Coordination of Damping Controllers: A Data-Informed Approach for Adaptability

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MOTIVATION

- The increased penetration of new technologies has heightened the variability of the grid, impacting the efficiency of damping controller (DC) devices. New adaptable approaches are necessary.
- Current adaptable WADCs face some challenges, such as dependency on up-to-date models for model-based approaches and security constraints for real-time fine-tuning in the case of data-driven approaches.
- How can inverter-based resources (IBR) be optimally used as DC only when necessary?

COORDINATION OF DAMPING CONTROLLERS

The coordination **seeks the on/off switching combination of all DCs that best improves grid damping** for the current operating condition and disturbance. This is achieved by identifying the coordination that **minimizes the total action**, a metric based on the kinetic energy released by synchronous generators.

Optimal controller coordination

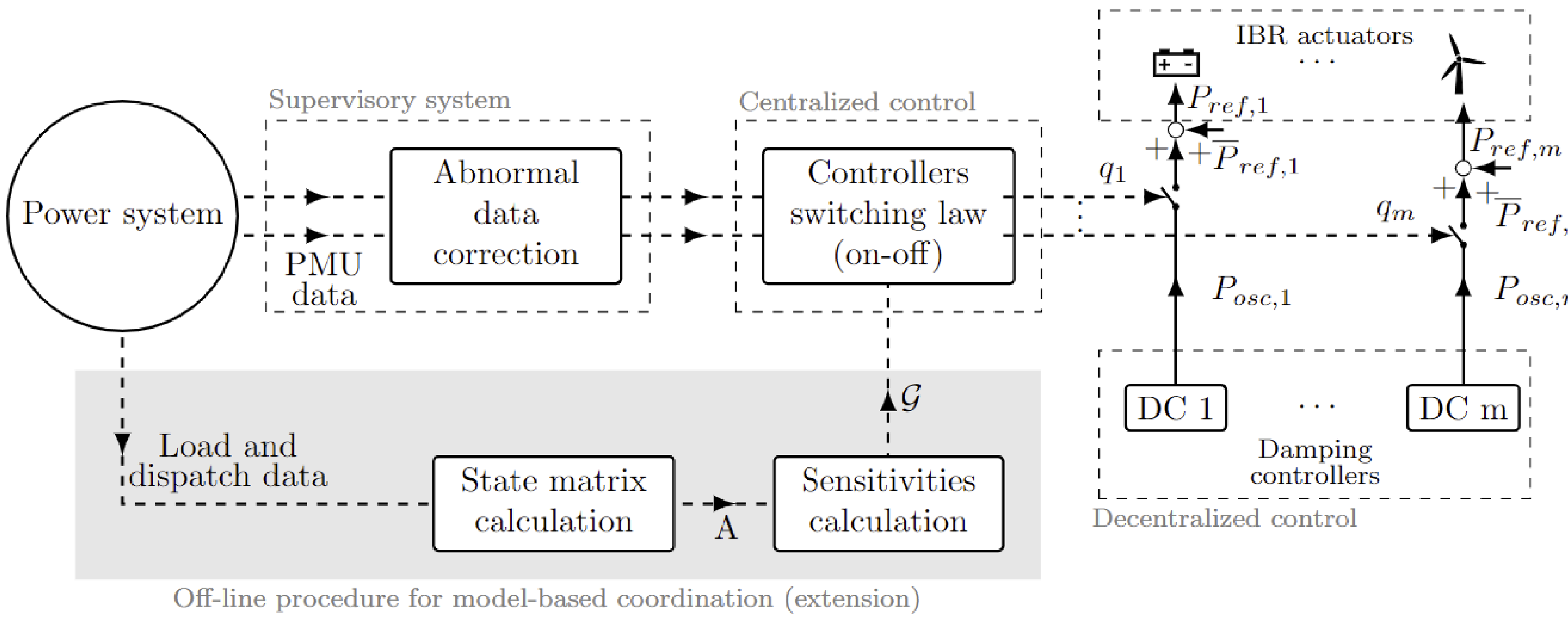
$$\gamma^* = \underset{\gamma_k \forall k \in \{1,\dots,n_c\}}{\arg\min} \hat{S}_\infty(y_0, \gamma_k)$$

Total Action

$$S_\infty = \lim_{\tau\to\infty} S(\tau) = \lim_{\tau\to\infty} \int_{t_0}^{t_0+\tau} E(t)\, dt$$

