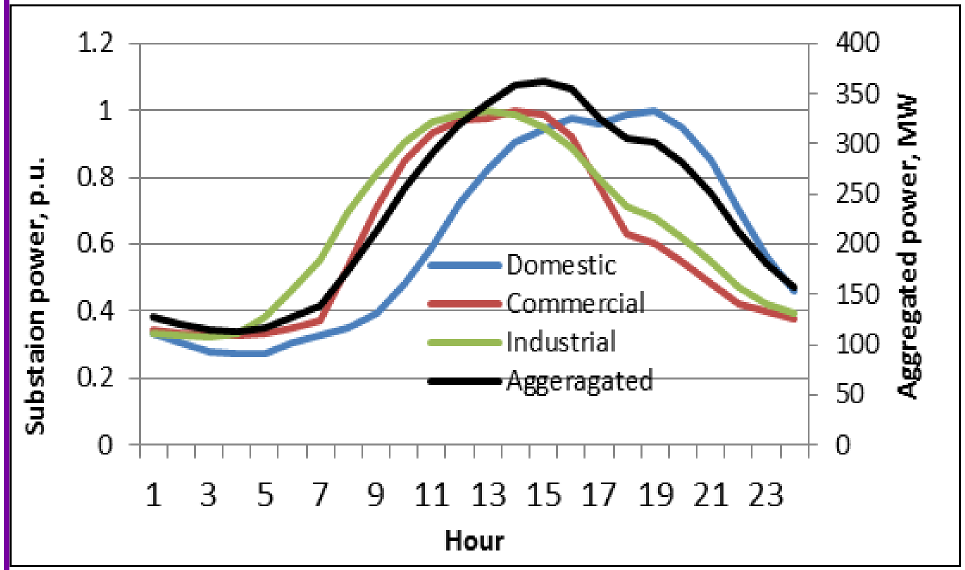
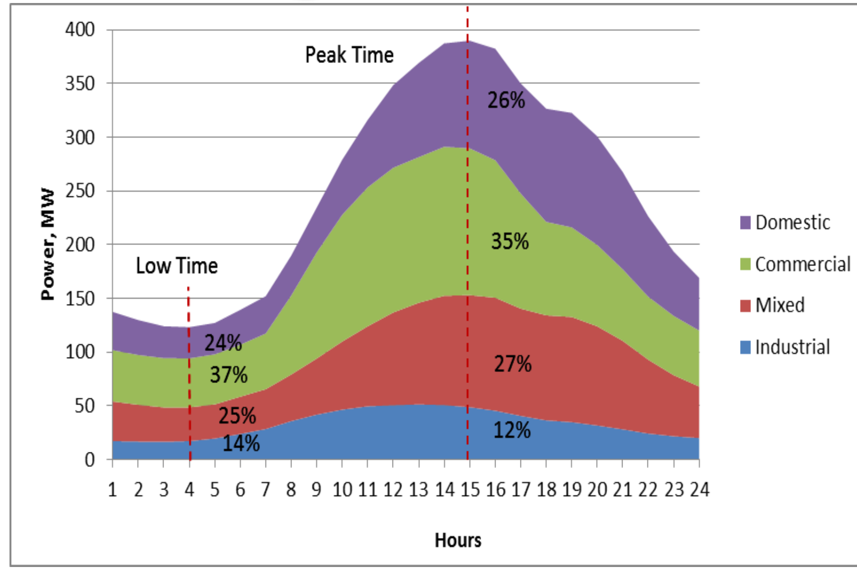
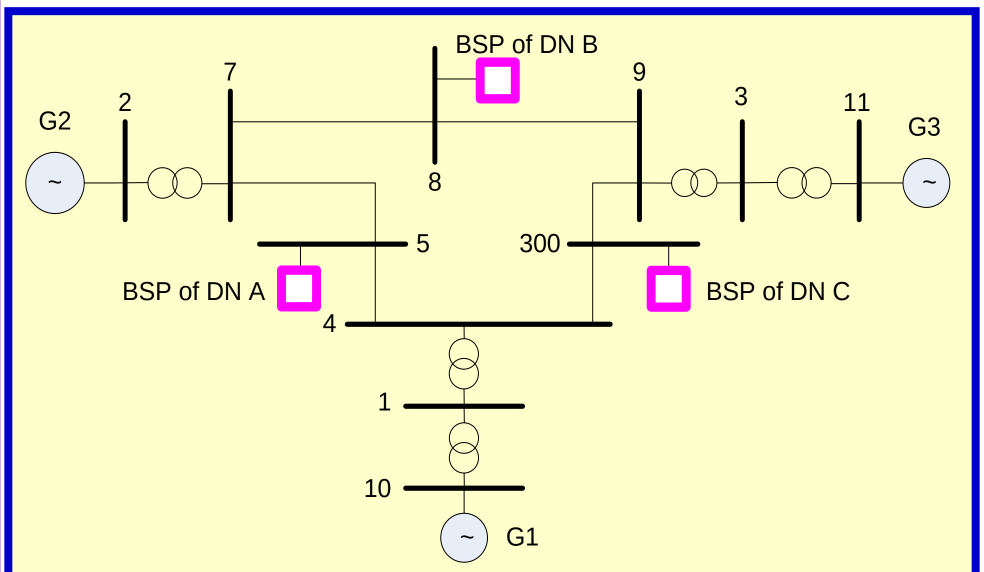
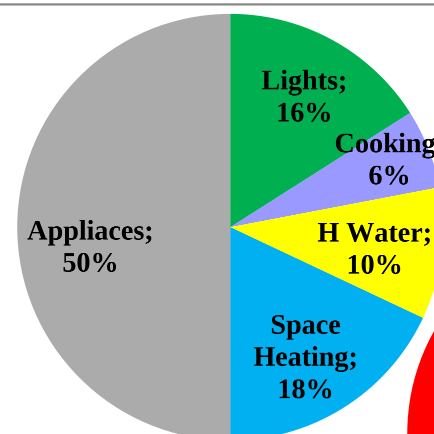
# How it can be used for voltage control

