XSICEL 2021

Transición energética en la 4ta revolución industrial

Universidad Tecnológica de Pereira

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Daily Pattern recognition of Harmonic Currents of Residential Low Voltage Networks

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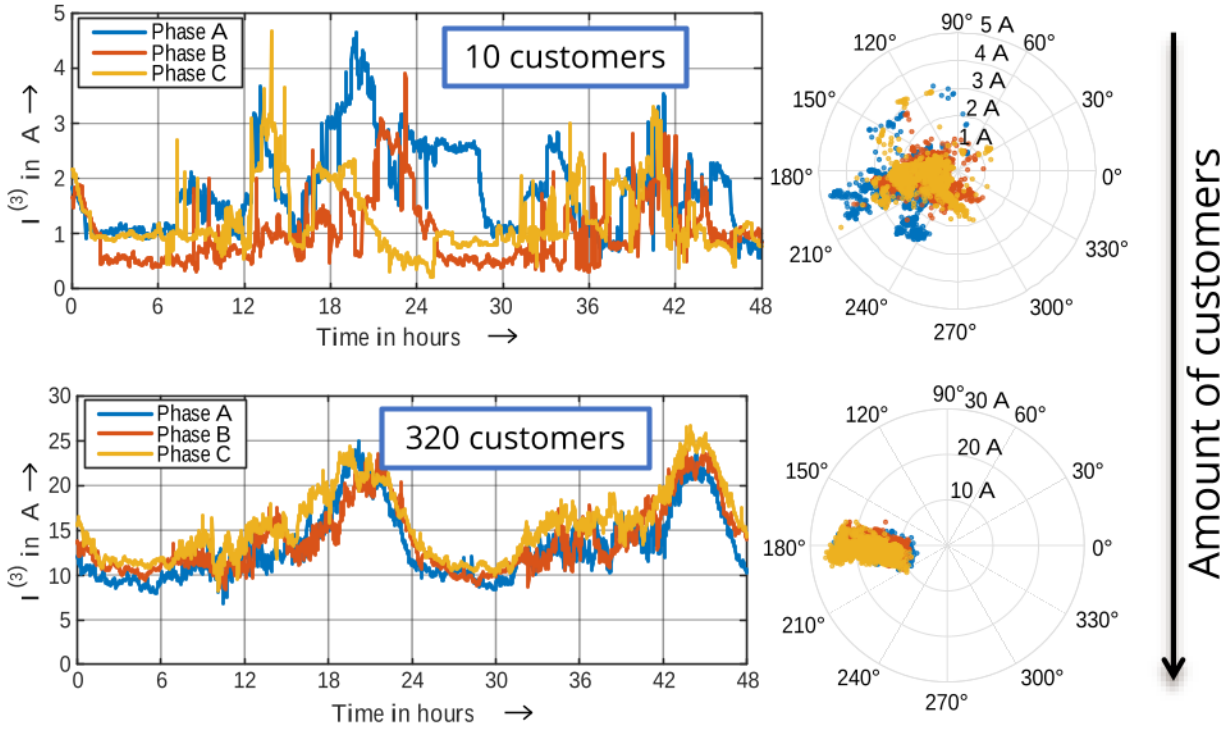
I. Introduction

- Harmonic emission characteristic depends on the number of aggregate customers



- "smoother" magnitude
- Prevailing direction of phase angles

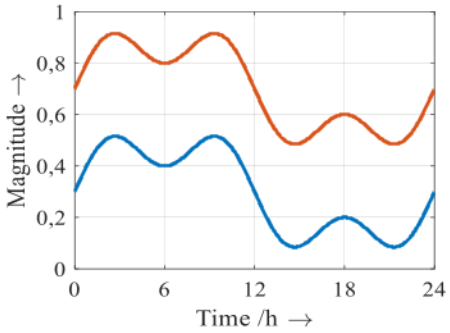
I. Introduction

- Daily pattern of harmonic magnitudes and phase angles?
  - Which harmonic orders?
  - Similar pattern for different networks?
- Modeling using time-series?

- Analyze the daily pattern characteristics of the harmonic currents in typical residential low-voltage networks.
  - Application of distance and similarity measures.
  - Measurements of different residential networks.

