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Novel Meter Placement Algorithm for Enhanced Accuracy of Distribution System State Estimation

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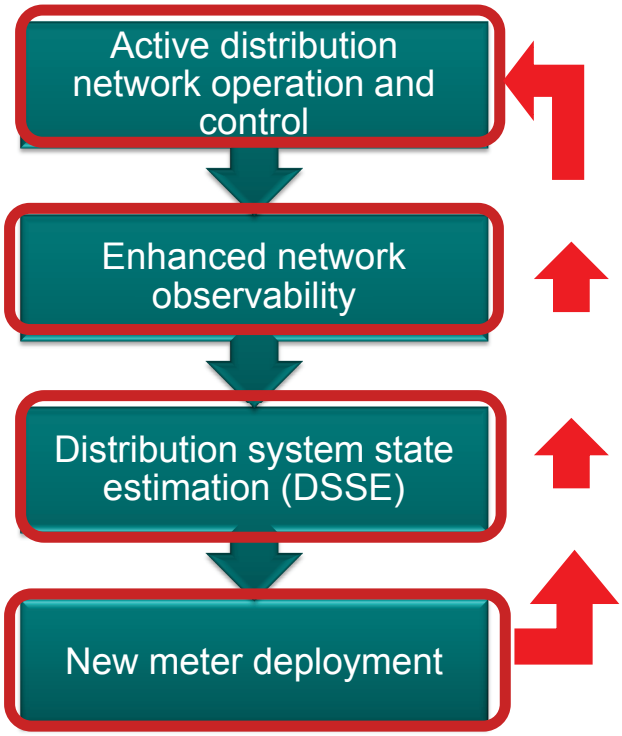
Background and Objective : Meter Placement and Distribution Management Systems

OBJECTIVE

Develop meter placement algorithm in the most economical way ensuring required accuracy from DSSE



DSSE based Meter Placement Algorithm

DSSE as Two Dimensional Error Reduction Problem

A. DSSE is modelled to reduce measurement residuals	B. DSSE is required to reduce true value residuals
$\text{Min} \sum_{i=1}^{M} \{\lvert z_i - h_i(x_{est})\rvert\}$	$\text{Min} \sum_{i=1}^{(2N-1)} \lvert x_{est_i} - \mu_i\rvert$
1. Select *potential meter positions* out of all candidate positions	**2.** Extensive Monte-Carlo based study for only *potential positions*

x_{est}	Voltage and phase angle estimation	h	Measurement equation
μ_i	Voltage and phase angle real value	N	No. of nodes
M	No. of measurements	z	Measurement vector

Reduce Measurement Residuals: Selection of Potential Meter Positions

- In Gauss-Newton state vector update equation, residual vector, [*z - h(x)*] is mapped by a multiplying factor S_f where,

Better converge

Small value of largest singular value

$$\Delta x = S_f [\, z - h(x) \,] \quad \text{s.t. } S_f = (H^T W H)^{-1} H^T W$$

Reduce measurement residual vector

- Small value of Δx may not be resulted from small [z - h(x)]
- S_f *maps* [*z - h(x)*]. The mapping effects (contraction or expansion) can be measured from maximum singular value of S_f

Short list the meter positions as the *potential positions* that give minimum values of their maximum singular values

Reduce True Value Residuals: Extensive Evaluation of Potential Meters Positions

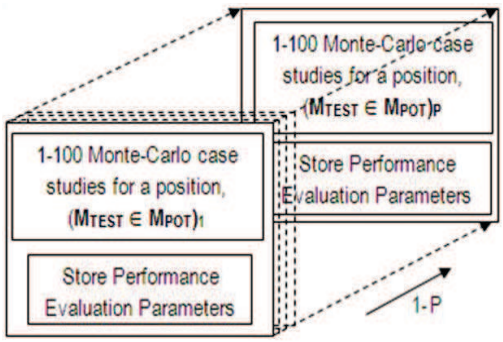
- Extensive Monte Carlo DSSE studies applying measurements with various error distribution
- Evaluate 'Performance Evaluation Parameters (PEPs)' to Calculate improvement after meter placement

1. $(V_{dev})^{mean\ of\ max}$ Mean of all maximum voltage estimation errors
2. $(V_{dev})^{max\ of\ max}$ Maximum of all maximum voltage estimation errors
3. $(V_{dev})^{mean}$ Mean of all voltage estimation errors