# Effect of demand management

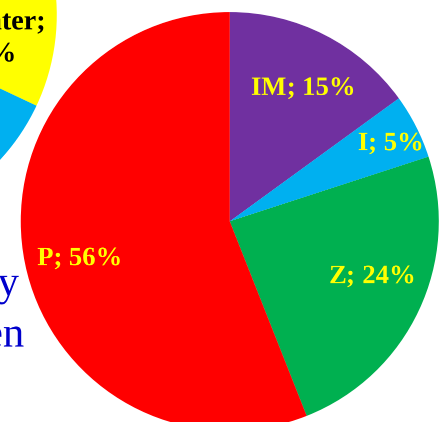


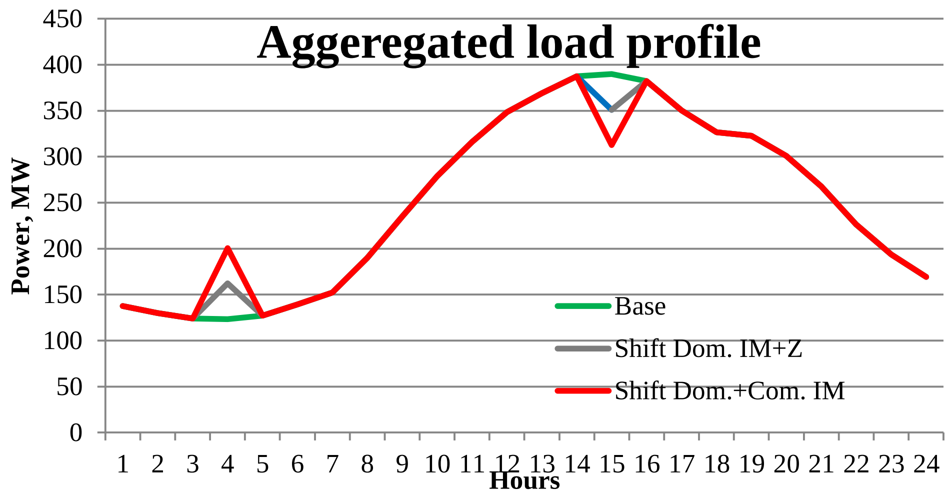



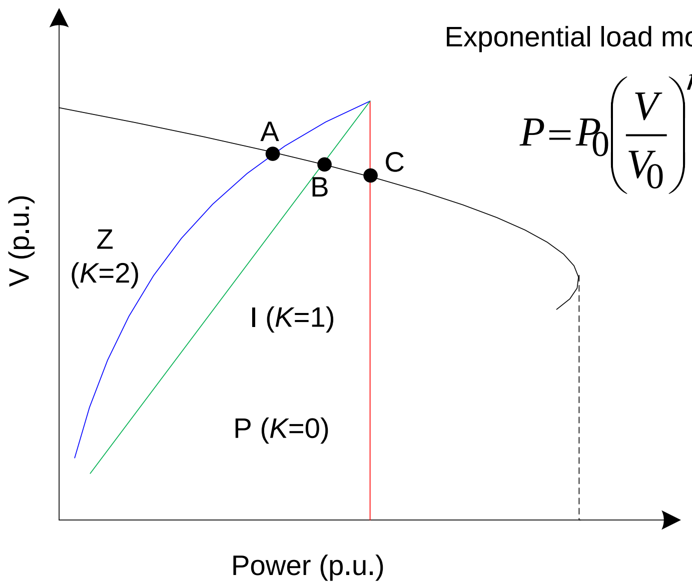




Domestic electricity consumption broken down by end use.



