Presented at 2012 3rd IEEE PES ISGT Europe, Berlin, Germany, October 14 -17, 2012

Innovative Smart Grid Technologies Berlin 2012 Europe

Panel

Novel State Estimation for Smart Distribution and Transmission Network Operation

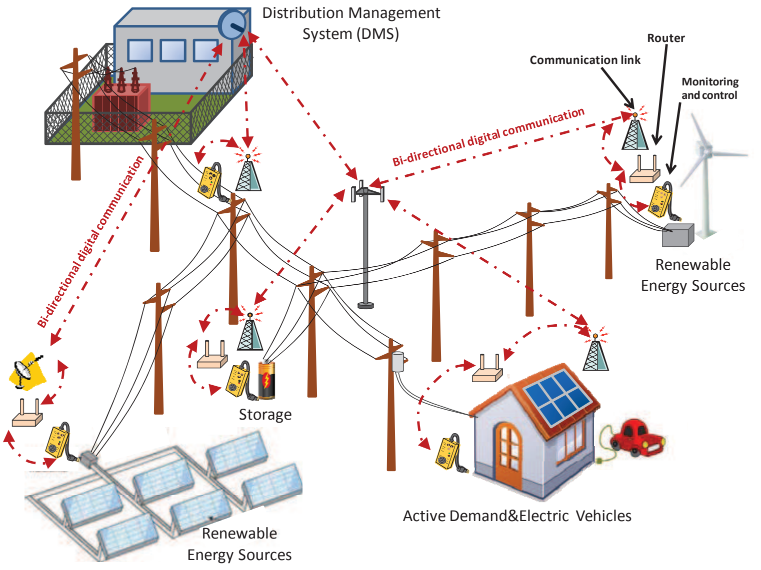
Impact of Distribution State Estimation on Active Operation of Distribution Systems

Fabrizio Pilo (University of Cagliari, Italy),
Giuditta Pisano (University of Cagliari, Italy)

INTRODUCTION

- ***Active networks*** are distribution networks with generators and storage devices and flexible loads subject to control.
- Distribution Management System (**DMS**) needs to know the state of the network to coordinate distributed energy resources and manage and control the system economically and safely.
- The distribution systems have a very large number of nodes but few measurements points.
- *Ad hoc* Distribution State Estimators are needed to provide to the DMS the estimated status of the network (starting from real measurements and historical data, e.g. **pseudo-measurements**).
- The **quality** of the estimates can **seriously** affect the system management.

CENTRALIZED DMS (Distribution Management System) FOR ACTIVE NETWORKS



DISTRIBUTION STATE ESTIMATION

- The status of a system **with a measurement device on each node** would be totally known!

➡ **Approach economically unfeasible.**

- The DSE algorithm on the basis of few measurements from the field and pseudo-measurements provides a **complete** and **consistent** model of the operating conditions of the network.
- State variables can be:
  - Node voltages;
  - Branch currents;
  - Nodal currents;
  - Active and reactive powers;
  - Phase angles;
  - Etc.

Berlin 2012 Europe
Innovative Smart Grid Technologies
IEEE PES Power & Energy Society
IEEE

DSE METHODS AND TECHNIQUES

- The existing algorithms adopted in the **transmission system** state estimation must be reconfigured for the **distribution system.**
- Approaches used in Literature
  - **Weighted Least Squares** (WLS) (mostly used)
  - Kalman filter
  - Probabilistic approach
  - Artificial Neural network
  - …

Berlin 2012 Europe
Innovative Smart Grid Technologies
IEEE PES Power & Energy Society
IEEE

DSE METHODS AND TECHNIQUES

- State variables: **branch currents**
- Input data:
  - Some measured branch currents (optimal placement of measurement devices);
  - **Pseudo-measurements of the load demand** (P and Q);
  - Measured powers from DG.
- Calculation of **nodal currents** by using nominal voltage
- **Node voltages** are determined with:

$$[V]=[Z]\cdot[I_{node}]$$

- **Iterative procedure:**
  1. calculation of I_{branch} simply dividing the voltage drop by the branch impedance.
  2. for each *i-th* branch equipped with a measurement device calculate the difference between the calculated current (I_{branch} h) and the measured one (I_{meas});
  3. sum these differences to assess a quantity Δ

$$\Delta = \sum_{i=1}^{N_{meas}} \left[I_{branch}(i) - I_{meas}(i) \right]$$

  4. adjust the node pseudo-measured powers on the basis of the quantity Δ;
  5. use the new pseudo-measurements to repeat the procedure (return to step 1).

