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Diesel Generator Model Development and Validation using Moving Horizon Estimation

Manisha Rauniyar[1], Phylicia Cicilio[2], Niranjan Bhujel[1],

Timothy M. Hansen[1], Robert Fourney[1], Hossein Moradi Rekabdarkolaee[1] ,

Ujjwol Tamrakar[3], Mariko Shirazi[2], and Reinaldo Tonkoski[1]

[1]South Dakota State University
[2]University of Alaska Fairbanks [3]Sandia National Laboratories

Presenter: Manisha Rauniyar

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Diesel-backed Microgrids

- renewables integrated into diesel genset backed microgrids
  - reduce overall fuel consumption
- diesel-backed inverter-based generation
  - faster, stochastic and non-linear dynamics
    - variability microgrid parameters
    - uncertainties in state variables
- optimal control of inverter resources is needed
  - require accurate modeling and online estimation techniques for genset

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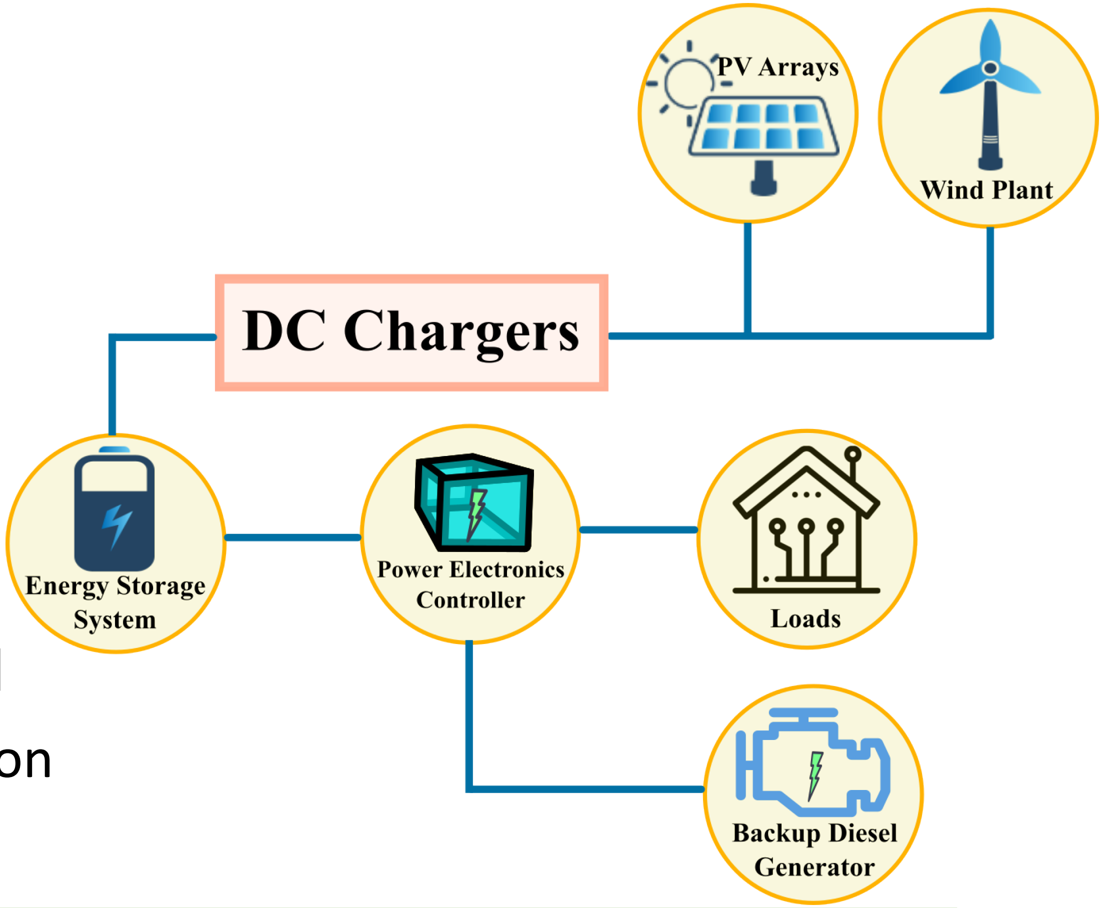

<u>Objective</u> : to model and validate a frequency dynamics model of the diesel genset using moving horizon estimation technique

