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Optimal Measurement Placement for State Estimation in Smart Grids

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State Estimation for Distribution Networks

Definition

- Because of the tremendous number of nodes and elements on any distribution system, it is technically impossible to continuously model the distribution grid in real time.
- Even if such modeling were technically feasible, it would be prohibitively expensive.
  - The cost of continuously measuring and communicating data from every node and element is more significant in comparison to the cost of planning, building, operating and maintaining them.

State Estimation for Distribution Networks

Concept

- Goal: Estimate the state variables using redundant set of measurements that included measurement errors
- Functions:
  - Measurement filtering
  - Topology checking
  - Detection and identification of bad measurements
  - Estimation
  - Observability analysis
    - If the system as a whole is not observable, some islands would be
    - If the system is unobservable, pseudo-measurements are used:
      - Reasonable values
      - Previous estimates

⇩

Interaction with historical data

State Estimation for Distribution Networks

Main Issues

- Convergence: Improved load models have a strong effect on convergence
- Results accuracy: a large number of pseudo-measurements acting in contradiction to the observed actual measurements, particularly in periods of light loading
- Key nodes: difficult process for determining the network nodes with highest weight
- Minimum number of telemetry for acceptable RTSE process

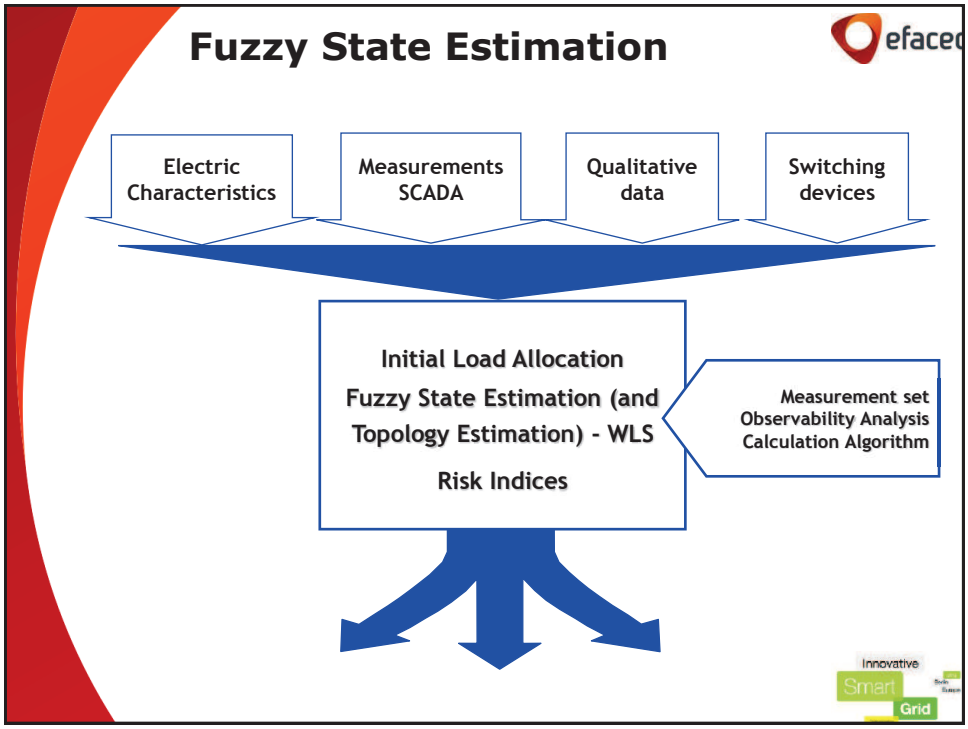
State Estimation for Distribution Networks

New Problems

- Low level of automation
- Insufficient tele-measurements (which may be unsynchronized)
- New kind of state variables (switching devices state)
- Topology identification included in the State Estimation process
- Dealing with splitting problem (voltage phase included as measurements)

What is affected by uncertainties?

- Several parameters are actually affected by uncertainties:
  - Demand
  - Volatility of some resources
    - Wind power – it is unrealistic not to consider it!
  - Market development and regulations
  - Reliability
    - Probabilistic models
  - New demand (value, location, year)
  - Generation costs
  - New generation (technology, location, year)
- Our world is more volatile than ever!


