UPEC 2018
53rd International Universities Power Engineering Conference
4th – 7th September 2018

# Stochastic Technical Losses Analysis of Smart Grids under Uncertain Demand

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UPEC 2018

# Contents

Glasgow Caledonian University
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# 1. Introduction

- Technical Losses in Low Voltage (LV) distribution networks → power flow (measurements)

- LV distribution networks are still in transition (not 100% Smart Grids). Power losses can not be substracted from the measurements.

- Problem: Presence of non-telemetered customers = Uncertain Demand

- Losses accuracy → load demand resolution

- high-resolution load demand profiles would allow a more accurate technical losses analysis

# 1. Introduction

| | |
|---|---|
| Upper Level | Monthly Energy Estimation |
| Middle Level | Daily Energy Estimation |
| Lower Level | Hourly Energy Estimation |
| High resolution | Intra-Hour load demand |

# 1. Introduction

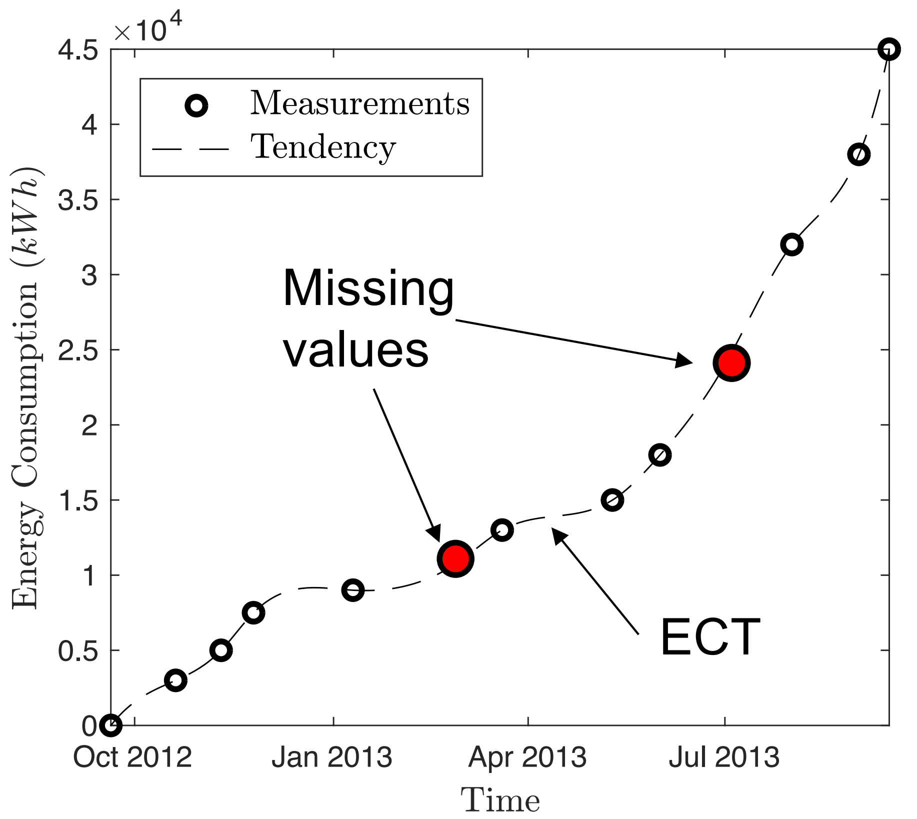
- Solution proposed: **a stochastic top-down approach for uncertain load demand estimation**

