A Maximum A-Posteriori Based Algorithm for Dynamic Load Model Parameter Estimation

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Measurement based parameter estimation

\[ \text{argmin}_p \| v_{\text{meas}} - v_p \|_2^2 \]

Load model

Simulation

PowerWorld

Simulation process

Test case

\[ p = [\%LM \%SM \%DL] \]

Source: PSS/E 33.5 Model Library
Impact of measurement noise

$\|v_{meas} - v_p\|_2^2$ is insensitive to parameters  

Parameter estimate is very sensitive to noise

George E. P. Box: “Essentially, all models are wrong, but some are useful”
Prediction accuracy

(a) Best case
(b) Average case
(c) Worst case
Solution 1: Use multiple disturbances

\[
\text{argmin}_p \left\{ ||v_{meas,\text{fault 1}} - v_{p,\text{fault 1}}||^2_2 + ||v_{meas,\text{fault 2}} - v_{p,\text{fault 2}}||^2_2 \right\}
\]
Solution 1: Results

[Graph showing total error vs SNR (dB) with different lines representing 1 Disturbance, 2 Disturbances, and 3 Disturbances. The graph also shows median and max values for each line.]
Solution 2: Maximum a-posteriori (MAP) estimator

\[
\text{argmax}_p \Pr\{p|\nu_{meas}\} = \text{argmax}_p \frac{\Pr\{\nu_{meas}|p\} \cdot \Pr\{p\}}{\Pr\{\nu_{meas}\}}
\]

\[
\prod_{t=1}^{T} f_V(\nu_{meas}[t] - \nu_p[t])
\]

\[
\prod_{n=1}^{N} f_P(p(n) - \mu_{p(n)})
\]
Solution 2: Implementation issue

\[
\begin{align*}
\text{One problem:} \\
&\bullet f_V(1\sigma) = 0.17 \\
&\bullet 30 \text{ seconds } @ \text{ 30 samples/s} \\
&\quad \Rightarrow T = 900 \\
&\bullet 0.17 \cdot 900 \approx 1.693 \\
&\bullet \text{Smallest double precision number } \approx 10^{-308}
\end{align*}
\]
Solution 2: Results

Prior $f_P$ dominates

Data $f_V$ dominates

$\mu P = p_{\text{real}}$

$\mu P = [0.2 \cdots 0.2]$
Summary

Problem: Lack of injectivity leads to bad objective function...

...which leads to poor predictions

Solution: MAP estimator

Implementational issues

$0.17^{900} \sim 10^{-693}$