Moving Horizon Estimation

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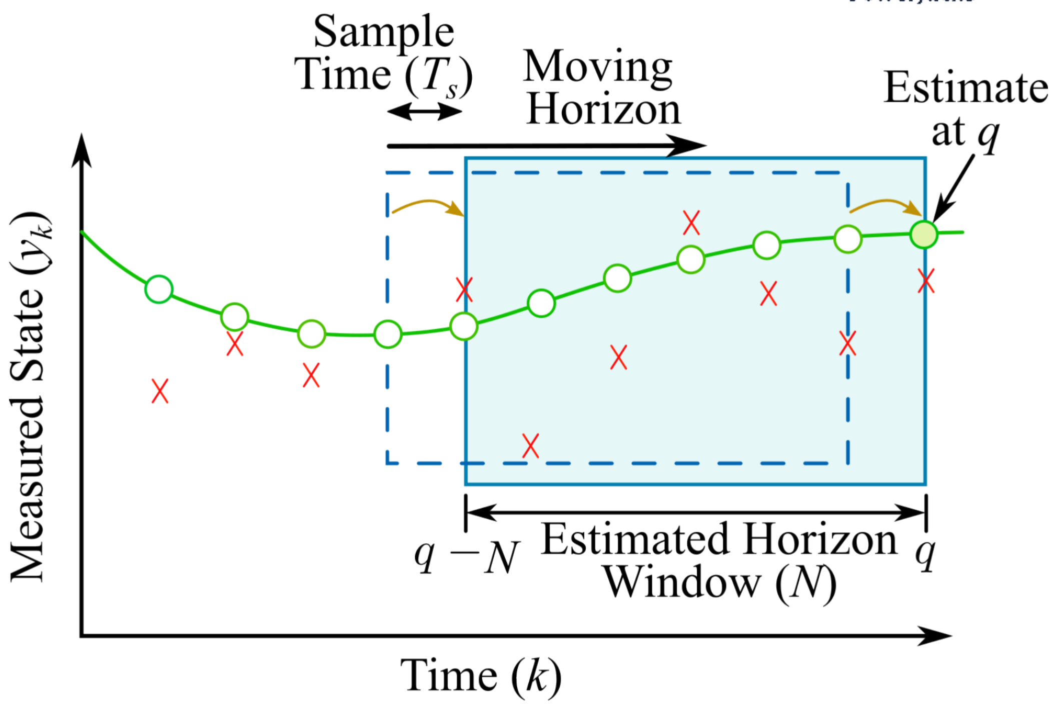
- finite horizon optimization-based estimation process
- infer state variables and parameters of system from its measurements
  - provides estimations for non-linear systems the presence of both Gaussian and non-Gaussian noise

    where,

    N= horizon length

    T_s= sampling time of MHE

    y_k= measured states at discrete time instant k



Inputs : measurements of system

Outputs : state and parameters estimates

× represent measurements and O represent the estimated values

Frequency Dynamics of Diesel Model

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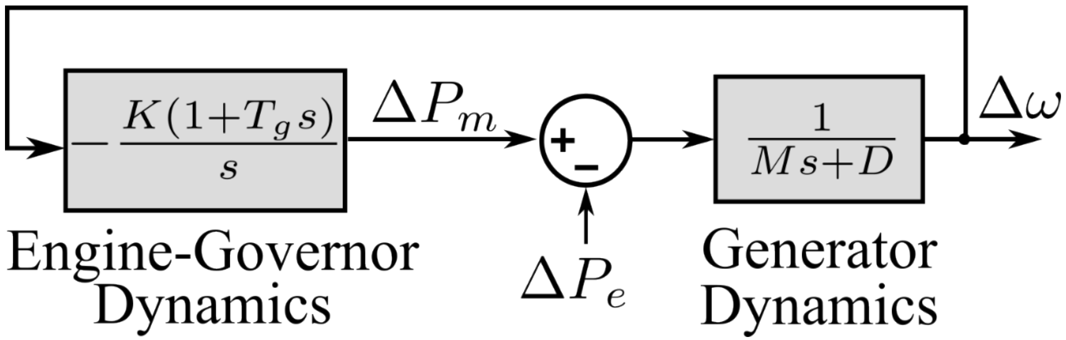
- system frequency dynamics:

$$\frac{\mathrm{d}}{dt}\begin{bmatrix} z \\ \omega \end{bmatrix} = \begin{bmatrix} 0 & -K \\ \frac{1}{M} & -\frac{D}{M}-\frac{KT_g}{M} \end{bmatrix}\begin{bmatrix} z \\ \omega \end{bmatrix} + \begin{bmatrix} 0 \\ -\frac{1}{M} \end{bmatrix} P_e$$