Oscillation Energy

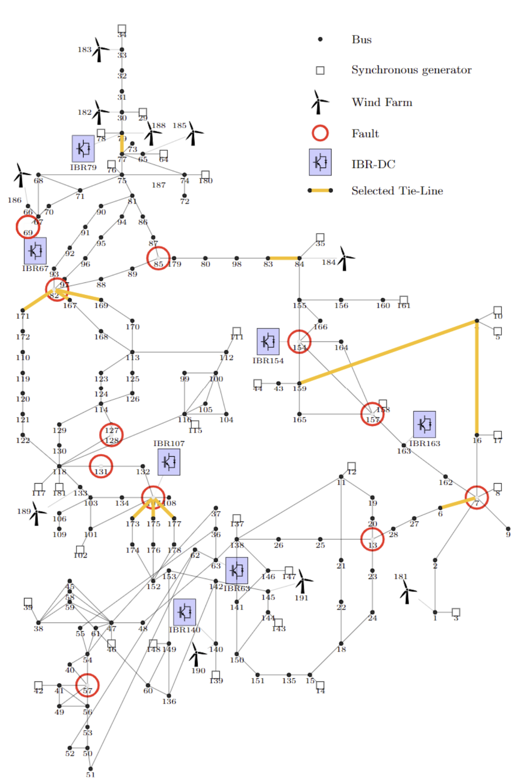
$$E(t) = \sum_{j=1}^{p} H_j \omega_s \Delta\omega_j^2(t)$$



Damping controllers' coordination framework

DATA-INFORMED COORDINATION

To achieve coordination, a deep neural network is trained as a total action function approximation algorithm. This network learns the nonlinear relationship between inputs, DC combinations, and total action.



WECC Test System

Data collection and training process

Algorithm 1 Data collection

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Define μ_i ∀ i ∈ {1, ..., n_o}          ▷ Vector of op. conditions
Define υ_j ∀ j ∈ {1, ..., n_d}          ▷ Vector of disturbances
Define γ_k ∀ k ∈ {1, ..., 2^{n_c}}      ▷ Switching combination
for each μ_i do
    Run power flow
    y_{01,i} = [p_{tl}]
    for each υ_j do
        for each γ_k do
            Run time-domain simulation
            if t = t_cl then
                y_{02,j} = [Δω_sg]
            if t = t_a then
                Activate coordination γ_k
            if t = t_e then
                Calculate total action S_{∞,i,j,k}
                Store in Φ the subset φ_s =
                {S_{∞,i,j,k}, y_{01,i}, y_{02,j}, γ_k}
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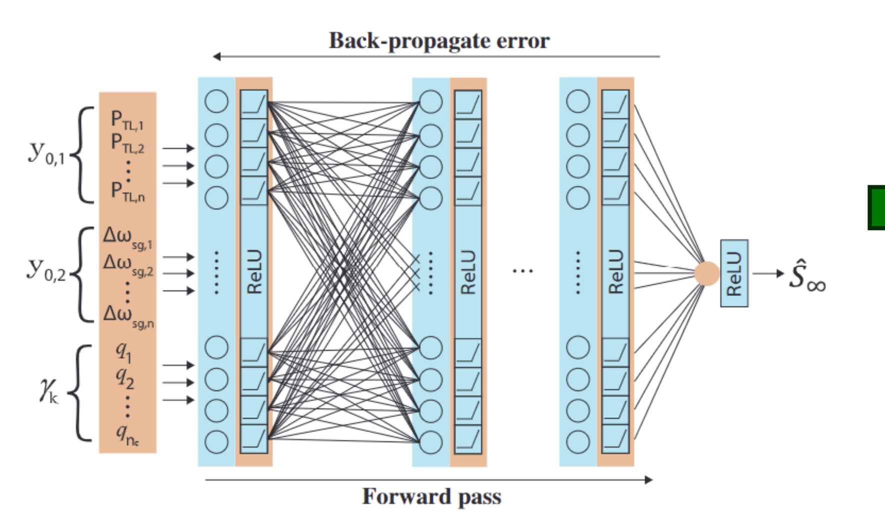
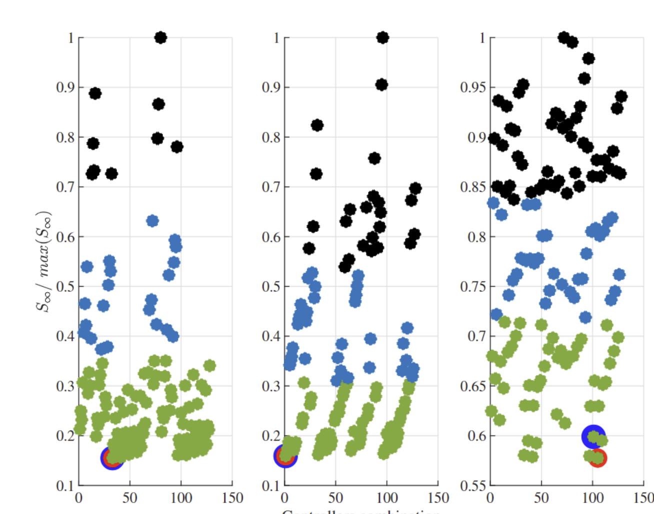
python™ TensorFlow