- The **algorithm stops** when the corrective quantity becomes smaller than a **prefixed threshold** or when the **maximum number of iterations** is reached.

ERROR (UNCERTAINTY) SOURCES

- **Pseudo-measurements** (reliance on historical data).
  - Stochastic behavior of loads an generation (especially RES)
- Inherent **uncertainty derived from the measurements**
  - accuracy of the instrumentation;
  - decay of the metrological characteristics.
- Anomalies or faults in the measurement system (**reliability of the measurement system**).
- **Insufficient redundancy.**
- Deviations from their nominal value of **network parameters** (resistance, reactance of the lines, etc.).
- Changes in **network topology.**
- **Reliability of communication system.**

➡ **Spurious results**

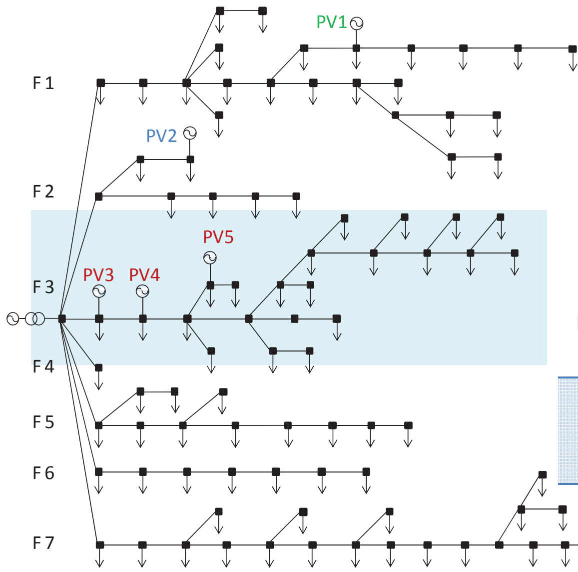
Optimal placement (number and position) of measurement devices

IMPACT OF DSE ON ACTIVE OPERATION OF DISTRIBUTION SYSTEMS

Example:

- Hypothesis:
  - suitable number of measurement devices, positioned in optimal sites;
  - "guaranteed" the prefixed level of **accuracy** of the estimates.
- In case of **a contingency** the DMS has to optimize the operation point
  - by minimizing the active power to be curtailed and modifying the power factor of the local generators.
- If the DSE **underestimates** the optimal operation point could **not solve the problem**.
- Otherwise **overestimated contingency condition** may lead to **extra costs for DSOs**.

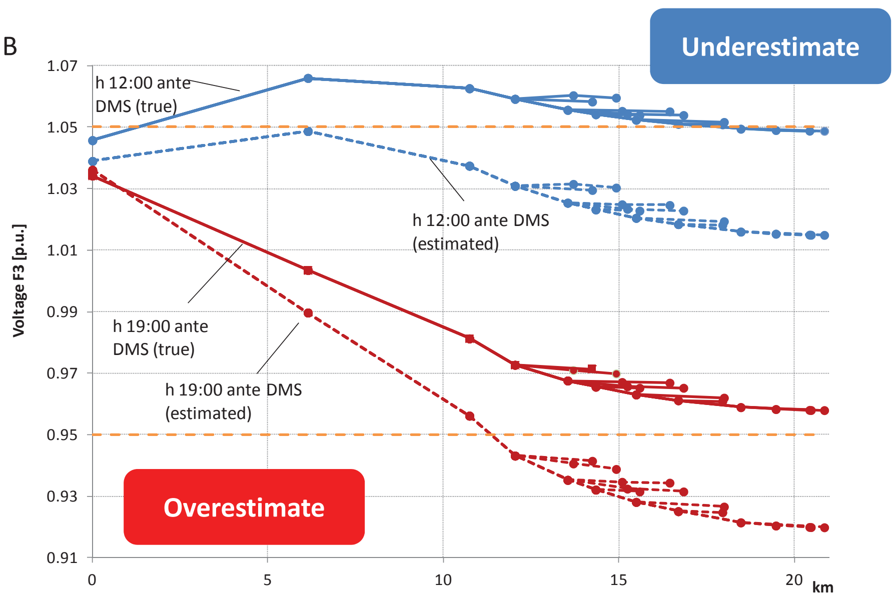
CASE STUDY: ATLANTIDE RURAL NETWORK



Network data
- 7 feeders
- total extension of about 160 km
- 103 MV nodes
- 1 HV/MV substation
- 5 PV plants