- exciter and flux dynamics are very fast, neglected
- simplified governor represented by single time-constant (T_g)
- M and D are parameters of generator dynamics
- model is used for **predictive model in MHE**

a_{12}, a_{21}, a_{22} = parameters
P_e = electrical power
ω = frequency
P_m = mechanical power

$a_{12} = K, a_{21} = \frac{1}{M}, a_{22} = \frac{D}{M} + \frac{KT_g}{M}$
D = damping constant
M = inertia constant
z = state variable
K = governor gain
T_g = time constant

Simulation Setup of Diesel Genset

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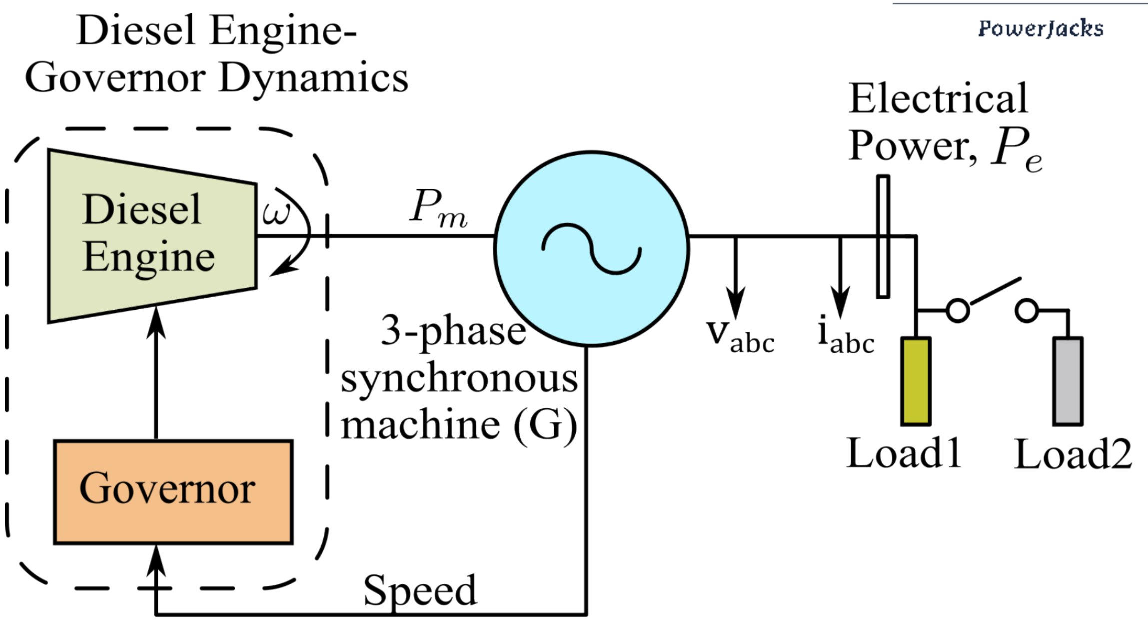
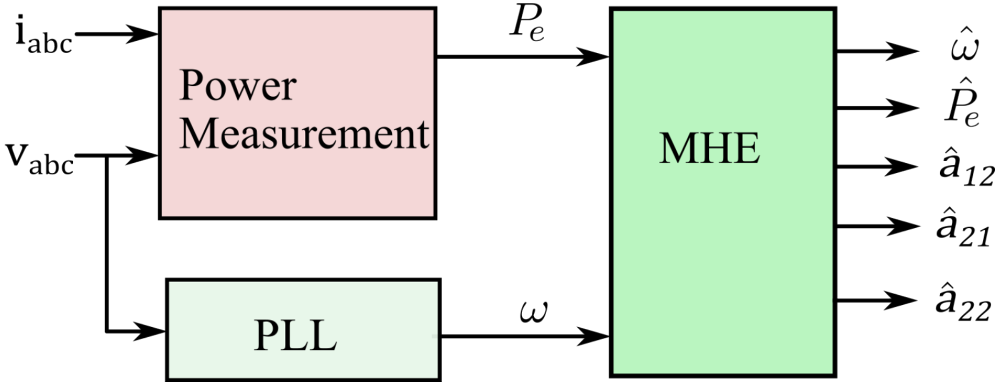
- actual simulations carried in **detailed gensets**
  - diesel genset : $406\ kVA, 460\ V$
  - base resistive load of 25% : $100kW$
  - perturbation power of 40% of total gen capacity :165kW