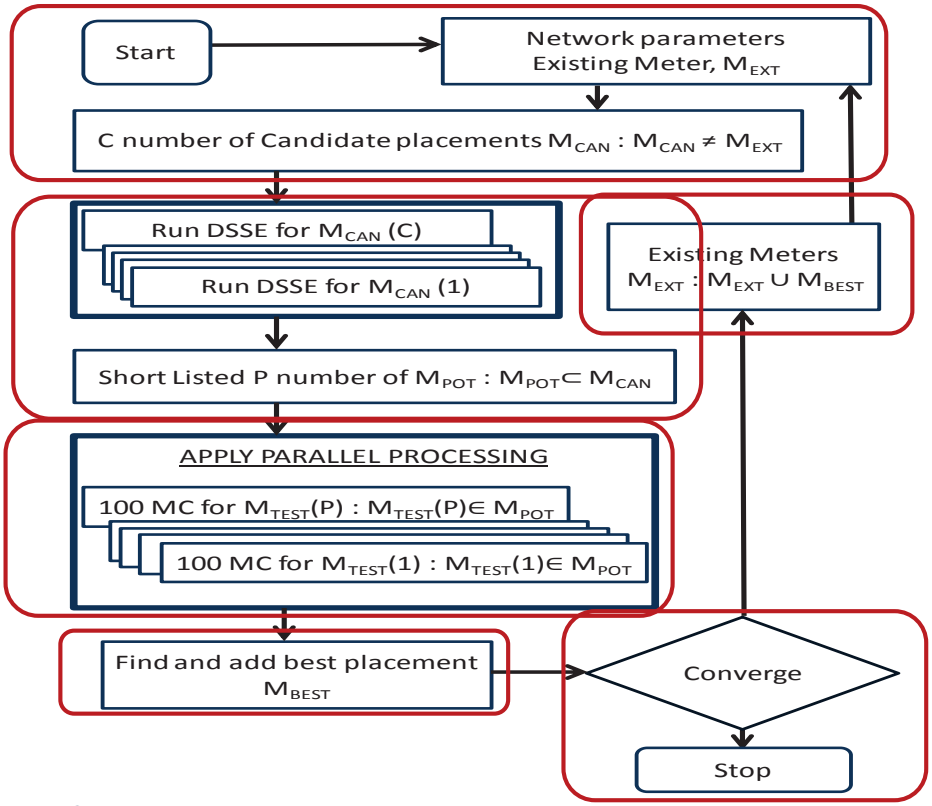
$$V_{dev} = 100 \times \frac{V_{est} - V_{re}}{V_{re}}$$

V_{est} = estimated value,
V_{re} = true value/load flow

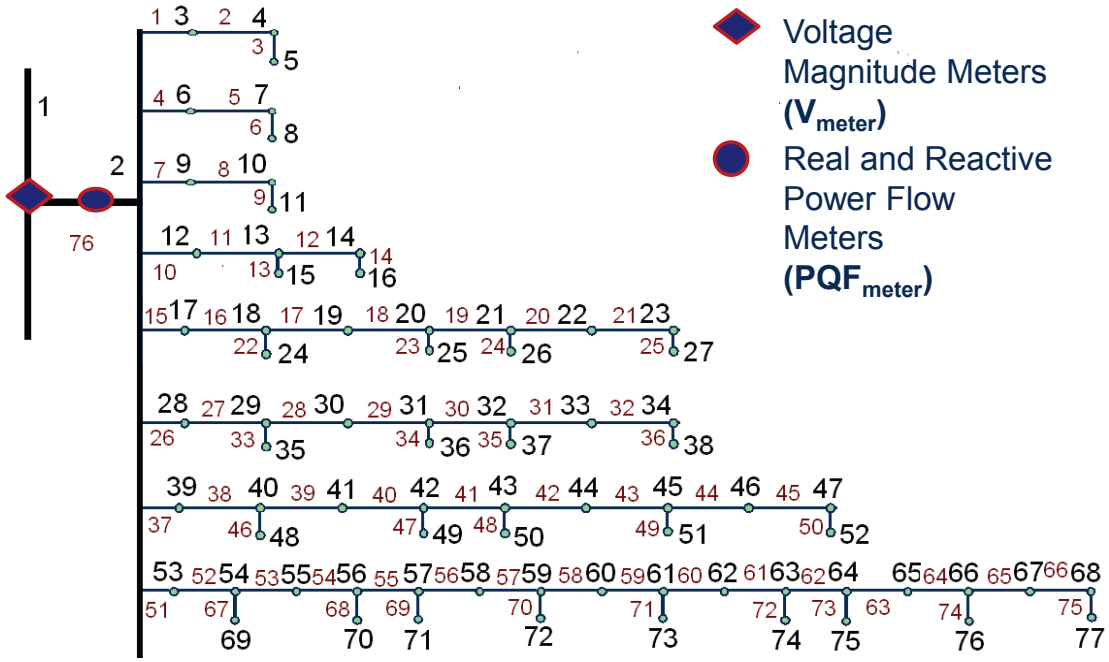
- Trace the position that reduces values of PEPs most after placing the meter