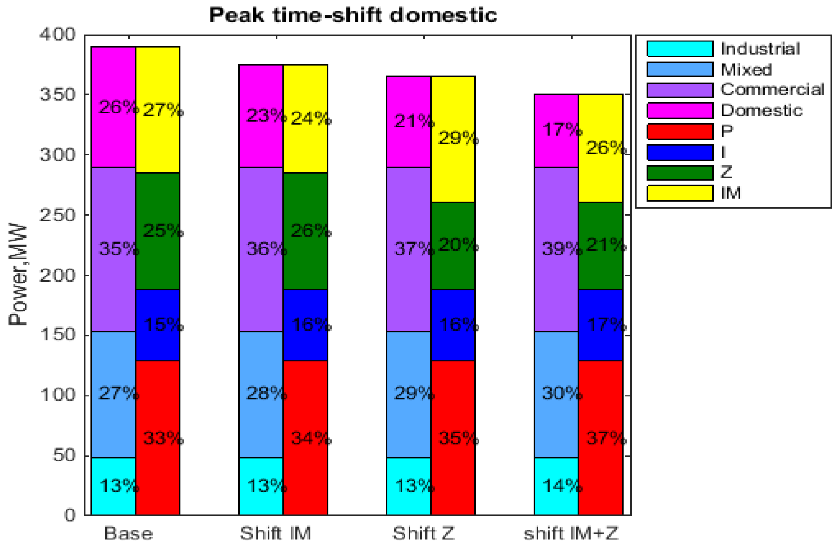
# Change in demand & composition

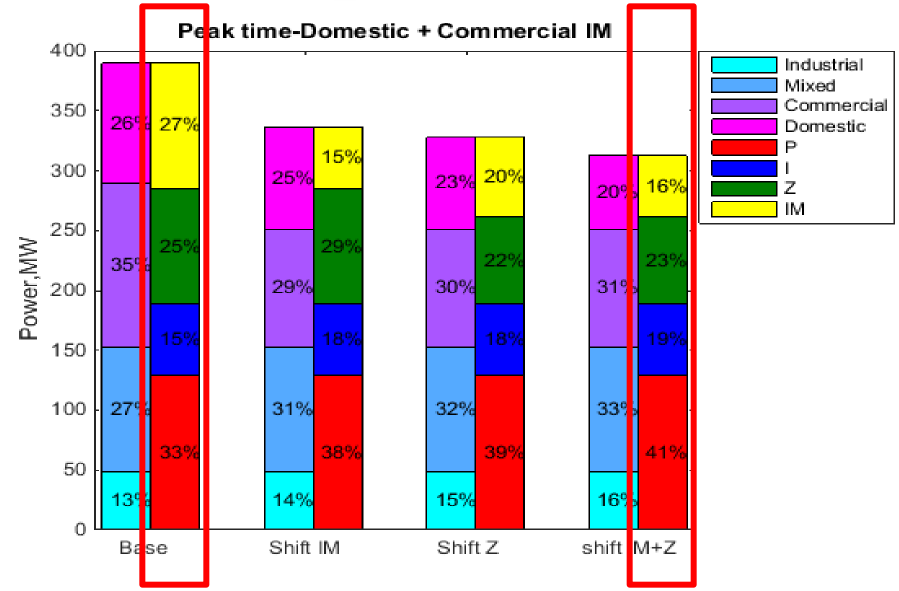


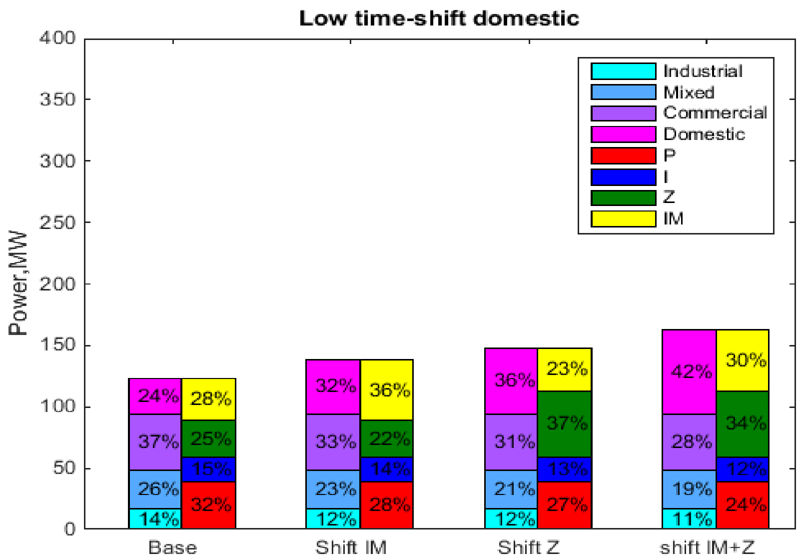



