How smart can we be with a few smart meters?

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Nobel Grid
Smart energy for people

Introduction

- **Demand response** (DR) has been increasingly considered as one of the cost-effective options for maintaining, restoring or increasing the flexibility of operation of the power network
- The effectiveness of a DR action depends on the end-users' flexibility, availability during the time in question and willingness to participate
- Tapping the flexibility potential requires enhanced **observability of the demand side in particular**

How can we use the existing smart meters to make the power network analysis smarter?

Smart meter rollout

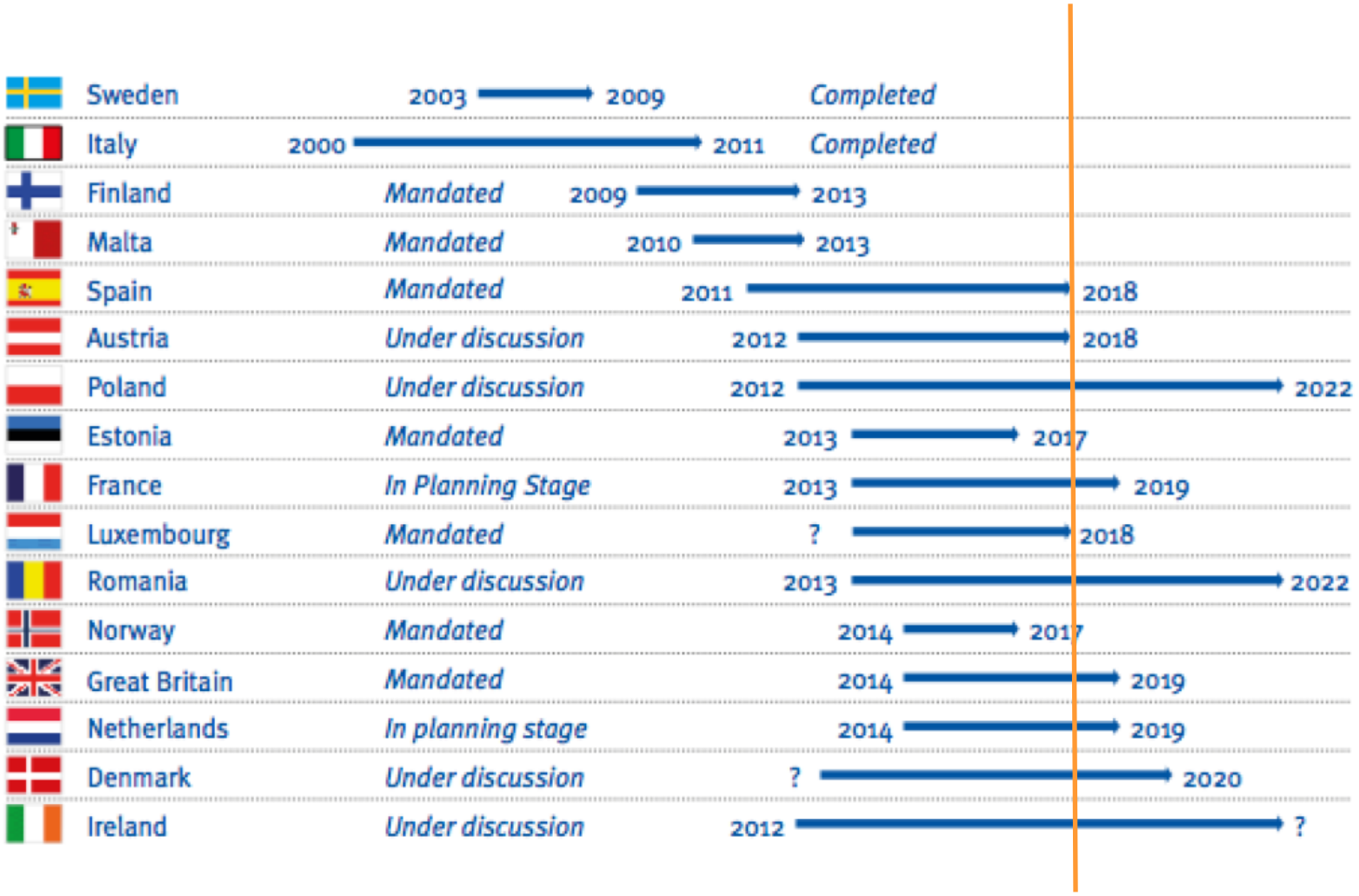
- 27 million* smart electricity meters should be installed in UK domestic sector by the end of 2020
- In Taiwan: 1 million** smart meters planned by 2020, followed by 3 million smart meters by 2024
- Reporting electrical consumption (active demand) every:

  60 min (Sweden), 30 min (UK), 15 min (Italy)

  – Problems with data aggregation
- Many data sources, large data size – how to make use of it?
- What are the benefits for the end-users on one side, and the network operator on the other?

*https://assets.publishing.service.gov.uk ** https://www.metering.com

Smart meter rollout in Europe*



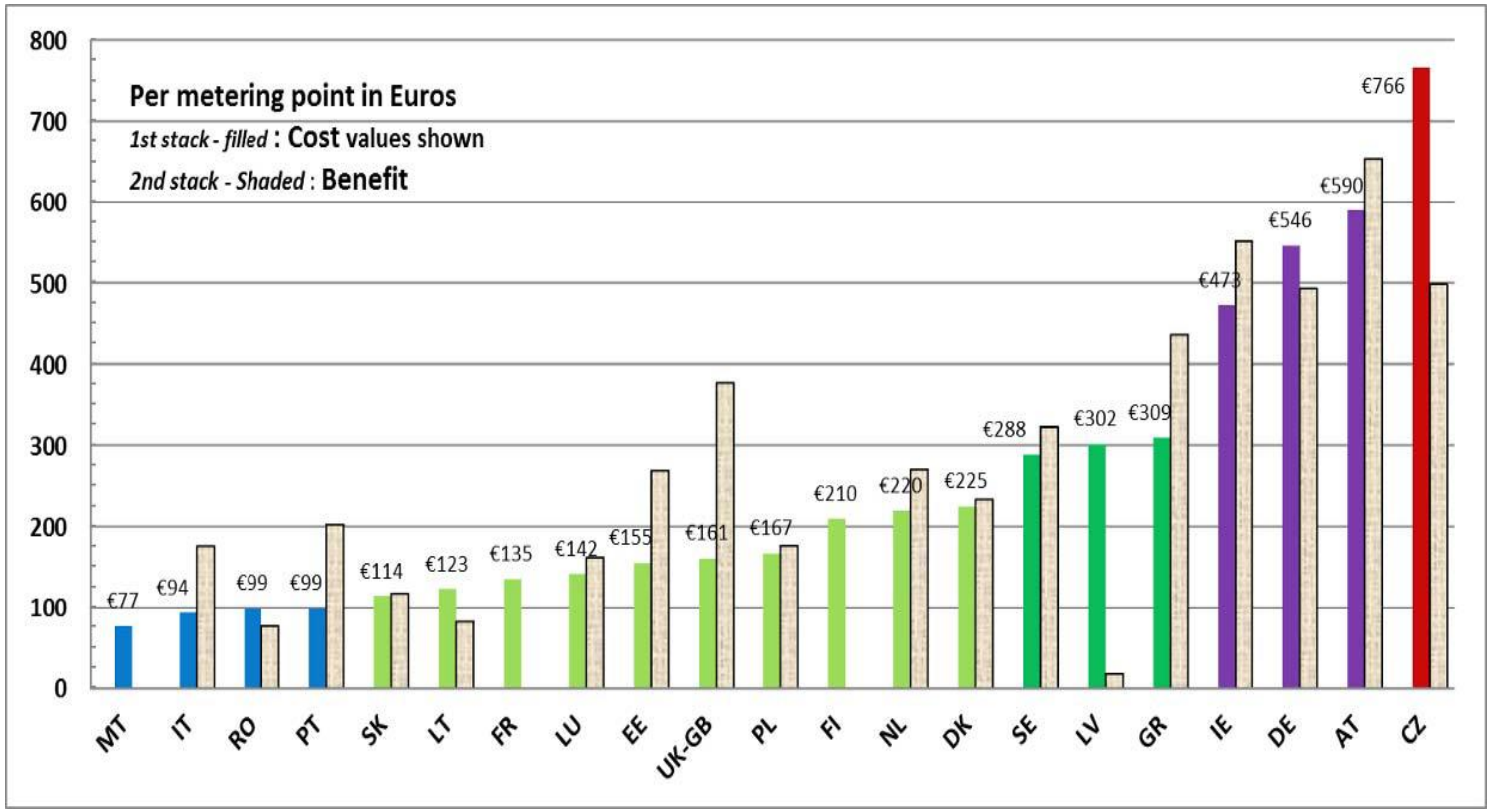
*https://eur-lex.europa.eu

Smart Meters – Pros and Cons

- Advantages for the end users
  - Close to real-time information on energy use -> potentially more savings
  - Access to historical consumption data -> potentially change in behaviour
- Advantages for the network operator:
  - Monitoring of low-level consumption
  - Faster identification of faults and users causing non-technical losses (fraud)
  - More accurate consumer profiling for tariffing purposes and advanced DSM
  - Utility companies are expected to save $157 billion by 2035 by using smart meters**
- Potential issues:
  - Inconsistent sampling rate (minutes, hours..), missing data, latency, noise
  - Privacy issues
  - Not all the meters will be reporting the consumption in real-time (even with 100% smart meter rollout)

* http://uk.businessinsider.com

Smart meter benefits for power utilities in EU countries*