The Complete Flowchart: Proposed Meter Placement Algorithm



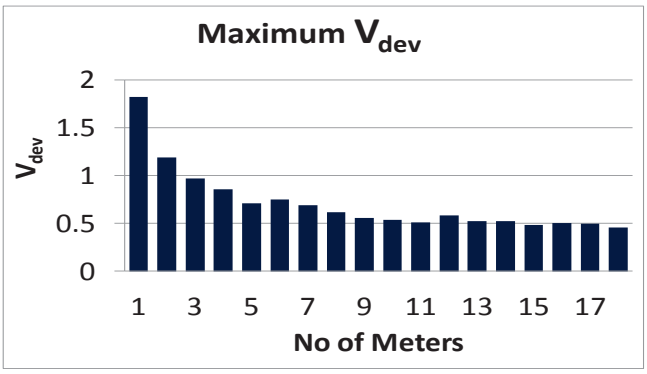
The Test Network: 77 Bus UKGDS
(Sensors with maximum of 1% error readings)

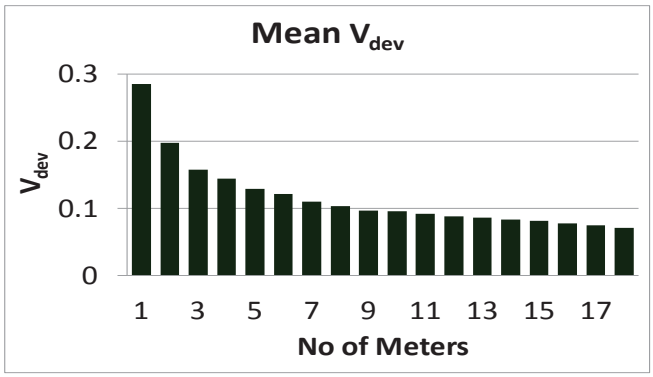


UKGDS 77 Bus Radial Network

1- 77 Nodes **1-76 Branches**

Improvement with Meter Placement





$$V_{dev} = 100 \times \frac{V_{est} - V_{re}}{V_{re}}$$

V_{est} = estimated value
V_{re} = true value/load flow

Insignificant improvement in voltage estimation error after placement of 7th meters

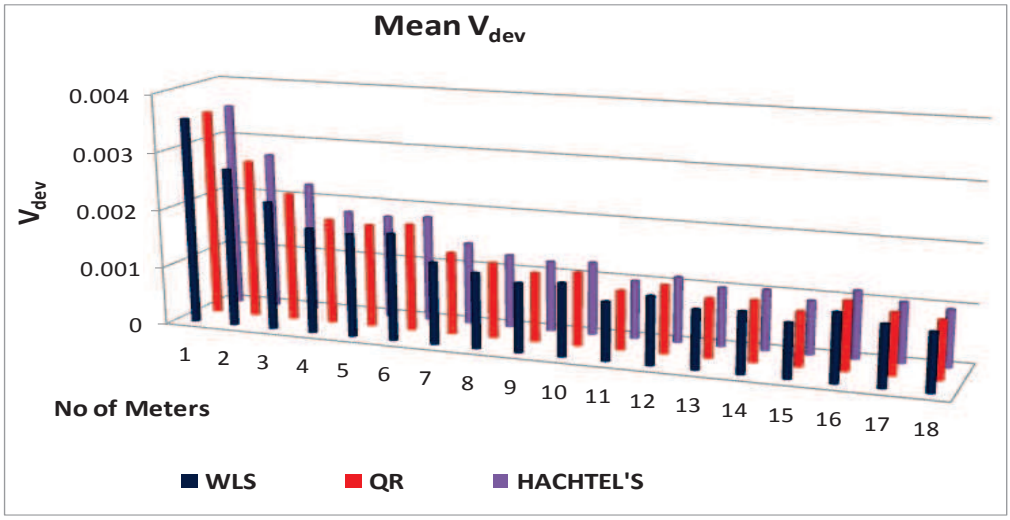
Performance Applying Different WLS Solution Process

WLS

QR (ORTHOGONAL)

HATCTEL'S AUGMENTED MATRIX

Multiplying factor, S_f does not exist in solution process



Conclusion and Future Work

- The meter placement algorithm shows strong evidence of consistent improvement of *voltage estimation error*
  - **Further research towards larger improvement in *phase angle estimation error***
- The proposed algorithm takes into consideration of active distribution network challenges, though the test network does not contain any active load or distributed generators
  - **Further tests with distributed generators on larger networks**
- The algorithm does not consider physical constraints, we assume that every node and branches having no meter as candidate position
  - **Consider physical constraints to position a meter**

THANK YOU

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