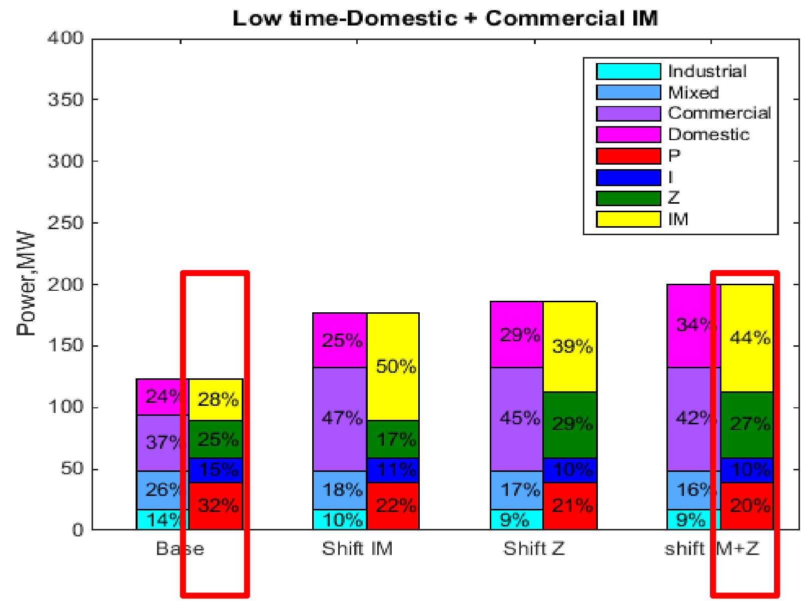

$$P = P_0 \left( \frac{V}{V_0} \right)^{\kappa}$$

# Change in demand composition

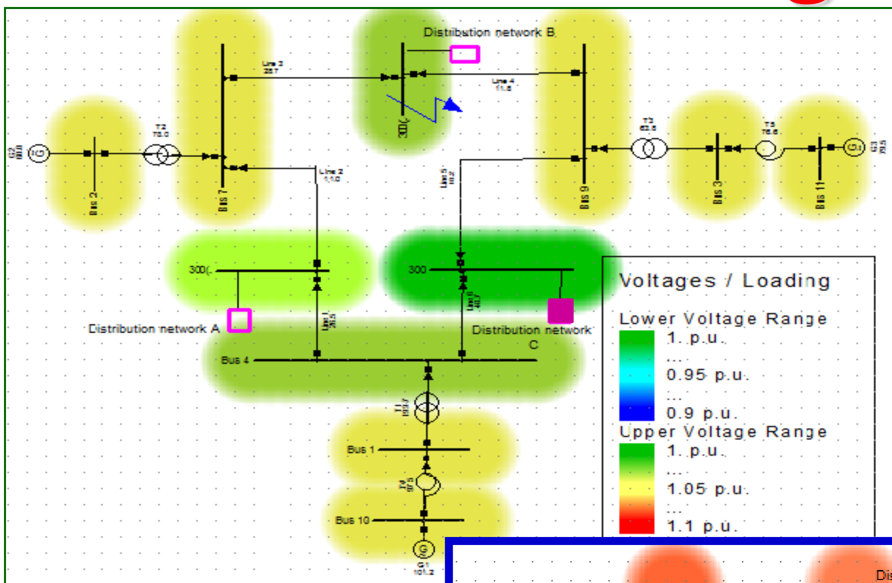


