Analysis of Hourly Impacts of Photovoltaic Systems and Electric Vehicles in a Distribution Network from Deterministic and Probabilistic Approaches

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V. Questions
“Distributed Energy Resources (DERs) are defined as a group of technologies connected in electrical networks (especially in distribution) that can be conformed to distributed generation sources (e.g., photovoltaic systems – PVS), battery energy storage systems (BESS), controllable power converters, electrical vehicles (EV), or demand management” IRENA
I. Introduction

Select a test network
- Real
- Test feeders

DERs integrated
- PVS
- BESS
- EV

Scenario
- Penetration levels
- Locations
- Charging strategy

Impact
- Voltage and frequency variations
- Loading
- Energy losses
- Power Quality
- Reliability
- Controlled and uncontrolled charging

Results
- Indicators to quantify the impact
- Reduction or increase of imported energy
- Identify negative and positive effects
- Penetration levels admitted
- Inverse power flow
I. Introduction

How to characterize the impact in distribution networks due to EV and PVS integration using indicators?

Parameters:
1. RMS voltage
2. Voltage unbalance
3. Power losses
II. Methodology

II.1 Load modelling

Each hour distribution's mean and standard deviation correspond to the load profile value in that hour and 5% of the mean value, respectively.
This study has historical irradiance and temperature data measured at the Universidad Industrial de Santander, Bucaramanga, Colombia. These data must be clustered in vectors for each hour where the solar resource is available (6:00 – 18:00).
II. Methodology

II.3 EV modelling

Distance traveled PDF | Arrival time PDF | Charge duration PDF

Electric vehicles are additional charges in the system; thus, a behavior that follows a normal distribution is assumed.

The number of vehicles and the charging power determine the PDF’s mean value. As proposed by literature, the standard deviation might be equal to 5% of the mean value.
II. Methodology

II.4 Study case

### Scenarios

<table>
<thead>
<tr>
<th>Sce.</th>
<th>PVS</th>
<th>EV</th>
<th>Location [Nodes]</th>
<th>Total cap. [MVA]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>✓</td>
<td>✓</td>
<td>611, 634, 645, 680, 692</td>
<td>633, 645, 675, 684</td>
</tr>
</tbody>
</table>

An IEEE 13 nodes test feeder is studied in this work, which has a substation conformed by a **5 MVA – 115/4.16 kV (Δ/Y)** three-phase bank of auto-transformer. The grid characteristics are shown in Kerting [1].
## II. Methodology

### II.5 Indicators

<table>
<thead>
<tr>
<th>No.</th>
<th>Ref.</th>
<th>Equation</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[2]</td>
<td>$IV = \frac{v_{i with \text{DER}}}{v_{i without \text{DER}}} - 1$</td>
<td>Shows the DER integration impact in the voltage of the i-th system node.</td>
</tr>
<tr>
<td>2</td>
<td>[3]</td>
<td>$VUF = \frac{V^-}{V^+} \times 100$</td>
<td>Calculates the grid voltage unbalance.</td>
</tr>
<tr>
<td>3</td>
<td>[4]</td>
<td>$P_{loss} = \sum (P_{import} - P_{consumption})$</td>
<td>Indicates the grid total electrical power losses percentage.</td>
</tr>
</tbody>
</table>

**IV**: Voltage variation index  
**$V^-$**: Negative sequence voltage  
**$V^+$**: Positive sequence voltage  
**$VUF$**: Voltage unbalance factor
The figure shows the variation between deterministic (trend line) and probabilistic (box plot) approaches for RMS voltage results in the Node 632 for the DER integration scenario.
III. Results

III.1 Voltage variation index

The figure presents the **voltage variation index** – IV, which analyzes the variation between the **base case** and the **integration scenario** for all nodes.

The higher differences occur in Phase C because it is the **most loaded phase** in the system.
III. Results

III.2 Voltage unbalance

Heat maps show a comparison between **probabilistic** and **deterministic** voltage unbalance results during a day and for all the nodes.

None of the nodes exceeds the 3% value, which is propitious for DER integration.
Figure shows the boxplot for network total active power losses during a day. **The highest losses** occur in Hour 16 because of the **load demand peak of the loads with the greater demand in the systems** (commercial and industrial ones).
IV. Conclusions

1. The higher variations between the two approaches in the analyzed parameters occur in great solar resource hours. The distributions' interquartile range increases in such hours, and its mean value is separated from the deterministic value.

2. The voltage unbalance, and power losses exhibit the more significant error in Hour 16. It is caused by the relation of these parameters with demand variation, which is strongly influenced by commercial and industrial loads.

3. When comparing deterministic and probabilistic approaches, it is possible to infer that a deterministic simulation is not reliable enough for analyzing the three parameters when PVS are integrated. For this reason, probabilistic analysis is recommended.

4. Results show that the integration of the EV capacity defined for this study does not cause representative effects in the studied parameters.


Thank you!

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Questions?