Assessment of PV and Wind Microgeneration’s Impact in the Power Quality of Low and Medium Voltage Distribution Networks

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Contextualization

Energy Quality Problems: HARMONICS!

- Electric Vehicles
- Nonlinear Loads
- μGeneration

Characterization: Harmonic Load Flow (HLF)

- Transformer Heating
- Resonance Conditions
- Greater Losses

Solution: Intelligent Domestic Agent (IDA)

Greater Complexity
Greater Data Volume
Greater Data Volume
Objectives – REIVE Project:

• Analyse the Impact of Microgeneration and Electric Vehicles integration in the low voltage grid and in Power:
  – Access Total Harmonic Distortion (THD).
  – Evaluate Neutral currents.
  – LNEG: Access flicker levels and dynamic voltage profile in local distribution network.

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Developed Work

• Development of a Harmonic Load Flow Tool (TEH) for 3-phase Balanced networks – Matlab.
• Development of a Modular Reconfigurable Consumer Model – IDA.
• Creation of a Power Quality Assessment Tool:
  • Low Voltage 3-phase networks.
  • Balanced and Unbalanced
  • 1 & 3-phase consumers.
  • Implementation in Matlab/Simulink.
Single-Phase Domestic Load Model

Intelligent Domestic Agent – IDA:

- Household Loads (HH).
- Non Linear Loads.
  - Electric Vehicles (EV).
- Microgeneration
  - Photovoltaic Generator (PV).
  - Wind Turbine Generator (WTG).

Connection Point To Low Voltage Network

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IDA - Components

• I – Current Injection/Consumption Models
  • Fundamental and Harmonic currents represented through ideal current sources.
  • Individual Input/output current spectrum for each Power Converter connected to the grid.

• II – Physical Models
  • Modelling of the behaviour of the components with fluctuations of renewable resources.

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Model Validation – Balanced/Unbalanced Networks

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Test Network I
Test Network II

**Challenges**
- 6 lines to substation.
- 142 clients 1 or 3-phase.
- Imprecise data regarding the connection of single-phase clients.

**Solutions**
- Aggregation of single-phase loads in a single ADI for each phase and for each bus bar.
- Aggregation of 3-phase loads in a single load for each bus bar.
- Sequential distribution of the ADIs for each line.
Test Methodology

Voltage FFT

![Voltage FFT Diagram]

Fundamental (60Hz) = 228.7, THD = 1.50%

Current FFT

![Current FFT Diagram]

Fundamental (60Hz) = 288.60, THD = 2.88%

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## Test Cases

<table>
<thead>
<tr>
<th>Case</th>
<th>Conditions</th>
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<tbody>
<tr>
<td>I</td>
<td>• Only Loads – peak scenario</td>
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</tbody>
</table>
| II   | • Loads – 25% of peak load  
      | • Electric Vehicles – all single-phase loads |
| III  | • Loads – 25% of peak load  
      | • Electric Vehicles – all single-phase loads  
      | • Microgeneration – 1 source for each bus bar |
| IV   | • Loads – 25% of peak load  
      | • Electric Vehicles – 1 per bus  
      | • Microgeneration – all single-phase loads |
Case III and IV - Branching

Utilization of Real World Signals Obtained from LV – PV Inverters.

- **Cases:**
  - (T) – Theoretical Model.
  - (S) – Current Model for Device 1.
  - (F) – Current Model for Device 2.
Results – Transformer (LV-Side)

Voltage (p.u.)

<table>
<thead>
<tr>
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<th>II (T)</th>
<th>III (T)</th>
<th>IV (T)</th>
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<td>0.990</td>
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THDv (%)

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<td>10.34</td>
<td>99.89</td>
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Current (A)

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THDi (%)
Different Device Signals

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Voltage THD Comparison

THD – According to IEC 61000-2-2 – 50th Harmonic – 2500 Hz

THD – Full Harmonic Spectrum – 21 kHz

Values for Case IV(F) at Bus 5

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Conclusions

• Voltage and Current Total Harmonic Distortion Values are conforming to IEC 61000-3-2, EN50160 standards.
• Results present a significant contribution as pre-normative recommendation in considering high frequency harmonics acquired from real device measurements (f>40).
Thanks For Your Time