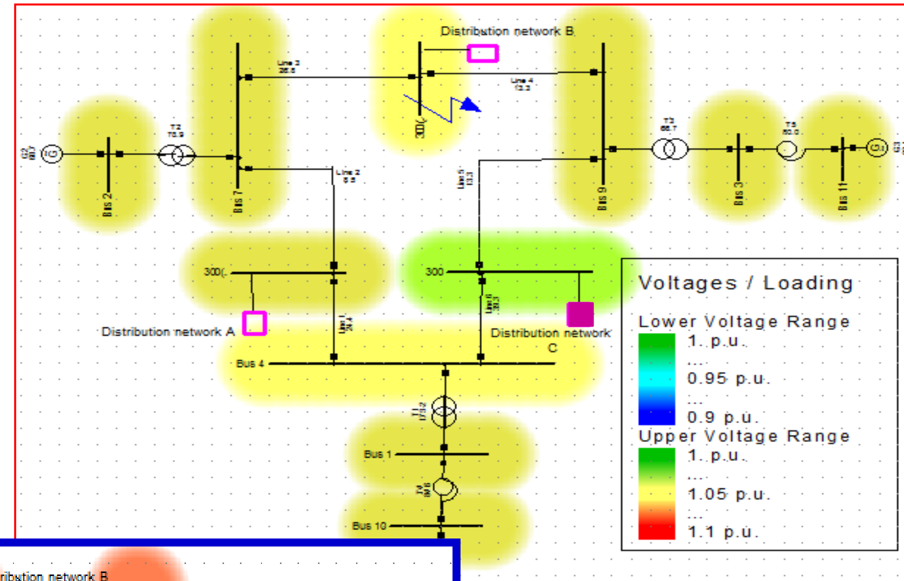



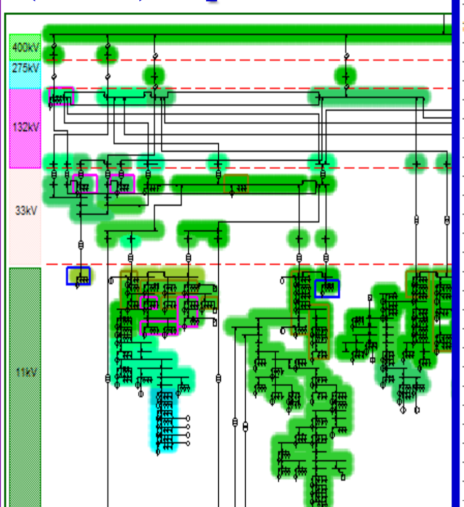



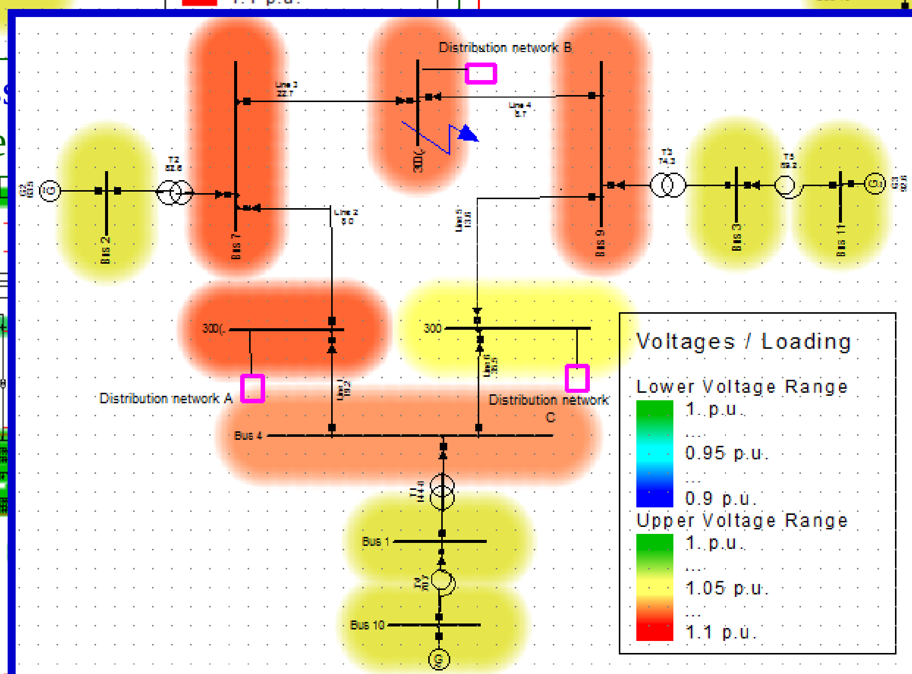
# Effect on voltage levels – TN & DN