Normalised cost and benefit values per metering point
(the observed period is either the roll-out period or the smart meter life time)

AT Austria
BE Belgium
BG Bulgaria
CY Cyprus
CZ The Czech Republic
DE Germany
DK Denmark
EE Estonia
EL Greece
ES Spain
FI Finland
FR France
HR Croatia
HU Hungary
IE Ireland
IT Italy
LT Lithuania
LU Luxemburg
LV Latvia
MT Malta
NL The Netherlands
PL Poland
PT Portugal
RO Romania
SE Sweden
SI Slovenia
SK Slovakia
UK United Kingdom

*https://ec.europa.eu

Smart Meter Data vs. Smart Grid Data Needs

Smart Meter Features		Information and Data collection					
		Load forecast	Fault detection	Distribution network state estimation	Amount of controllable loads	Customers' willingness to participate in DSM	Amount of DER
Measurements	imported active power/energy	X		X	X		
	exported active power/energy						X
	imported reactive power/energy	X		X	X		
	exported reactive power/energy						X
	rms voltage	X	X	X			
Detection	under voltage		X				
	over voltage		X				
	voltage sags		X				
	voltage swells		X				
Sampling step	15 min (Italy)						
	30 min (UK)						
	60 min (Sweden)						
Additional features	load switch		X				

Smarter Meters

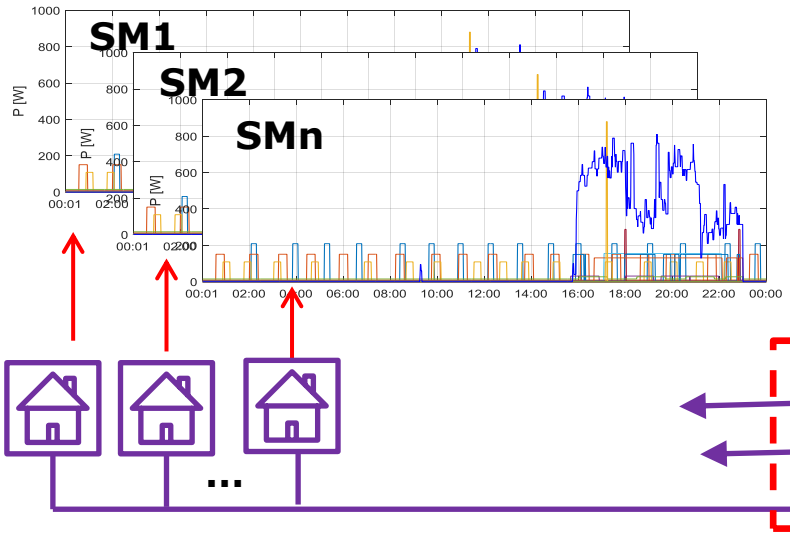
- **Smart meters with sub-metering capabilities for the assessment of time-based demand flexibility**

