(a) Two-State Microgrid Model

Variables:

x_1: Storage state-of-charge

x_2: Frequency/power deviation

$$\frac{dx_1}{dt} = \eta_{in} \cdot u \cdot \mathbb{1}_{\{u>0\}} - \frac{1}{\eta_{out}} \cdot u \cdot \mathbb{1}_{\{u<0\}} - d(t)$$

Storage Dynamics (Conservation Law)

$$\frac{dx_2}{dt} = -\alpha x_2 + \beta \cdot P_{gen} - \beta \cdot P_{load} + \gamma x_1$$

Frequency Dynamics (Droop Control)

u: Control input

P_{gen}, P_{load}: Generation/load power

(b) UDE Modification

$\beta \cdot P_{gen}$ (Original)

$f_\theta(P_{gen})$ **(Neural Residual)**

$$f_\theta(P) = \sum_{i=1}^{3} w_i \tanh(W_{i1} P + b_i)$$

Single hidden layer, 3 units, 9 parameters