- non-Gaussian noise of covariance 10^{-7} added to frequency

- model and estimate diesel gensets parameters with validating steps

- sample time of 0.003 s and horizon length of 700 chosen for MHE





Parameter Estimation Results and Analysis

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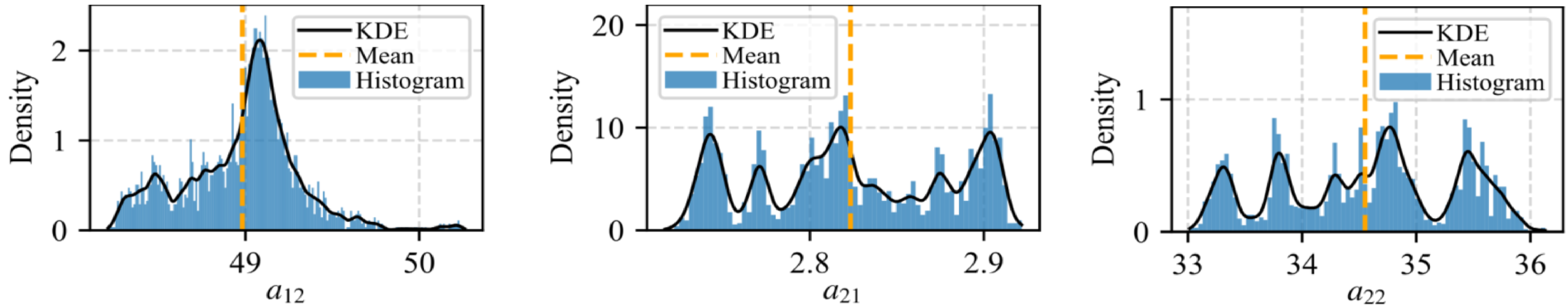

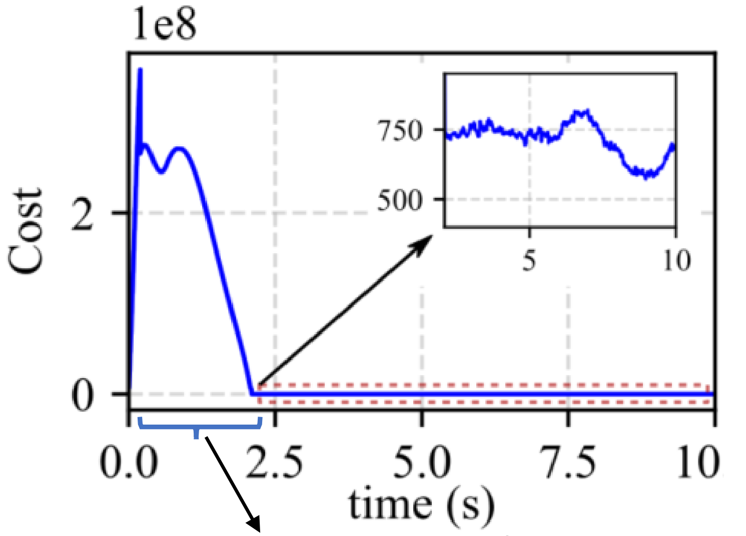

convergence time of MHE = 2.1 s

- mean of a_{12} = 48.67, CoV = 0.678%
- mean of a_{21} = 2.84, CoV = 1.997%
- mean of a_{22} = 34.63, CoV = 2.24%
- cost function is not exactly zero after convergence
  - because of the noise in the measurements