Fuzzy State Estimation
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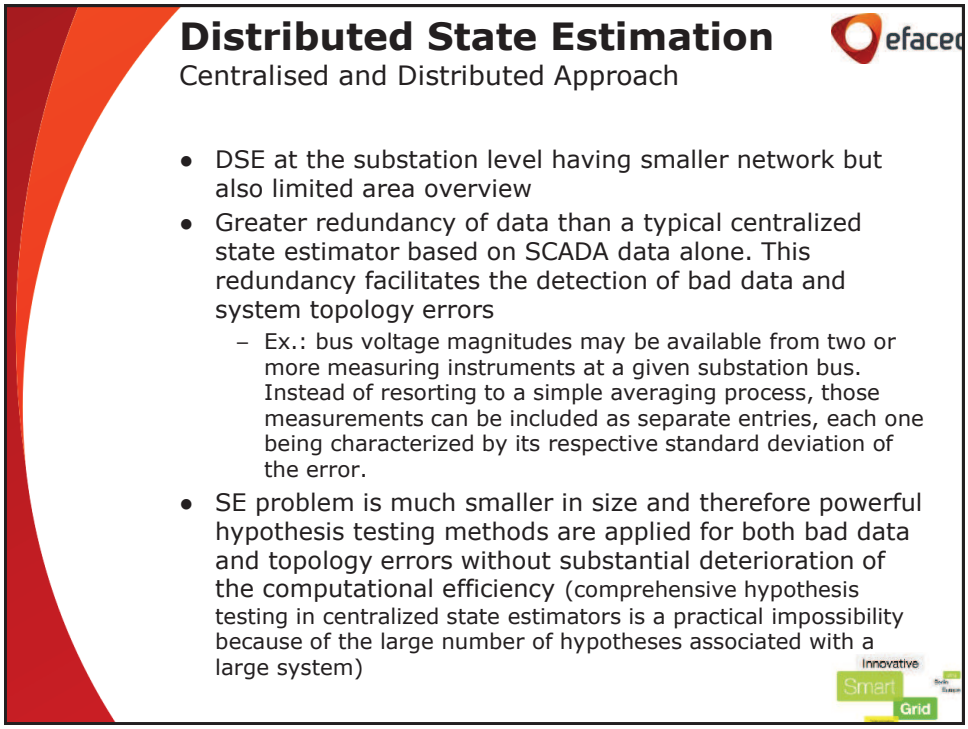
Electric Characteristics
Measurements SCADA
Qualitative data
Switching devices
Initial Load Allocation
Fuzzy State Estimation (and Topology Estimation) - WLS
Risk Indices
Measurement set Observability Analysis Calculation Algorithm
Innovative Smart Grid


Distributed State Estimation
Centralised and Distributed Approach
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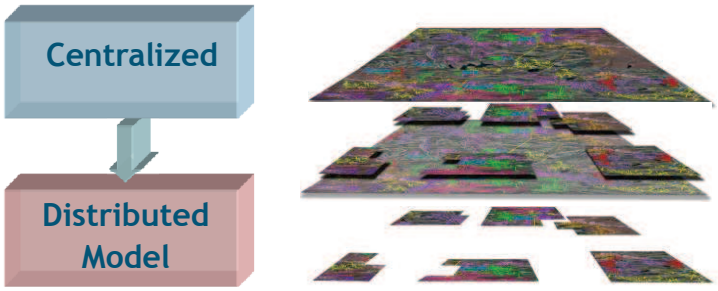
• DSE at the substation level having smaller network but also limited area overview
• Greater redundancy of data than a typical centralized state estimator based on SCADA data alone. This redundancy facilitates the detection of bad data and system topology errors
– Ex.: bus voltage magnitudes may be available from two or more measuring instruments at a given substation bus. Instead of resorting to a simple averaging process, those measurements can be included as separate entries, each one being characterized by its respective standard deviation of the error.
• SE problem is much smaller in size and therefore powerful hypothesis testing methods are applied for both bad data and topology errors without substantial deterioration of the computational efficiency (comprehensive hypothesis testing in centralized state estimators is a practical impossibility because of the large number of hypotheses associated with a large system)
Innovative Smart Grid