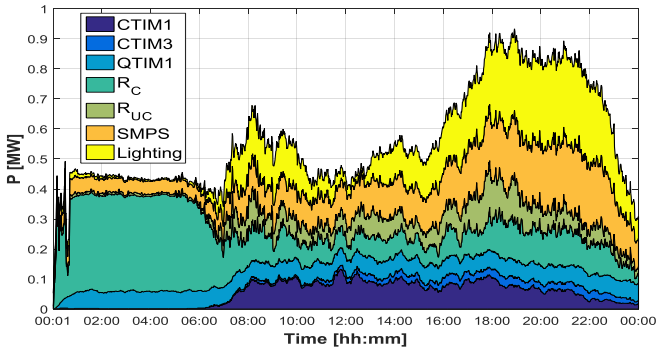
Controllable load categories:

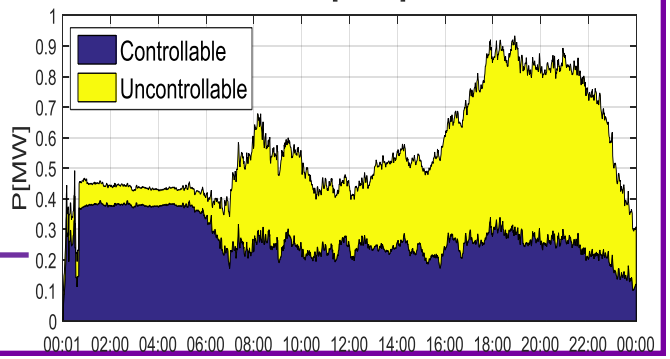
- **CTIM1:** Dish washer, tumble dryer, washing machine, washer-dryer, vacuum cleaner
- **QTIM1:** Fridge/freezer
- **R_C :** Water heater, electrical shower, electrical space heating

Uncontrollable load categories:

- **R_{UC}** : Iron, hob, oven
- **SMPS**: Answer machine, CD player, Clock, telephone, high fidelity (HiFi) appliances, Fax machine, PC, printer, TV, VCR-DVD, receiver, microwave
- **Lighting**