Estimates Validation and Model Accuracy

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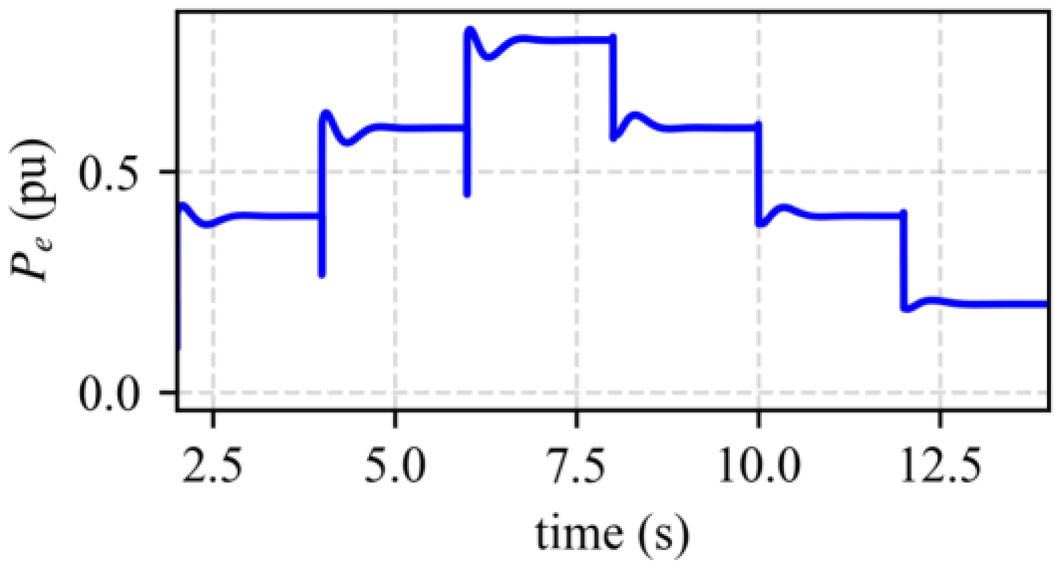

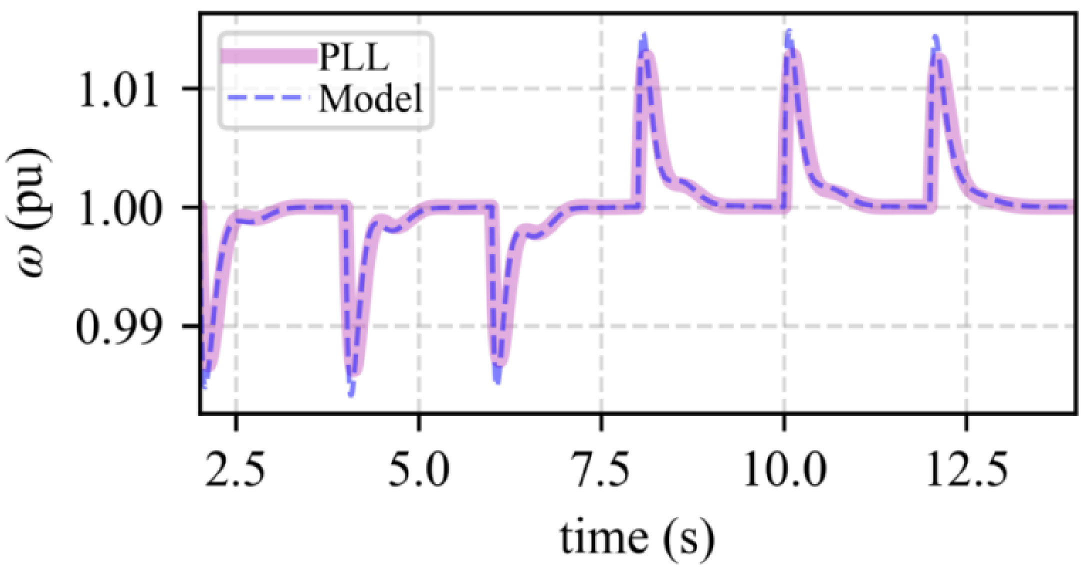

- validation achieved using estimated parameters in model
  - different loading conditions
  - using the electrical power (P_e) from detailed genset as input
- base load : 80 kW, 20% load change at every 2s
- $\text{NRMSE} = 3.17\%$

Conclusions

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- MHE provides online estimates of states and parameters of a diesel genset
  - under typical PLL measurement noise and distributions
- developed and validated frequency dynamics model of gensets
  - can be used in design and estimation of renewable integrated diesel generator system

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