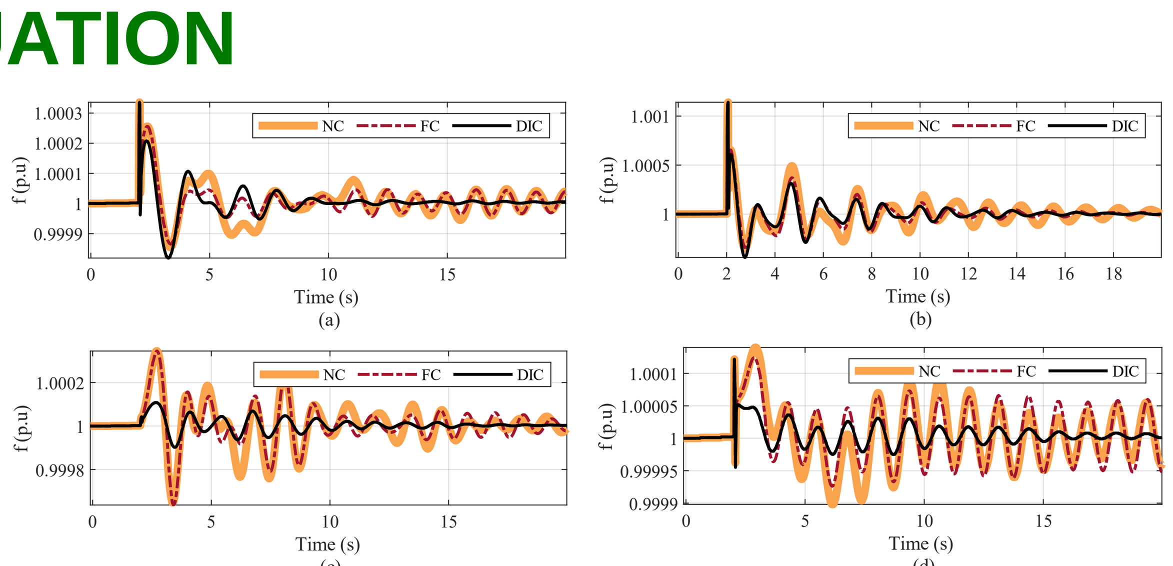
Total Action Function Approximator

$$\gamma^* = \underset{\gamma_k \forall k \in \{1,\dots,n_c\}}{\arg\min} \hat{S}_\infty(y_0, \gamma_k)$$

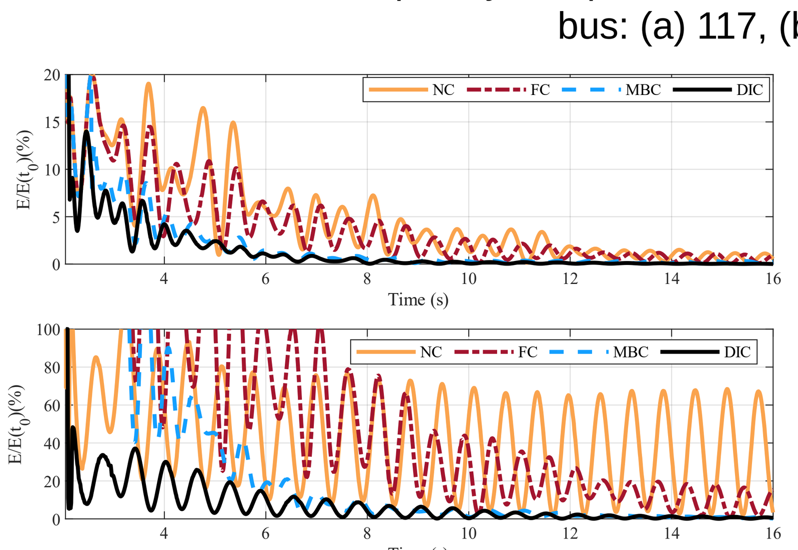


Controllers' combination search space for three different cases

EVALUATION



Frequency comparison for different control scenarios. Frequency at bus: (a) 117, (b) 14, (c) 161, and (d) 69.



Comparison between MBC and DIC for short-circuit at bus: (a) 157, and (b) 69.

TABLE II: TA reduction per control scheme

	Short-circuit at bus 157		Short-circuit at bus 69	
Coordination	Total Action	Reduction (%)	Total Action	Reduction (%)
No DC	1.241	-	0.840	-
FC	0.998	19.60	0.998	-18.79
DIC	**0.328**	**73.53**	**0.295**	**64.87**
MBC	0.500	59.72	0.473	43.65

REMARKS

- The results show that adaptability can be achieved by using a DNN as a switching law to find the combination that minimizes TA.
- It is not necessary to consider all possible disturbances and operating conditions; a carefully selected subset has been proven to be sufficient for generalization.
- The computational time of the coordination is 78 ms per 1,000 tests.
- Coordination allows for the efficient use of IBR as DC.

REFERENCES

- Zelaya-Arrazabal, F., Pulgar-Painemal, H., Liu, J., Li, F., & Silva-Saravia, H. (2023). Coordination of Damping Controllers: A Data-Informed Approach for Adaptability. arXiv preprint arXiv:2312.07739.
- Zelaya-Arrazabal, F., Liu, J., Zhao, J., Pulgar-Painemal, H., Li, F., & Silva-Saravia, H. (2022, October). Data-driven adaptive dynamic coordination of damping controllers. In 2022 North American Power Symposium (NAPS) (pp. 1-6). IEEE.

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