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Estimation of the Random Error Variance of Measurements on Time-Varying Values

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Contents

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- Weighted Least Square (WLS) State Estimation

$$\min \sum_{k=0}^{n} w_j \left(z_j - z_j(x)\right)^2$$

- Principle for selection of w_j

$$w_j = \frac{1}{\sigma_j^2}$$

- Meaning of w_j:
  – higher accuracy, greater w_j

01 Background

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- Setting of measurement weigh by type, e.g. (per unit value)
  - Weigh of P: 5.0
  - Weigh of Q: 2.0
  - Weigh of V: 10.0
  - ...
- Seems reasonable, actually arbitrary!
- Still applied in some online SE software!

01 Background

- Calculation of the weigh through available information on the accuracy
  – Measurement full scale (f)
  – Measurement accuracy class (p)
- Formulation

$$\sigma = \frac{fp}{3 * 100}$$

- Reference
  - DOI: 10.7500/AEPS20150615015

01 Background

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- Illustration of per unit weigh calculated from full scales and accuracy levels

kV	Measurement Weigh (per unit)		
	P	Q	V
110	7695	1924	6944
500	85	21	6944

01 Background

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- Real situation
  - For P&Q measurements: great difference at different voltage levels
  - No direct correlations between the P/Q & V measurement weigh
- Weigh setting by measurement type is far from reality

01 Challenge

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- To get more reliable accuracy information on each measurement: error variance

$$s^2 = \frac{1}{n-1}\sum_{i=0}^{n}(z_i - \bar{z})^2$$

- $z_i s$ are should be taken from a constant value.
- In power system, the variance can be calculated only through offline way.
- **Can the variance be estimated online and from time-variant values ?!**

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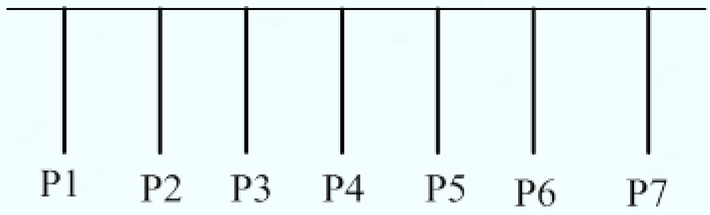
- To construct constant value
- Typical case: zero injections in to a logical bus

$$c = \sum_{i=0}^{7} P_i \equiv 0$$



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- Relation between variance of c and variance of P_i

$$S_c^2 = \sum_{k=1}^{7} {S_{P}}_i^2$$

- Useful deduction
  - ${S_{P}}_i^2 < S_c^2$
  - ${S_{P}}_i^2 = S_c^2/7$, with the assumption that all ${S_{P}}_i^2$ are equal

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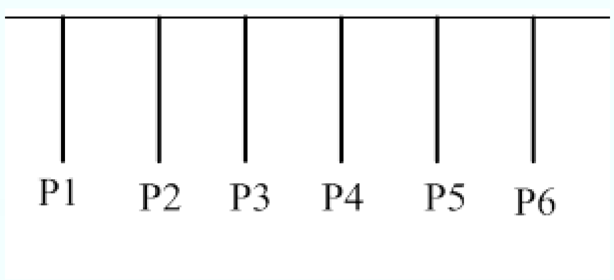
- Furthermore, if p7 is switched off from the bus at some time

$$c' = \sum_{i=0}^{6} P_i \equiv 0$$



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- Update of the variance relation

$$S_{c\prime}^{2} = \sum_{k=1}^{6} S_{P_i}^{\;2}$$

- **New and very valuable deduction**

$$S_{P_7}^{2} = S_{c}^{2} - S_{c\prime}^{2}$$

- By this way, all $S_{P_i}^{\;2}$ can be estimated

03 Generalized Formulation

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- If we can construct a linear transformation from n time-variable v_i to m time-invariant values C_j

$$C = Av$$

- and S_C^2 and S_v^2 are the variance of C and v, it follows

$$S_c^2 = BS_v^2, \qquad B_{ij} = A_{ij}^2 \geq 0$$

03 Generalized Formulation

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- If $rank(B) = m = n$
  - $S_v^2 = B^{-1} S_C^2$
  - As C is time-invariant, S_C^2 can be estimated though multiple measurements.
  - **S_v^2 then can be estimated indirectly.**
- If $m > rank(B) = n$
  - Least Squared S_v^2 can be estimated,

$$S_v^2 = (B^T B)^{-1} B^T S_C^2$$

- If $rank(B) < n$
  - S_v^2 can be estimated with some other assumption, e.g. minimum difference among the element of S_v^2.

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03 More Applications

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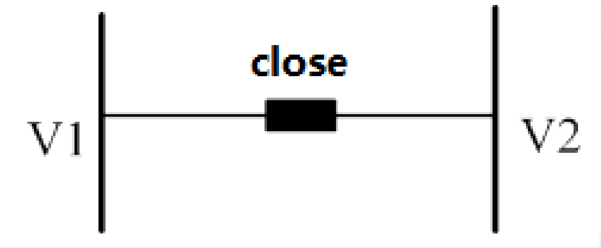
- Fore zero power injection, **system error** of the each element measurement can be estimated through similar way.
- Certain linear combinations can be constructed for bus bars that are connected together, so that the measurement error variance can be estimated for **voltage magnitude and phase**.



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- Well verified by site data.
- More data will be collected to evaluate both the method and measurement quality.
- Estimation of measurement error variance is separated from the main SE problem.
- The results of variance estimation will provide more solid base for online SE.

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Thanks

Q&A

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