Future Network Evolution



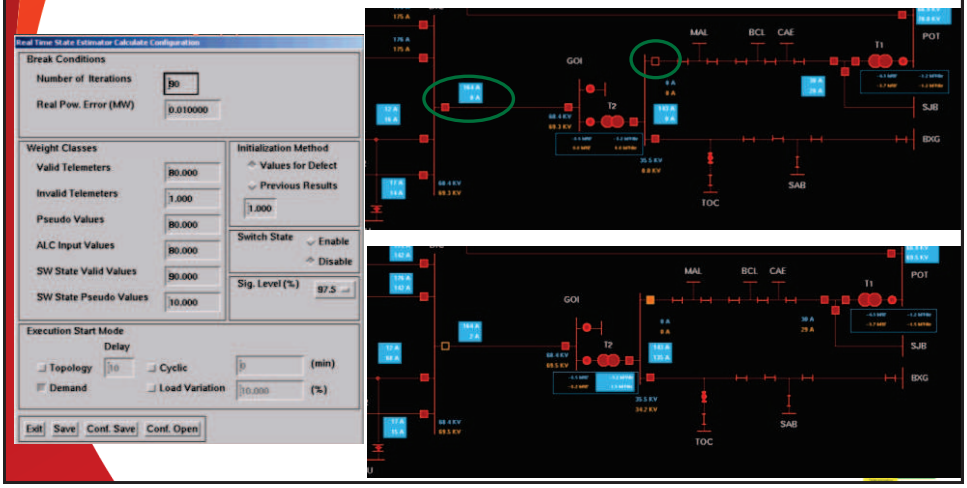
A hybrid approach sharing all the advantages of both centralized and distributed model-driven approaches

Real Time State Estimator

Application example

Ampla, Brasil – 69kV, 34.5kV and 13.8kV networks

- Performed after topology change



DSE – Smart Grids projects as a source of information

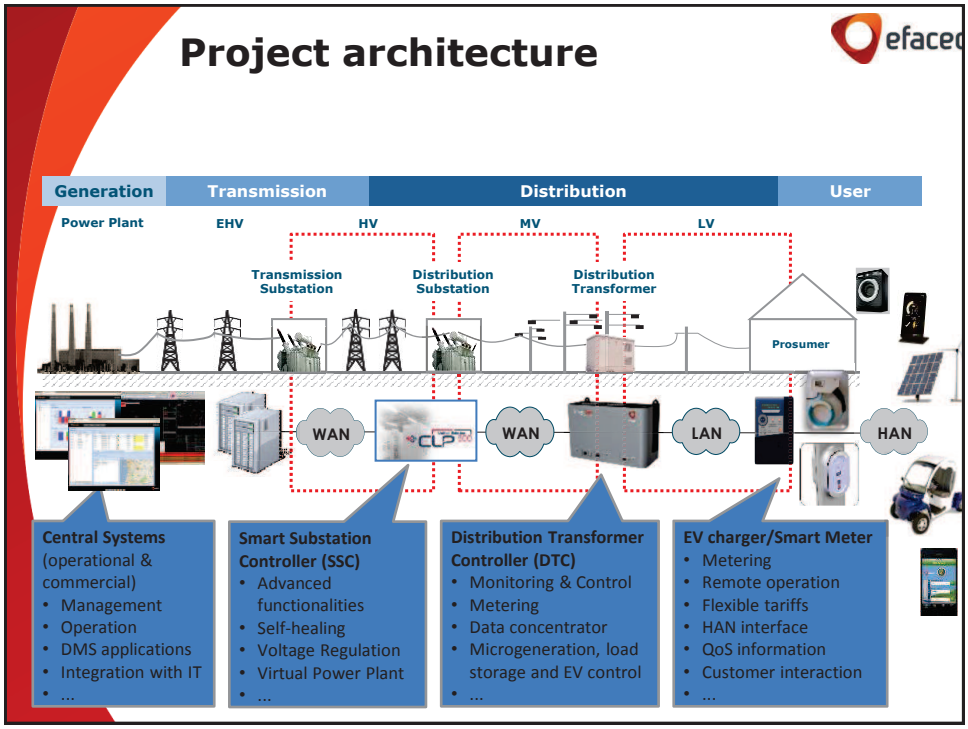
- The deployment of smart grids projects is a new source of data for DMS applications
- DSE can benefit from data collected at the MV and LV networks:
  - Smart meters at customers
  - Smart meters at micro and minigenerators
  - Data concentrators
  - Sensors at LV level
  - MV/LV transformer stations monitoring
  - Distribution automation
  - Digital HV/MV substations