## 2. Methodology

Upper Level

### Monthly Energy Estimation

- *Non- Telemetered customers*
- *Energy Consumption Tendency (ETC) Curve*

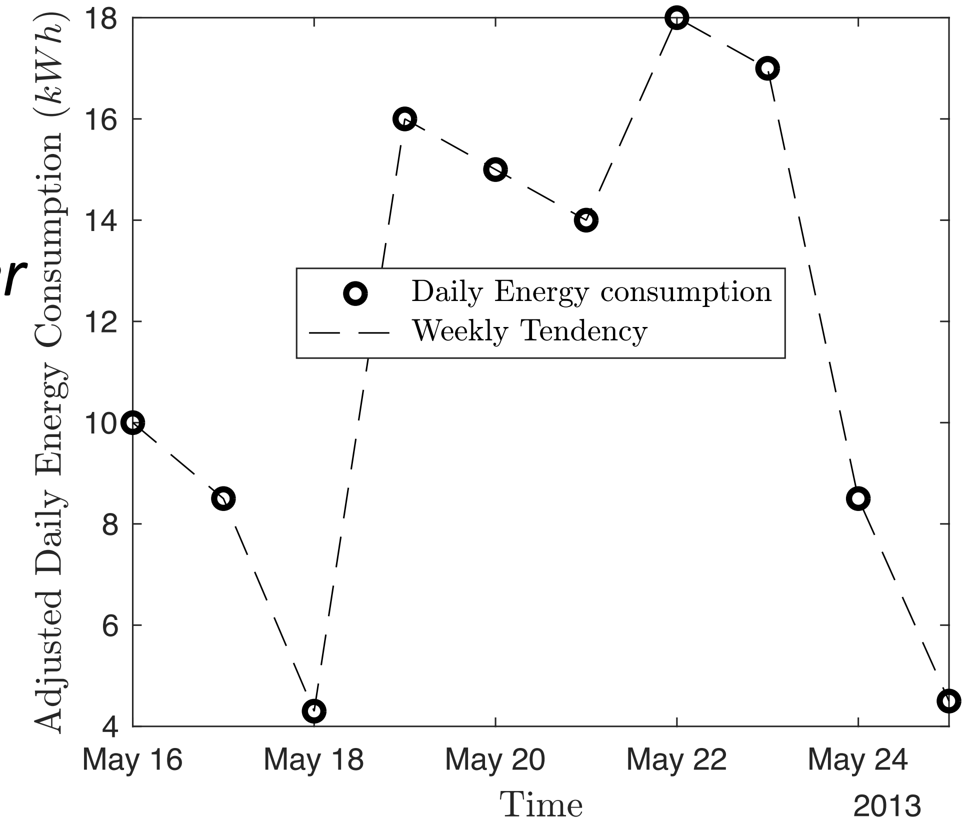


# 2. Methodology

## Middle Level

## Daily Energy Estimation

- *Weekly Energy Consuption (WEC) profile*
- *Supervisor Smart Meter In Secondary Substation*



## 2. Methodology

## Hourly Energy Estimation

### Lower Level

- *NLP Optimization :*

*Minimize cuadratic error*

Minimize: Objective function

$$\sum_{i\in\Omega_c'}\sum_{d\in\Omega_d}\sum_{h=1}^{24}\left(P_{(i,h,d)}-\hat{P}_{(i,h,d)}\right)^2 + \sum_{i\in\Omega_c''}\sum_{d\in\Omega_d}\left(E_{(i,d)}-\hat{E}_{(i,d)}\right)^2 + \sum_{d\in\Omega_d}\sum_{h=1}^{24}\left(\sum_{i=\Omega_c}P_{(i,h,d)}-\hat{P}^{s}_{(h,d)}\right)^2 \quad (1a)$$

Subject to: Constraints

$$\sum_{i\in\Omega_c}\sum_{h=1}^{24}P_{(i,h,d)}=\sum_{i\in\Omega_c}E_{(i,d)}\ \forall\, d\in\Omega_d \quad (1b)$$

$$\sum_{i\in\Omega_c}\sum_{h=1}^{24}P_{(i,h,d)}\le\sum_{h=1}^{24}P_{(s,h,d)};\ \forall\, d\in\Omega_d \quad (1c)$$

$$\sum_{i\in\Omega_c}E_{(i,d)}\le\hat{E}^{s}_{(d)};\ \forall\, d\in\Omega_d \quad (1d)$$