II. Distance and similarity measures

1. Distance Measures:
   - Euclidean distance in time domain
   - Minkowski distance in time domain
   - Euclidean distance in frequency domain

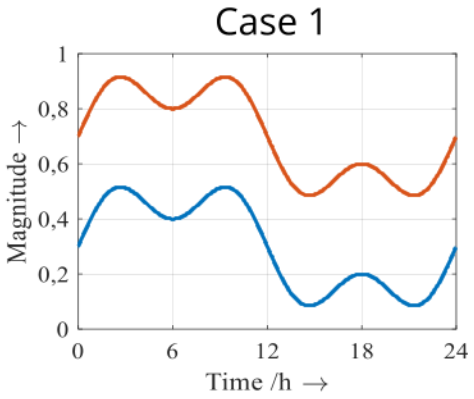


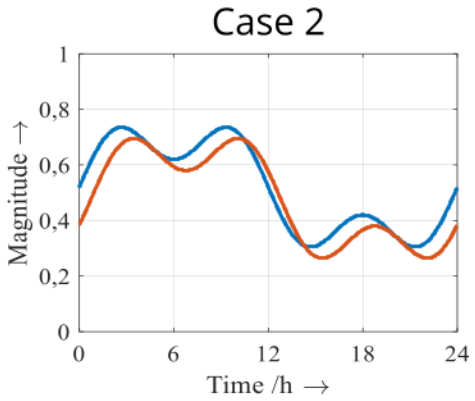
2. Similarity measures:
   - Cosine measure
   - Pearson's correlation coefficient

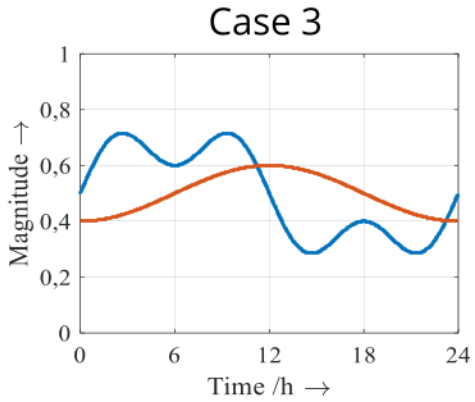
$$\mathrm{DM_E} = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2} = 15.18$$

$$\mathrm{SM_P} = \frac{\sum_{i=1}^{n} (x_i - \mu_x)(y_i - \mu_y)}{\sqrt{\sum_{i=1}^{n} (x_i - \mu_x)^2 \sum_{i=1}^{n} (y_i - \mu_y)^2}} = 1$$

II. Distance and similarity measures

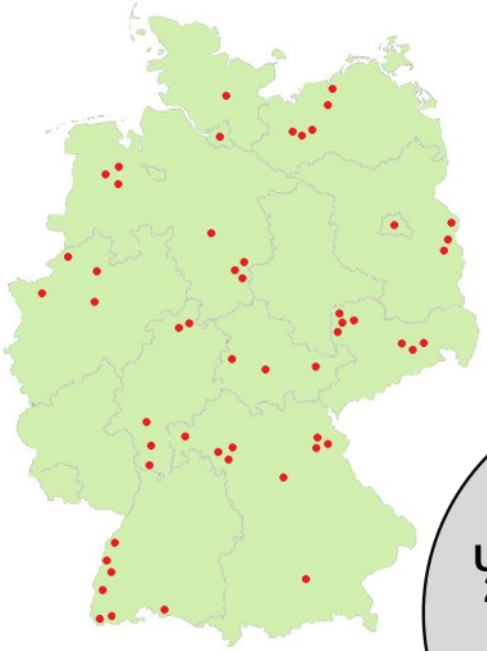


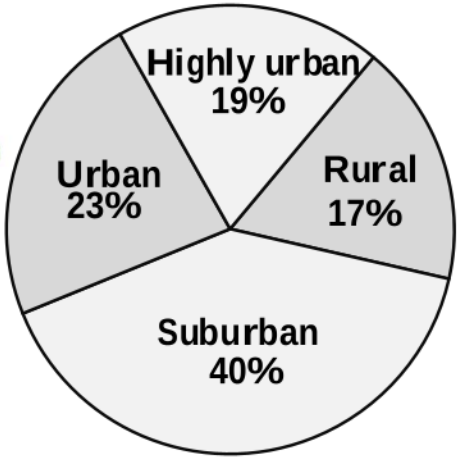




Case	Distance			Similarity	
	DM_E	$DM_{M\infty}$	DM_{FFT}	SM_C	SM_P
1	15.18	0.4	0.4	0.966	1
2	2.45	0.14	0.082	0.995	0.95
3	6.57	0.29	0.245	0.944	0

