Identification of Parameter Errors

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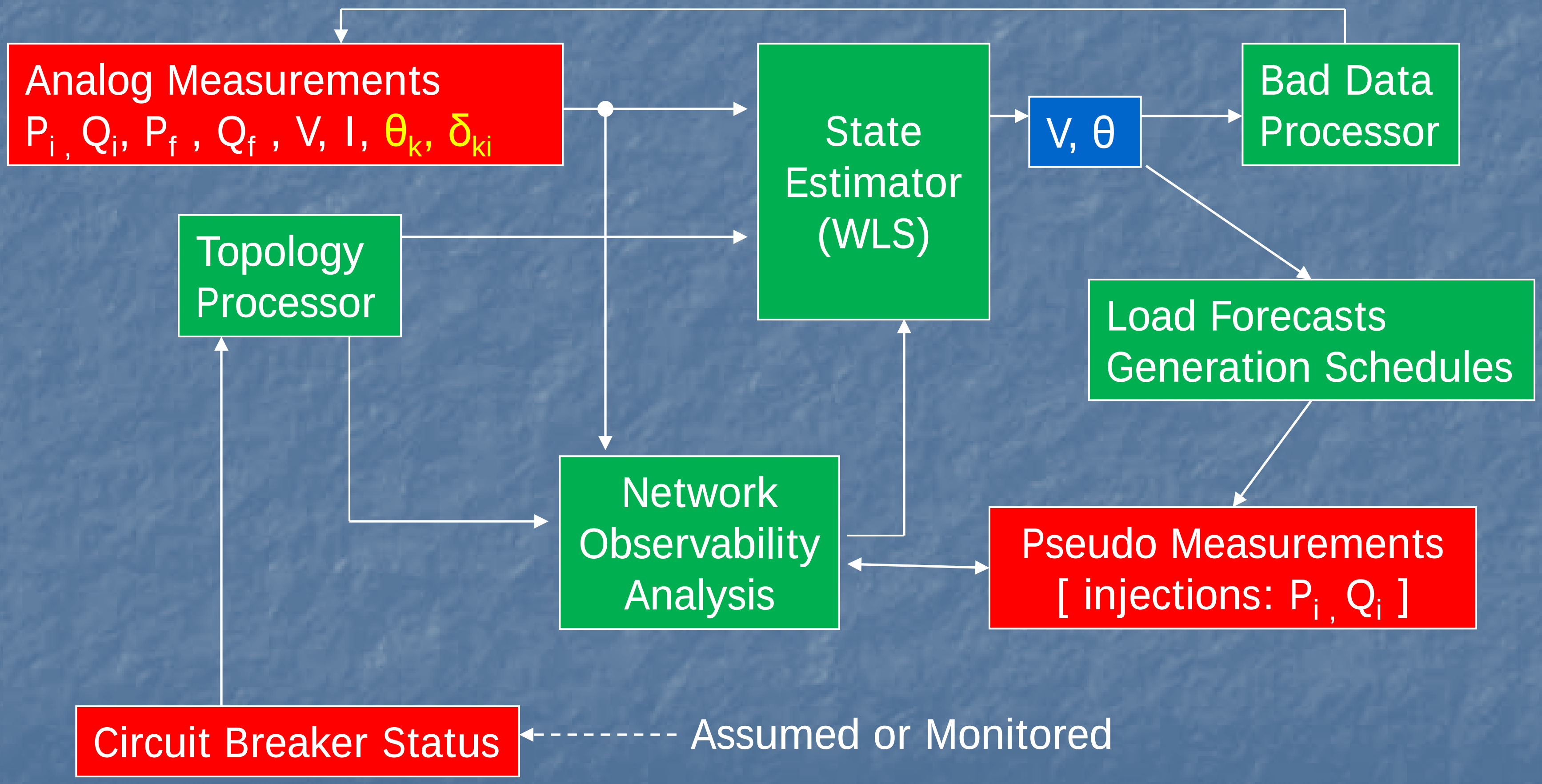
IEEE PES General Meeting, Panel on Parameter Errors
Minneapolis, MN
July 29, 2010

Outline

- Parameter Error Identification Problem
- Methods of Parameter Error Identification based on Suspect Parameter Estimation
- Discussion of Lagrange Multiplier based Method
- Illustrative Examples
- Conclusions