# 2. Methodology

High resolution | Intra-Hour load demand

- *Markov Chains*

$$\Pr\{X_{t+1} = j | X_0 = i_0, \dots, X_{t-1} = i_{t-1}, X_t = \mathrm{i}\} = \Pr\{X_{t+1} = j | X_t = \mathrm{i}\} = p^{(t)}{}_{\mathrm{i},j} \quad (2)$$

$$P = \begin{bmatrix} p_{1,1} & \cdots & p_{1,k} \\ \vdots & \ddots & \vdots \\ p_{k,1} & \cdots & p_{k,k} \end{bmatrix} \quad (3)$$

$$\hat{f}(\tau) = \frac{1}{n\hat{h}} \int_1^{24} \varphi(\tau) \left( \frac{\tau - S_d(t)dt}{\hat{h}} \right) \quad (6)$$

# 3. Case Study

- Demonstration Smart Grid project **OSIRIS** (Spain)
  - Utility Gas Natural Fenosa (Naturgy)
  - 1 substation 630 kVA (8 Feeders)
  - 32 Customers (10 non-telemetered)
  - Total power contracted: 442 kW
  - Yearly data: 2013-14 (incomplete)

OSIRIS

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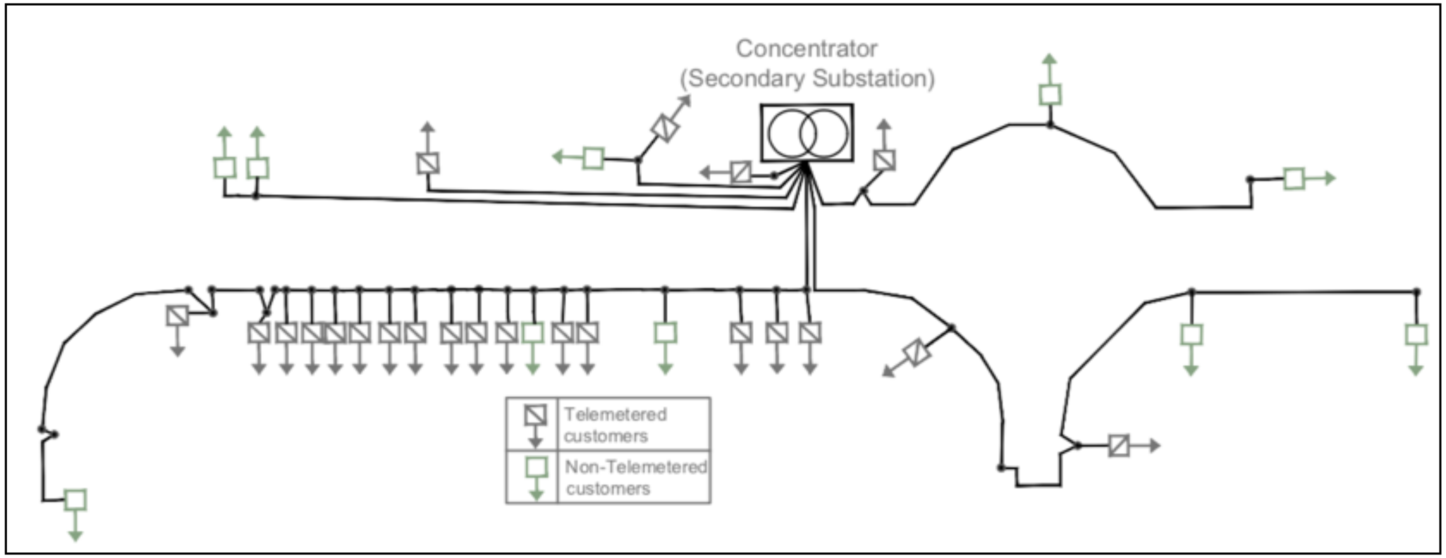
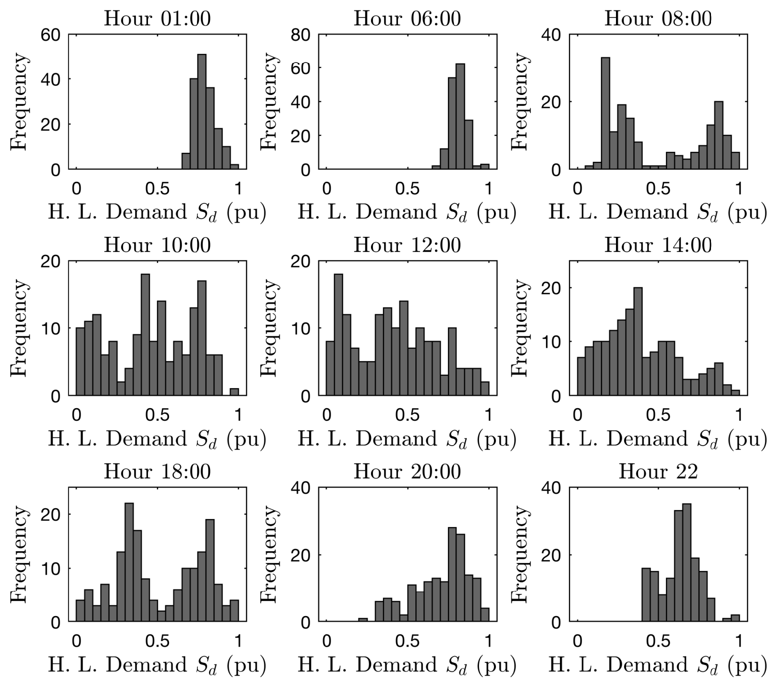
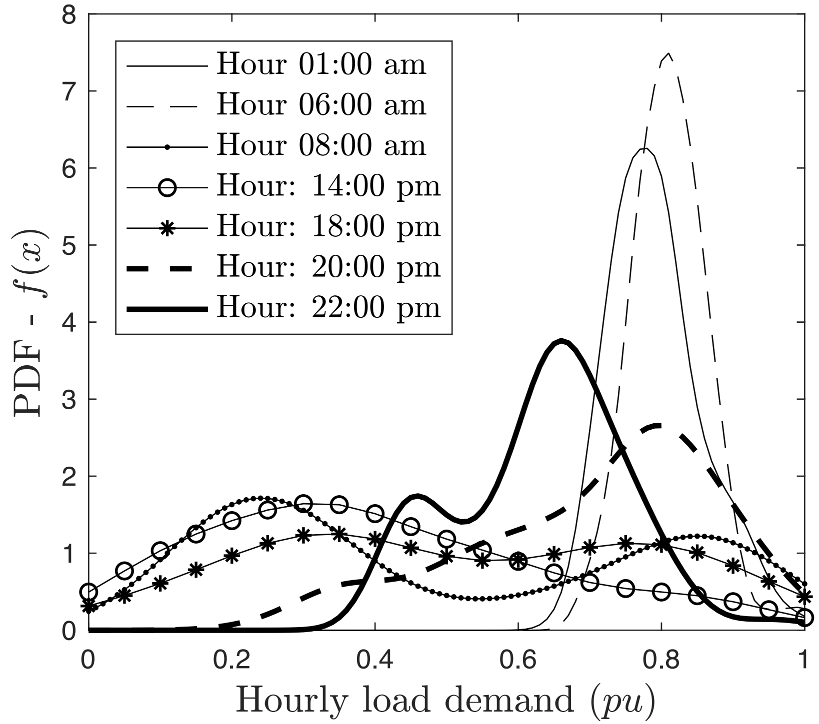