III. Measurement campaign

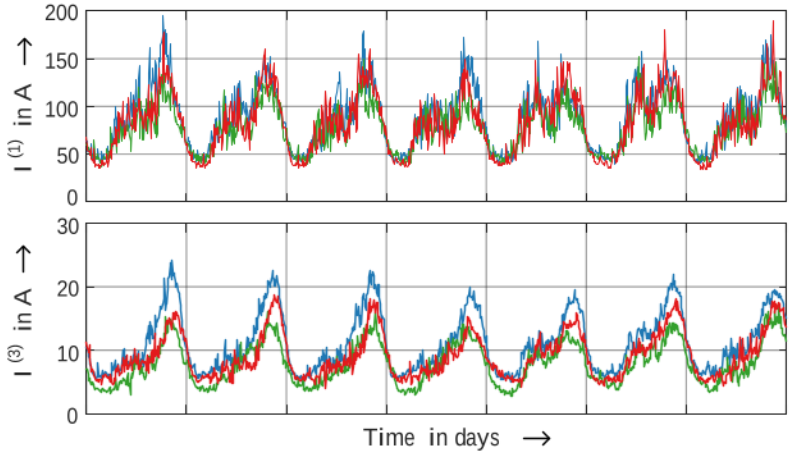


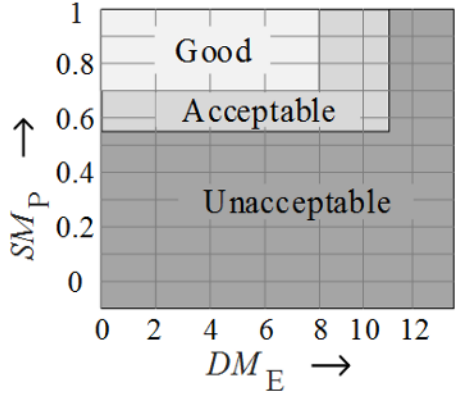


- 37 residential low-voltage networks
- Minimum 80% of residential customers
- Low penetration of PV systems ($P_{\mathrm{G\,TOT}} < 0.1 \cdot S_{\mathrm{rT}}$)
- Minimum 1 week of measurements in winter
- Holidays were excluded
- Magnitude and phase angle of current harmonics
- Electrical characteristics of the network, climate and social conditions

IV. Application of distance and similarity measures

- Current magnitudes are normalized (min-max normalization) and smoothed (moving average, window of 10 minutes).
- Method is applied to phase components and sequence components.
- Thresholds for the distance and similarity measures obtained based on the fundamental and third harmonic currents.

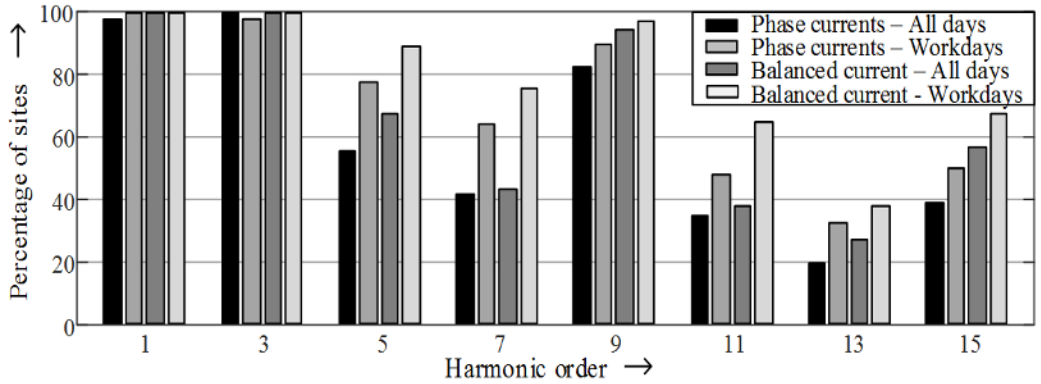




IV. Application of distance and similarity measures

Similarity for single sites

- $\mathrm{DM_E}$ and $\mathrm{SM_P}$ measures were calculated between the daily curves of each site and each phase.
- Harmonic currents of a site have a daily pattern only if at least 80% of the days are similar between them (80% of the days have good or acceptable $\overline{\mathrm{DM}}_{\mathrm{E},i}$ and $\overline{\mathrm{SM}}_{\mathrm{P},i}$).



IV. Application of distance and similarity measures

Similarity between sites

- $\overline{\mathrm{DM}}_{\mathrm{E},i}$ and $\overline{\mathrm{SM}}_{\mathrm{P},i}$ were calculated between all daily curves of the balanced component of harmonic current magnitudes of sites with clear daily patterns.

	Harmonic order							
	1	3	5	7	9	11	13	15
Percentage of days	100	100	97.4	93.3	97.6	84.5	81.7	73.9

Daily patterns ✓
Time-series modeling ✓

V. Conclusions

- Only the fundamental, 3rd and 9th harmonic magnitudes show a clear daily pattern during the whole week in more than 80% of the measured residential networks.
- For other harmonic orders the randomness of the harmonic magnitudes is higher and a daily pattern is not recognizable for all the networks.
- If the balanced component of the harmonic currents is used instead of the phase currents, and if only workdays are considered, the results improve considerably.
- Daily patterns of the harmonic currentmagnitudes of almost all residential networks (>80% of the networks) have very similar characteristics.
- Harmonic phase angles do not show a clear daily pattern.

Thank you for your attention!

Questions?

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