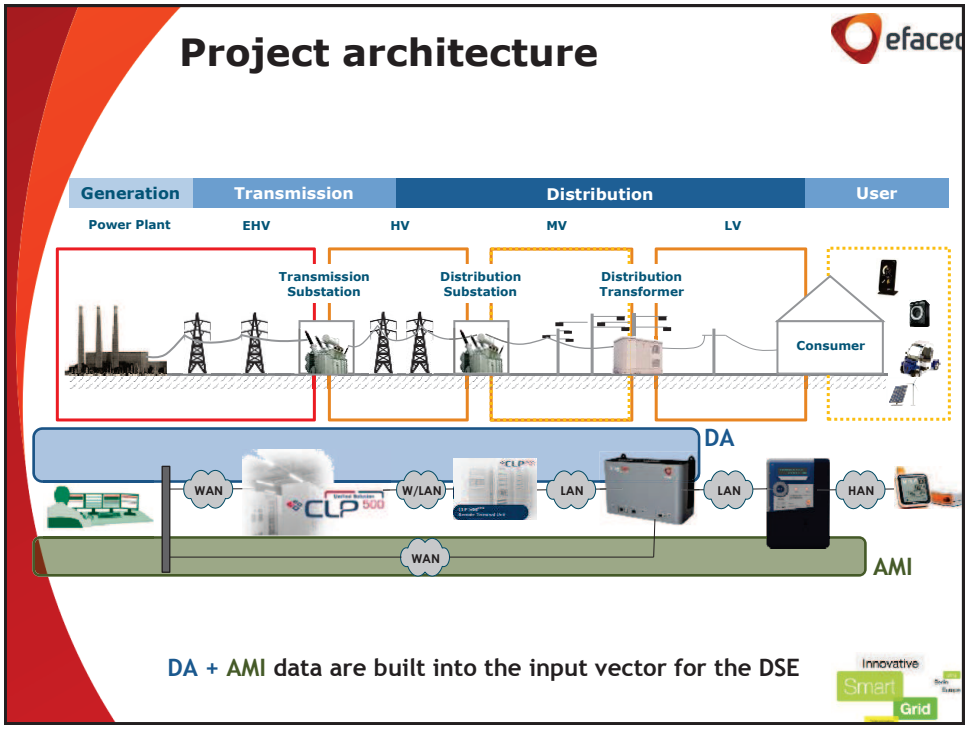
DSE – Smart Grids projects as a source of information

Example - Self-healing/distribution automation + AMI project

- CT and VT spread across the MV network
- FCI installed at key nodes
- Remotely controlled (topology) Reclosers with voltage and current measurement
- Distribution Transformer Controllers (DTC) that collect data from smart meters and sensors at LV network and is able to execute advanced control strategies
- Smart meters at microgeneration sites
- Smart meters at customers premises
- Demand Response could be used
- Several communication technologies used (RF Mesh, PLC, GPRS)

All these new sources of data provide the required redundancy and network observability to increase DSE accuracy


Project architecture
Generation
Transmission
Distribution
User
Power Plant
EHV
HV
MV
LV
Transmission Substation
Distribution Substation
Distribution Transformer
Prosumer
WAN
WAN
LAN
HAN
Central Systems (operational & commercial)
• Management
• Operation
• DMS applications
• Integration with IT
• ...
Smart Substation Controller (SSC)
• Advanced functionalities
• Self-healing
• Voltage Regulation
• Virtual Power Plant
• ...
Distribution Transformer Controller (DTC)
• Monitoring & Control
• Metering
• Data concentrator
• Microgeneration, load storage and EV control
• ...
EV charger/Smart Meter
• Metering
• Remote operation
• Flexible tariffs
• HAN interface
• QoS information
• Customer interaction
• ...


Project architecture
Generation
Transmission
Distribution
User
Power Plant
EHV
HV
MV
LV
Transmission Substation
Distribution Substation
Distribution Transformer
Consumer
DA
WAN
W/LAN
LAN
LAN
HAN
WAN
AMI
DA + AMI data are built into the input vector for the DSE
Innovative
Smart
Grid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Thank you!
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