# 3. Case Study

## Statiscial study of load demand

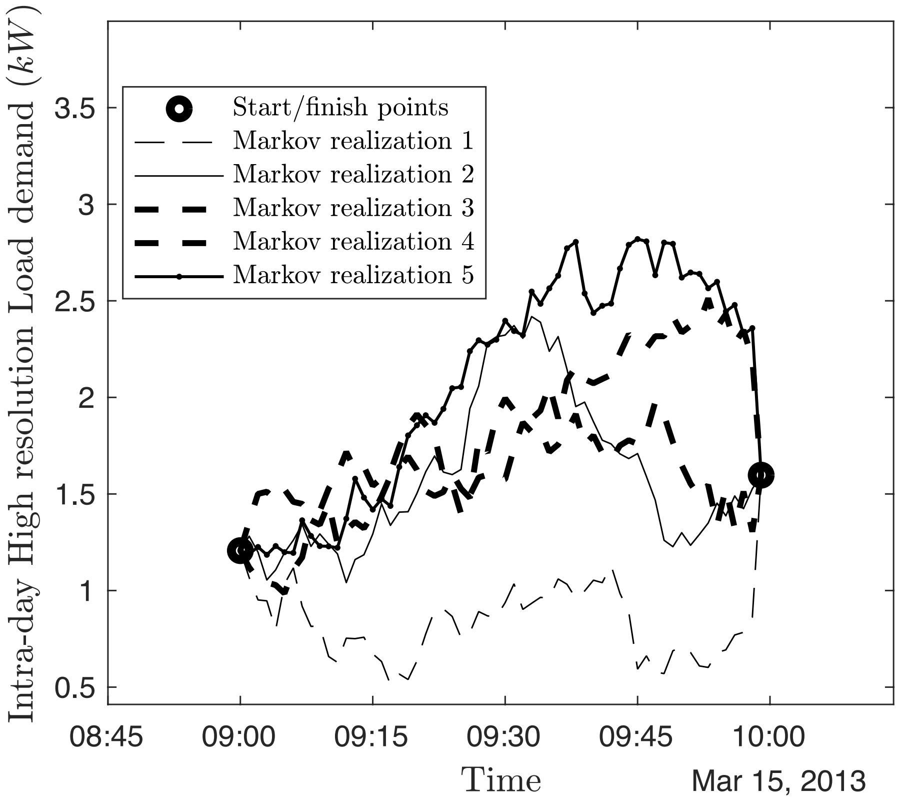



## PDFs estimated



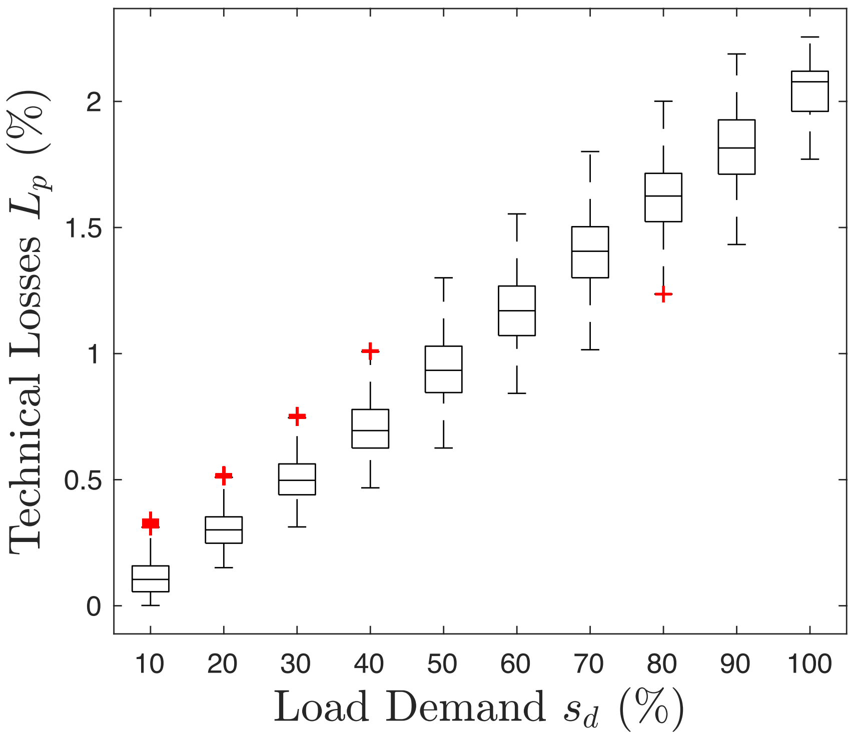
# 3. Case Study

## Realizations of the Markov Process



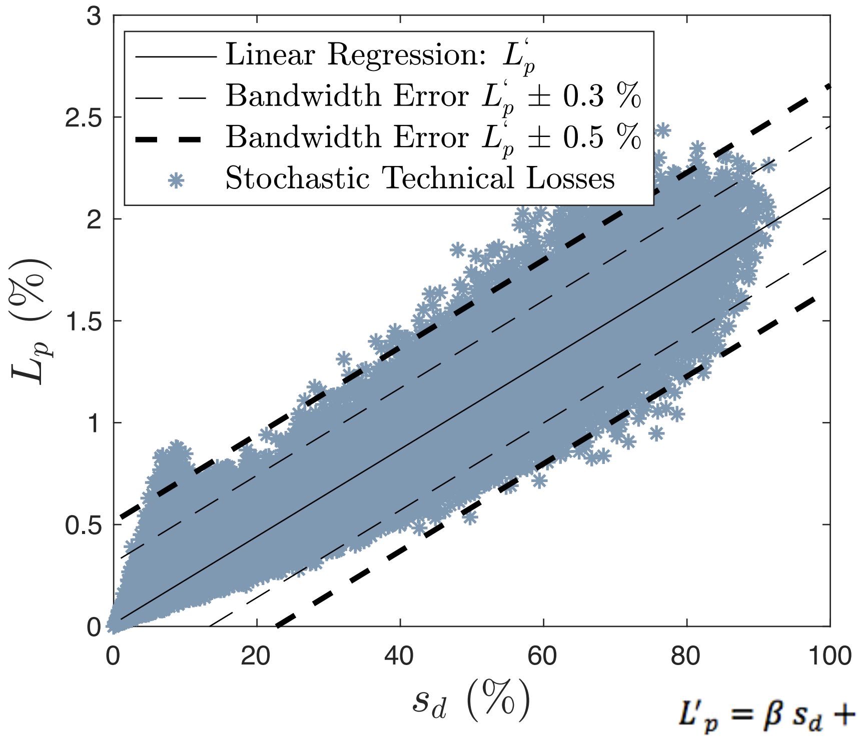
# 3. Case Study

## Technical Losses Calculated With power flow




$$L_p = \frac{P_L}{S_d} = \sqrt{3}\frac{\sum_s I_s^2 r_s l_s}{V_n I_T}$$

## Stochastic Losses Obtained



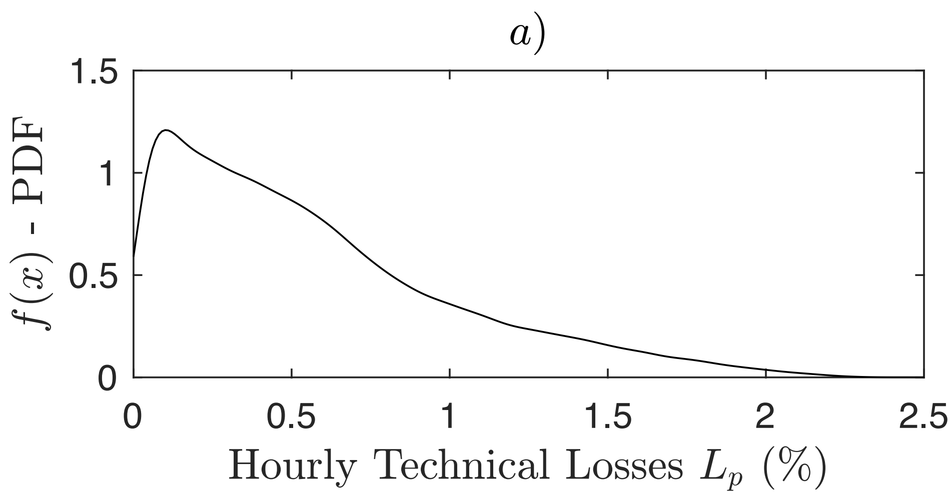

$$L'_p = \beta\, s_d + \alpha$$

$$\beta = \frac{Cov[s_d, L_p]}{Var[s_d]}$$

$$\alpha = \overline{L_p} - \beta \overline{s_d}$$

# 3. Case Study

## Probability Distribution Losses



# 4. Conclusions

- A stochastic top-down method to analyze Technical Losses in (still in transition) LV distribution Networks have been proposed

- Presence of non-telemeterd customers in LV networks as well as missing load demands have been taked into account

- Missing hourly load demand values have been estimated through an NLP optimization process

# 4. Conclusions

- Intra-hour high-resolution load demand profiles have been synthetically generated by means of Markov Chains

- For every stochastic realization of the Markov process, a balanced three-phase load flow analysis has been carried out to obtain the network losses

- Losses obtained have been statistically analyzed using a linear regression fitting to find the expected value

# Thank You

# Questions?

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