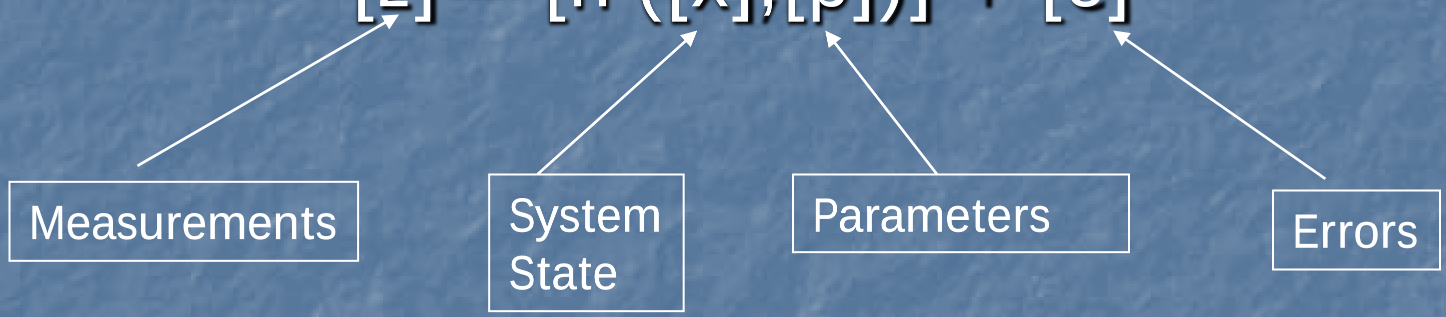
State Estimation



Measurement Model

Given a set of measurements, [z] network topology and parameters:

$$[z] = [h\ ([x],[p])] + [e]$$



Methods to Identify Parameter Errors

<u>Selecting a suspect set of parameters</u>

- Static parameters
  - Based on single scan
  - Based on multiple scans
- Time-varying parameters
  - Kalman Filter based parameter estimation

<u>Direct identification of erroneous parameters</u>

  - Use of normalized Lagrange multipliers

Suspect subset of parameters=[p]

Based on a single scan:

$$y = \left[x_1, x_2, \ldots, x_n \mid p\right]$$

AUGMENTED STATE VECTOR

$$[z] = [h(y)] + [e]$$

- Select a subset of parameters [p] which are suspected to be erroneous.
- Augment the state vector with [p]
- Estimate the new unknown [y]

Suspect subset of parameters=[p]

Based on multiple scans:

$$[z^1] = [h(x_1^1, x_2^1, \ldots, x_n^1, p)] + [e^1]$$

$$[z^2] = [h(x_1^2, x_2^2, \ldots, x_n^2, p)] + [e^2]$$

$$\vdots$$

$$[z^k] = [h(x_1^k, x_2^k, \ldots, x_n^k, p)] + [e^k]$$

$$[Z] = [h([Y],[p])] + [E]$$

Time-varying parameters

$$x_{k+1} = x_k + w_k$$
$$p_{k+1} = p_k + v_k$$
$$z_k = h(x_k, p_k) + e_k$$

- Use Kalman filter to update the covariance matrices.

Method Based on Normalized Lagrange Multipliers

- No need to pre-select a suspect set of parameters
- Errors in analog measurements and parameters can be distinguished

Problem Formulation

Every network parameter is assumed to have an error:

$$p = p_t + p_e$$

Parameter Used
By the State Estimator

Parameter Error

True Value of Parameter

Problem Formulation

State Estimation with Equality Constraints:

$$\min J(x, p_e) = \tfrac{1}{2}[z - h(x, p_e)]^T W [z - h(x, p_e)]$$

$$s.t. \quad p_e = 0$$

$$c(x, p_e) = 0$$

Lagrangian:

$$L = \frac{1}{2} r^t W r - \mu^t c(x, p_e) - \lambda^t p_e$$

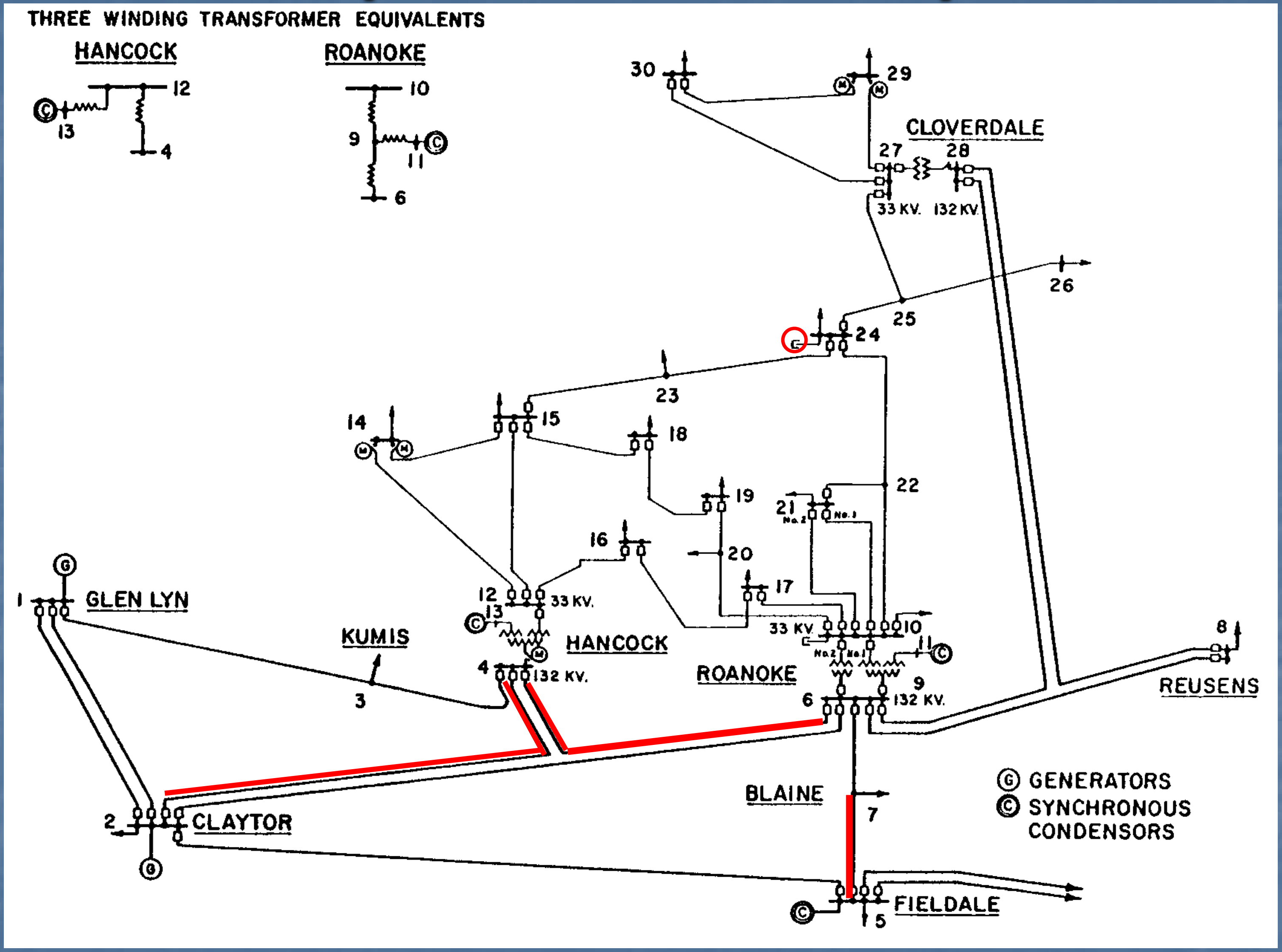
Error Identification Algorithm

Step 1. WLS State Estimation assuming all parameter errors are zero.

Step 2. Test for Bad Data or Parameter Errors

Step 3. Correct the Parameter or Measurement Error

Example: 30-bus system



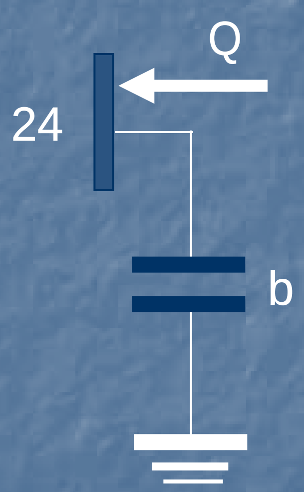
Test I: reactance of line 5-7 is incorrect.

Test II: real power flow on line 5-7 is incorrect.

Test I		Test II	
Measurement/ Parameter	***Normalized residual /*** λ^N	***Measurement/ Parameter***	***Normalized residual /*** λ^N
x_{5-7}	25.47	p_{5-7}	19.5
x_{7-6}	22.01	r_{5-7}	12.34
x_{2-5}	21.92	p_5	10.56
r_{7-6}	15.78	q_6	9.97
r_{2-5}	15.42	x_{7-6}	9.86

Unidentifiable errors

Example : Susceptance of shunt cap at bus 24 is incorrect.



Measurement/ Parameter	***Normalized residual /*** λ^N
b_{24}	12.72
q_{24}	12.72
q_{22-24}	5.78
q_{22}	5.23
q_{23-24}	4.65

Equal

Simultaneous errors

Errors: reactance of line 2-4
transformer tap of TR 4-9
power flow measurement on line 4-2

Error identification cycle					
1st		2nd		3rd	
z/ p	r^N / λ^N	**z/ p**	r^N / λ^N	**z/ p**	r^N / λ^N
x_{2-4}	60.56	t_{4-9}	23.87	p_{4-2}	5.07
p_{4-2}	46.48	p_{9-4}	17.99	p_3	3.75
x_{4-5}	40.49	t_{4-7}	10	p_4	3.02
x_{2-5}	30.24	r_{7-9}	9.78	r_{2-4}	2.86
t_{4-9}	25	p_4	9.68	p_{4-5}	2.25
Identified and Eliminated error					
x_{2-4}		t_{4-9}		p_{4-2}	

Correction of errors

SEQUENTIAL CORRECTION

Step	Bad Parameter	Estimated Parameter	TRUE Parameter
1st	x_{2-4}	0.174	0.17632
2nd	t_{4-9}	0.96015	0.96

SIMULTANEOUS CORRECTION

Bad Parameter	Estimated Parameter	TRUE Parameter
x_{2-4}	0.17633	0.17632
t_{4-9}	0.96	0.96

Conclusions

- Given enough measurement redundancy, suspect parameters can be estimated simultaneously with the states.
- Methods exist to identify parameter errors without the need to specify a suspect set.
- Parameter error processing can be an off-line function that is run at desired intervals.