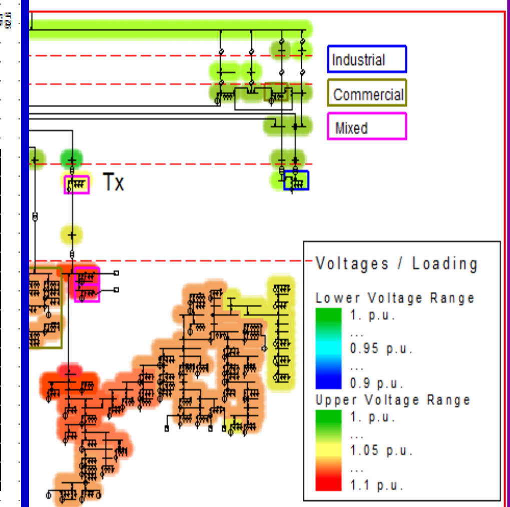


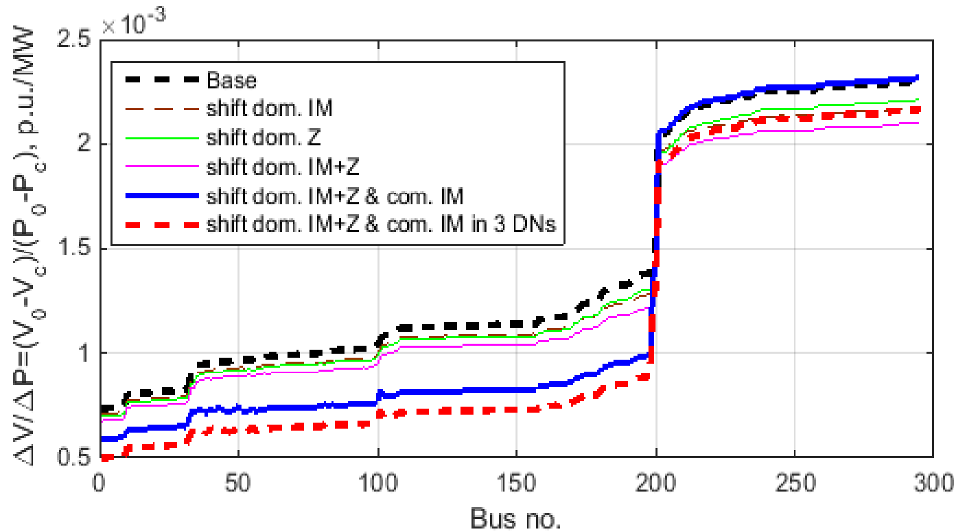

Voltage level of transmiss … fting **domestic** load
(Z+IM) at **peak time**. Le … at domestic buses