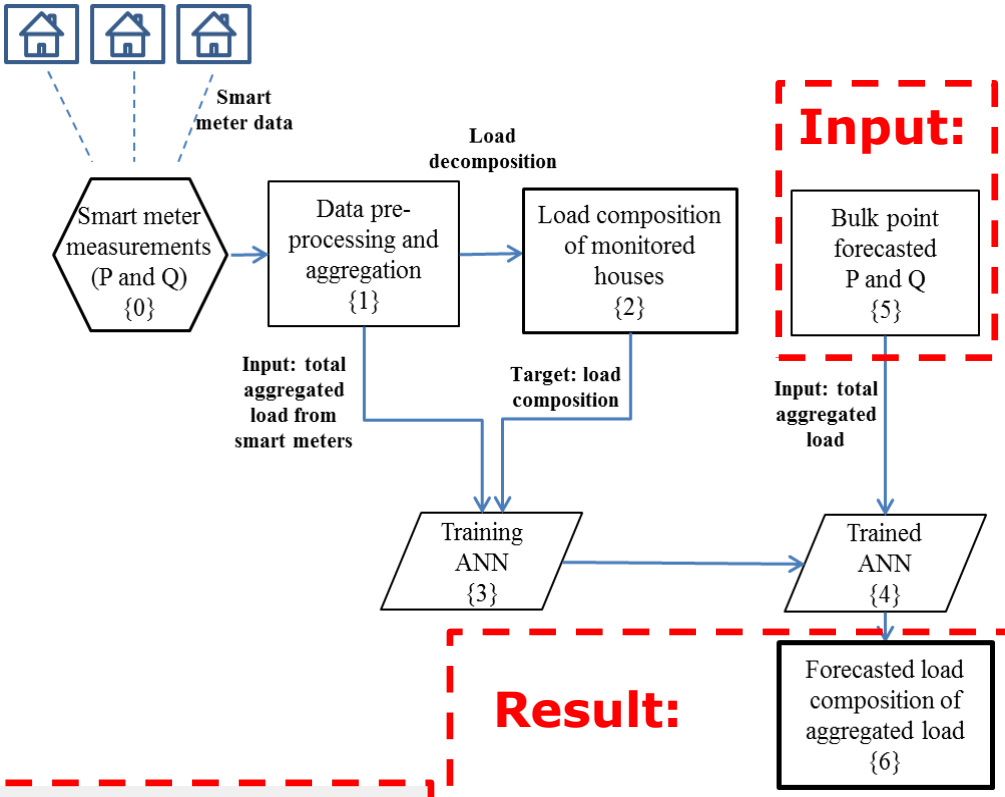


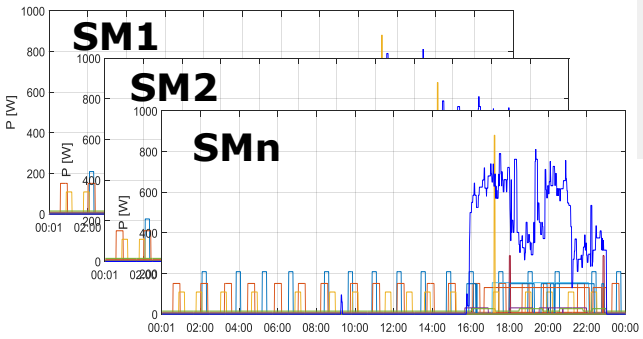
Can we assess demand flexibility with a few smart meters?

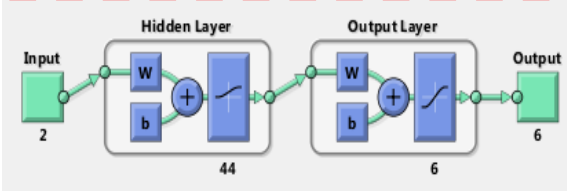
Assumptions:

- Some smart meters have **sub-metering capabilities**
- **Day-ahead forecast of active and reactive demand is available** at the aggregation level (substation)
- There are **missing data** samples and time series coming in various time steps

Aim: assess the required smart meter coverage (in %) which will provide acceptable accuracy of the load composition at the aggregation point

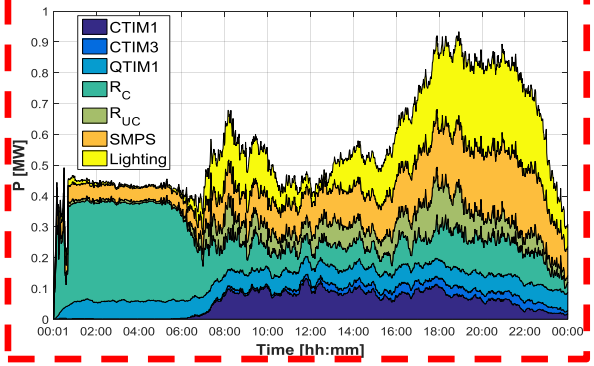




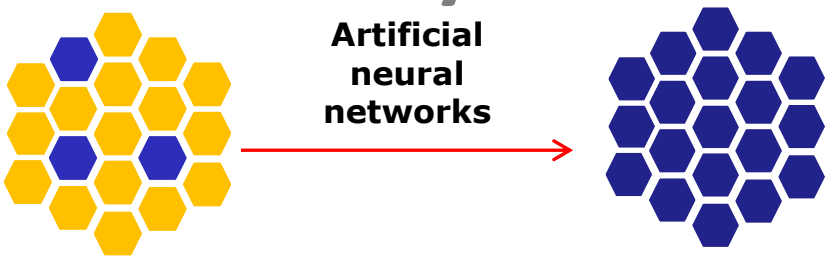


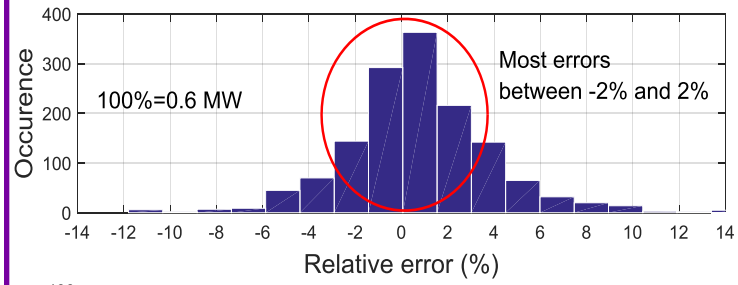
Training the ANN

Result:

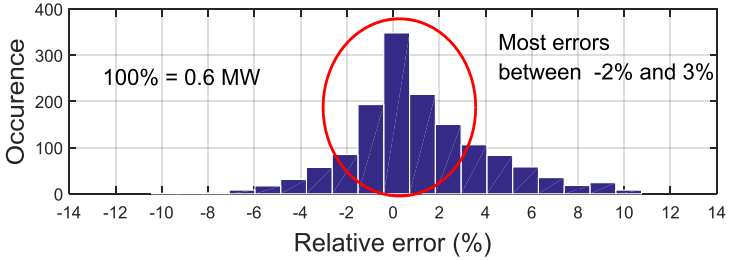


Can we assess demand flexibility with a few smart meters?

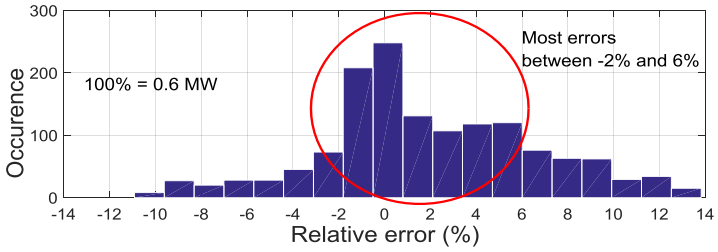




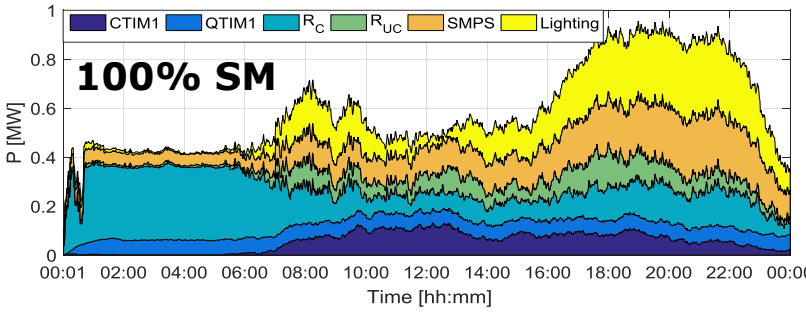
100% SM

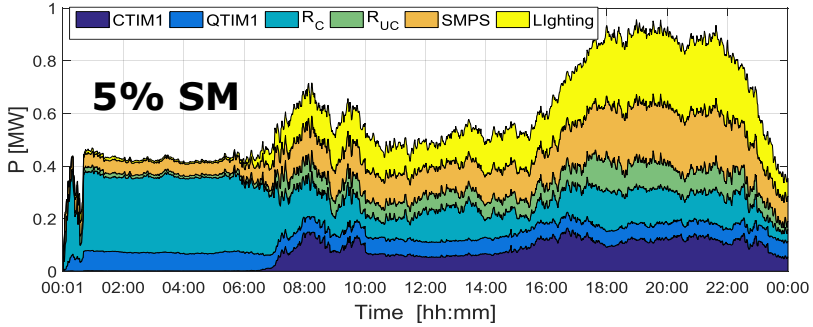


50% SM

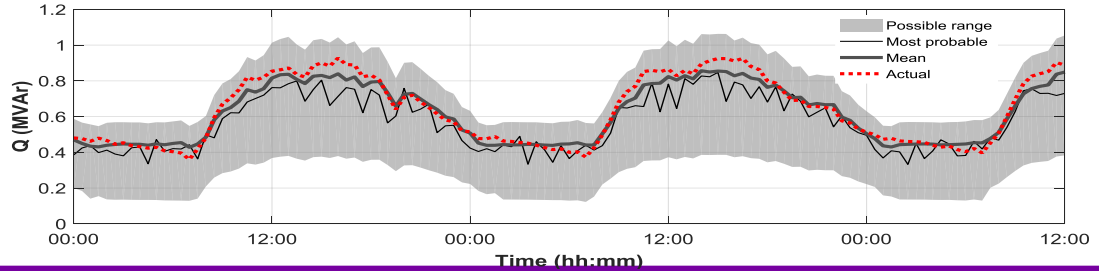


5% SM





Estimation of reactive power demand



Summary

- Demand response enables participation of demand-side flexibility in the network operation
- Data mining method (artificial neural networks) is used to **predict** (day ahead) **aggregate demand flexibility**, even with very **limited observability** of the end-users
- Proposed approach deals with missing data and different sampling steps
- At a network level, the results can show how the **flexibility will change** over the time and from bus to bus
- There is no techno-economic justification for sub-metering technologies to be installed at every user's premise; **a limited number of devices would suffice**.
- Only limited historical data required – **savings from the data perspective**