Installed Power	Load Demand	Energy Losses
20MVA	20.23 MVA	5.374 MWh (2.13 %)

CASE STUDY: ANTE DMS OPERATION UNDERSTIMATE & OVERESTIMATE

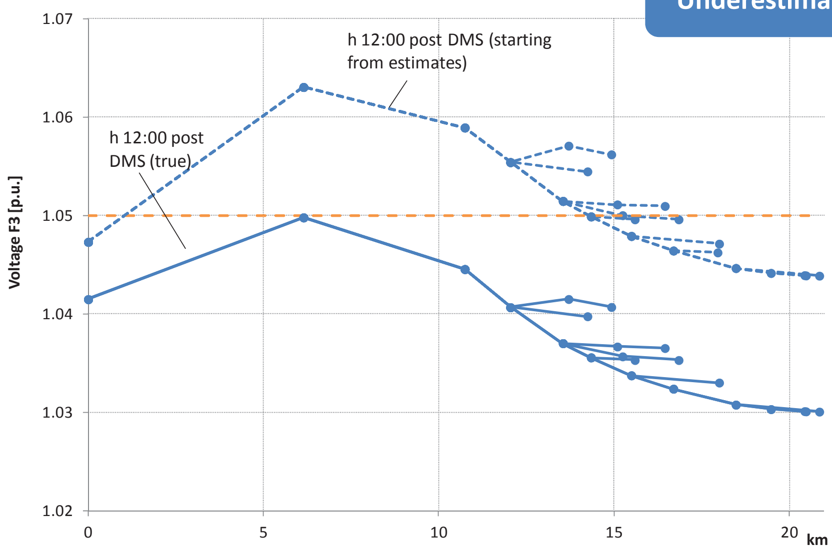


Berlin 2012 Europe
Innovative Smart Grid Technologies

CASE STUDY: POST DMS UNDERESTIMATE

ATLANTIDE

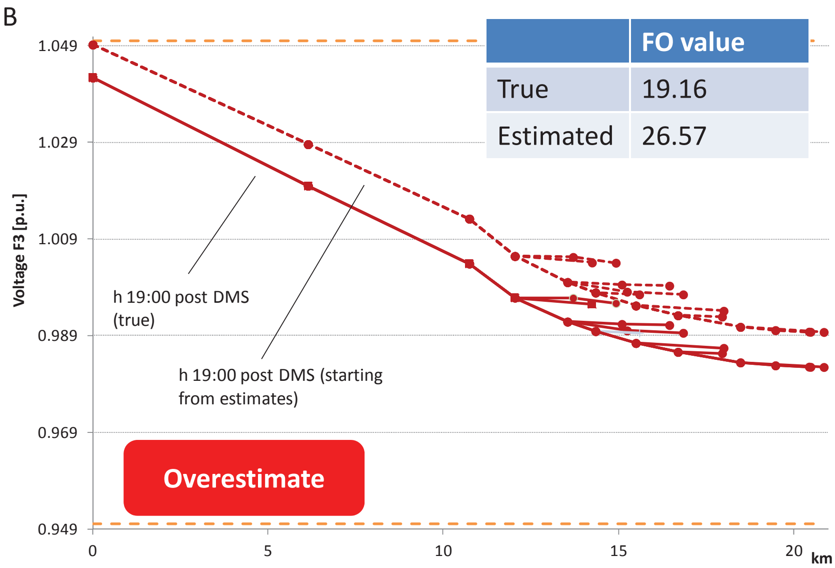
Underestimate



Berlin 2012 Europe
Innovative Smart Grid Technologies

CASE STUDY: POST DMS OPERATION OVERESTIMATE

ATLANTIDE



	FO value
True	19.16
Estimated	26.57

STARTING POINTS FOR THE DISCUSSION

- Increasing accuracy or reducing cost?
- Smart meters and synchro-phasors are the solution?
- New sources of uncertainties in active distribution networks estimation and operation:
  - active loads and generators may give negative response to the dispatching commands

THANK YOU FOR YOUR ATTENTION!

Contacts:
giuditta.pisano@diee.unica.it
pilo@diee.unica.it

ATLANTIDE http://www.progettoatlantide.it