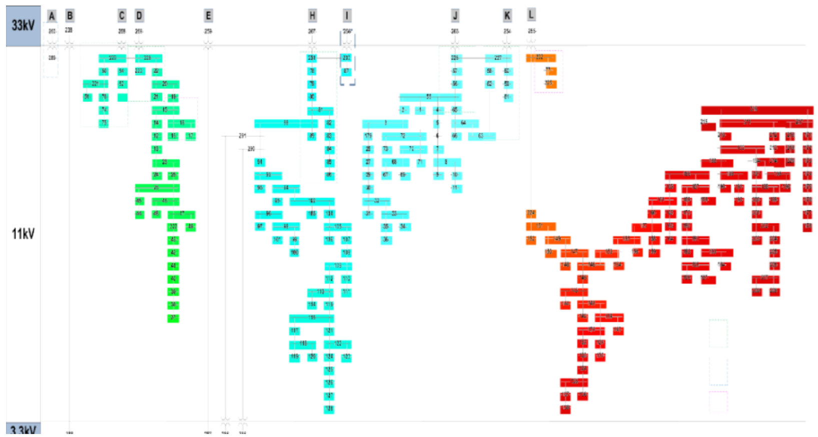


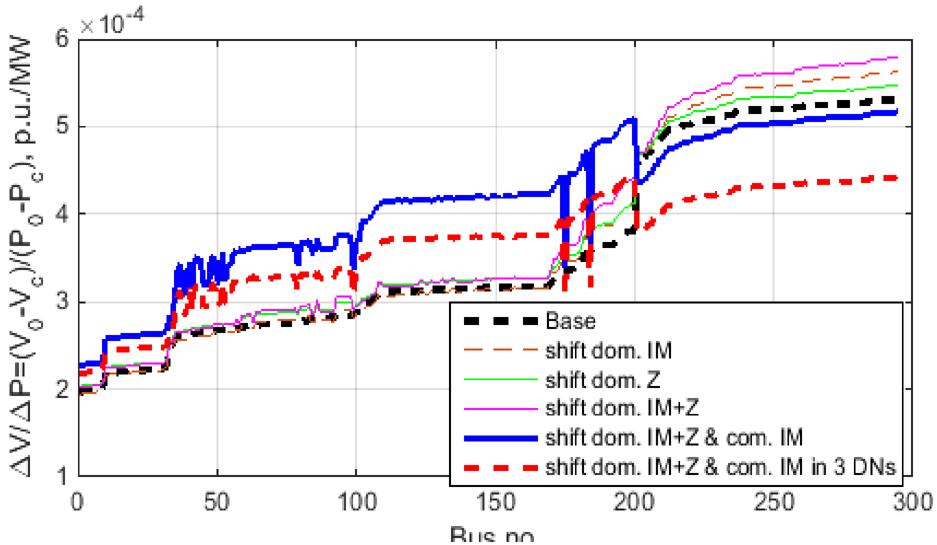



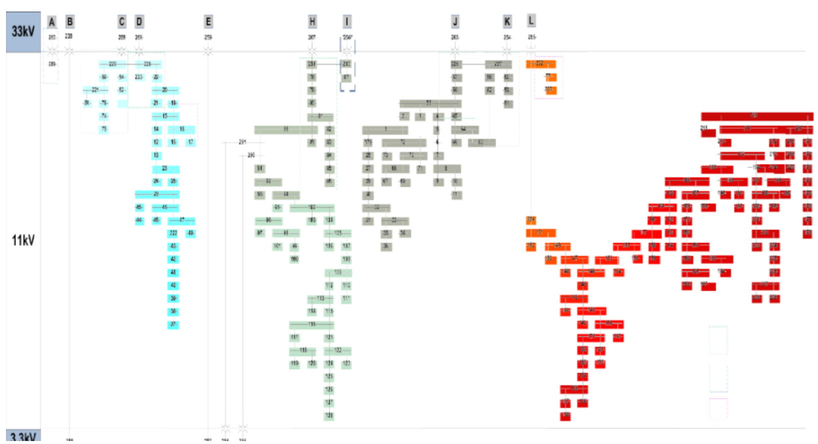
# Sensitivity analysis of PV curves - DN




ΔV/ ΔP = (V0-Vc)/(Po-Pc) from operating point to critical point at **peak** (above) and **low** (below) time