Further reading

Journal papers

1. Yizheng Xu and **J.V. Milanović**, "Artificial intelligence based methodology for load disaggregation at bulk supply point", *IEEE Transactions on Power Systems*, Vol. 30, No 2, 2015, pp. 795 – 803
2. **J.V. Milanović** and Yizheng Xu, "Methodology for estimation of dynamic response of demand using limited data", *IEEE Transactions on Power Systems*, Vol. 30, No 3, 2015, pp. 1288 – 1297
3. Yizheng Xu and **J.V. Milanović**, "Day-ahead Prediction and Shaping of Dynamic Response of Demand at Bulk Supply Points ", *IEEE Transactions on Power Systems*, Vol. 31, No. 4, 2016, pp. 3100 - 3108.
4. J. Ponoćko and **J. V. Milanović**, "Forecasting Demand Flexibility of Aggregated Residential Load Using Smart Meter Data," paper accepted in IEEE Transactions on Power Systems, 2018

Conference papers

1. Yizheng Xu and **J.V. Milanović**, "Development of probabilistic daily demand curves for different categories of customers", 22nd International Conference & Exhibition on Electicity Distribution – CIRED 2013, Stockholm, Sweden 10–13 June 2013, (Paper 0421)
2. Yizheng Xu and **J.V. Milanović**, "Framework for Estimation of Daily Variation of Dynamic Response of Aggregate Load ", *4th IEEE PES ISGT Europe 2013*, 6-9 October 2013, Copenhagen, Denmark (ISGT0044)
3. Yizheng Xu and J.V. Milanović, "Accuracy of ANN Based Methodology for Load Composition Forecasting at Bulk Supply Buses", *13th International Conference on Probabilistic Methods Applied to Power Systems*, *PMAPS 2014*, Durham, UK, 7-10 July 2014.
4. Yizheng Xu and **J.V. Milanović**, "On Accuracy of Demand Forecasting using Artificial Intelligence Based Methods", *IEEE PES ISGT Europe 2014*, Istanbul, Turkey, October 12-15, 2014.(ISGT0434)
5. Yizheng Xu and **J.V. Milanović**, "Estimation of Percentage of Controllable Load in Total Demand at Bulk Supply Point", *9th Mediterranean Conference on Power Generation, Transmission Distribution and Energy Conversion, MedPower 2014*, Athens, Greece, November 2-5, 2014.
6. Yizheng Xu and **J.V.Milanović, "**Probabilistic Estimation of Rated Demand at Bulk Supply Point" *IEEE Eindhoven PowerTech 2015*, Eindhoven, The Netherlands, 29 June - 2 July 2015 (Paper ID: 47)
7. J. Ponoćko and **J. V. Milanović**, "Application of data analytics for advanced demand profiling of residential load using smart meter data," in PowerTech, 2017 IEEE Manchester, 2017, pp. 1-6.
8. J. Ponoćko and **J. V. Milanović**,, "Smart Meter-Driven Estimation of Residential Load Flexibility," in CIRED conference, Glasgow, 2017
9. J Ponoćko, **J. V. Milanović**, R. Preece and N.C Woolley, "Application of Data Analytics for Information Retrieval from a Typical DSO's Database", in Innovative Smart Grid Technologies (ISGT) Europe, Ljubljana, 2016
10. J. Ponoćko and **J. V. Milanović**, "Comparative Analysis of Data availability and Data Requirements for Efficient Management and Control of Future Distribution Networks," in Med Power conference, Belgrade, 2016
11. K. Li, J. Ponoćko, L. Zhang and **J. V. Milanović**, "Methodology for Close to Real-time Profiling of Aggregated Demand using Data Streams from Smart Meters," in Med Power conference, Belgrade, 2016