# Summary

**Given**

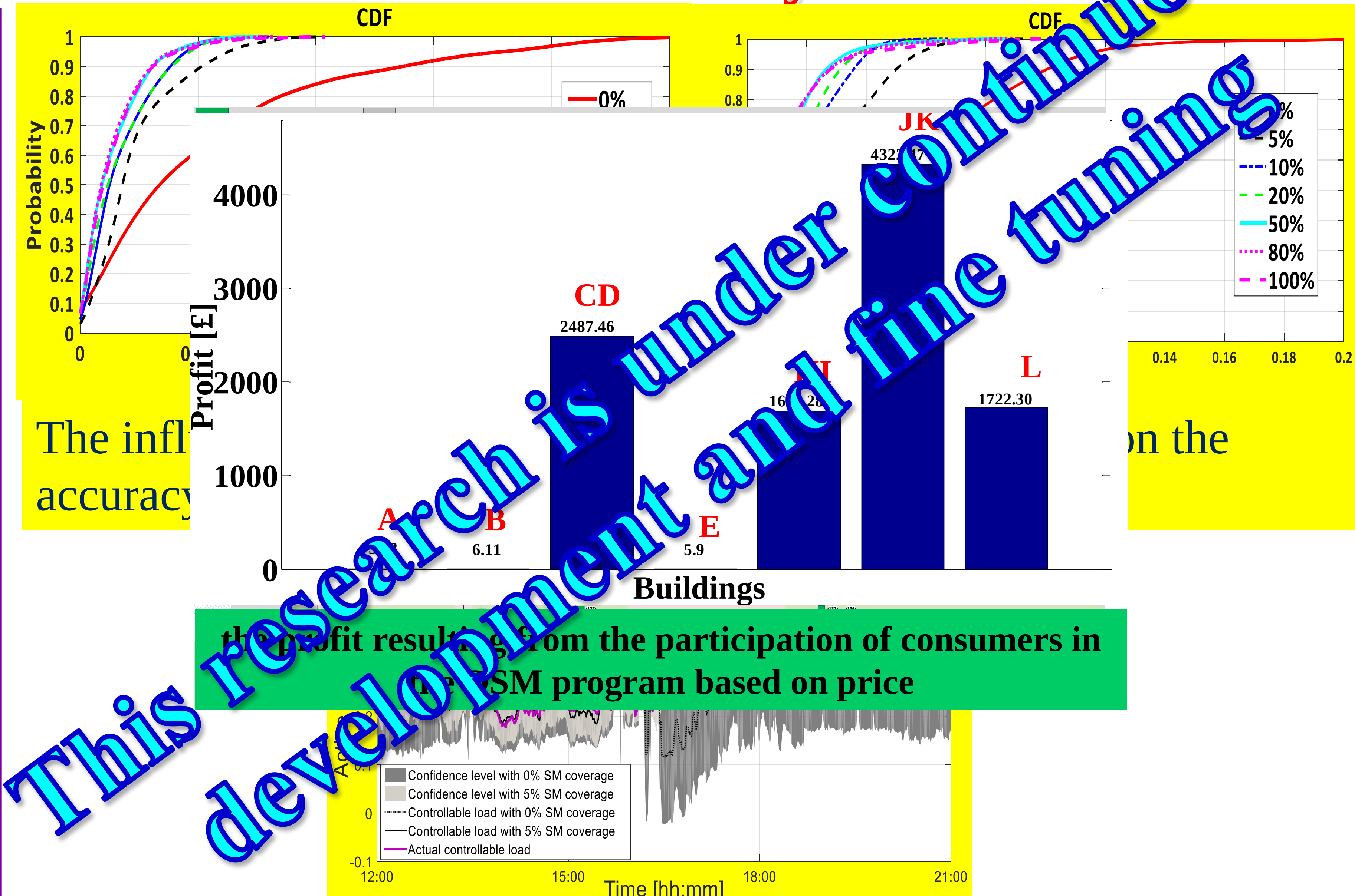
- On-line measurements form installed smart meters
- General information about demand composition at a bus *(e.g., 30% commercial, 10% industrial and 60% domestic)*
- Standard P, V and Q *(or a combination of those)* half-hourly (or at other time intervals) measurements over some period of time in the past
- Weather forecast for the following day

**It can be forecasted/estimated**

- Total P and Q demand
- Demand composition in terms of categories
- Demand composition in terms of controllable and non-controllable demand
- Dynamic P and Q response

at that bus (aggregation point) at any given time "now" or in the future) and how it will change if we "move" part of demand to a different hour

# Summary




The infl… on the accuracy…

the profit resulting from the participation of consumers in the DSM program based on price

This research is under continuous development and fine tuning