Decentralized and Coordinated V-f Control for Islanded Microgrids Considering DER Inadequacy and Demand Control

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Introduction

This poster presents a **decentralized** and **coordinated** control framework to regulate the output of inverter-based generations and reallocate limited DER capacity for V-f regulation.

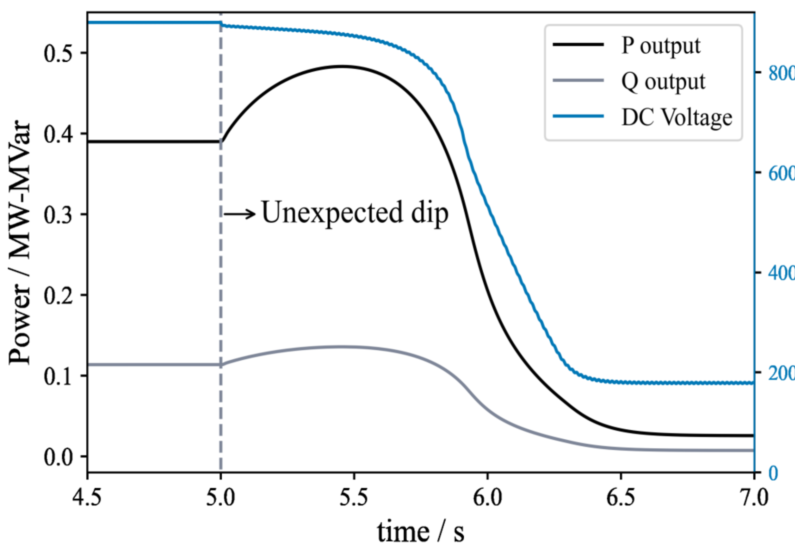

Fig. 1 DC voltage dip due to DER inadequacy

Motivate

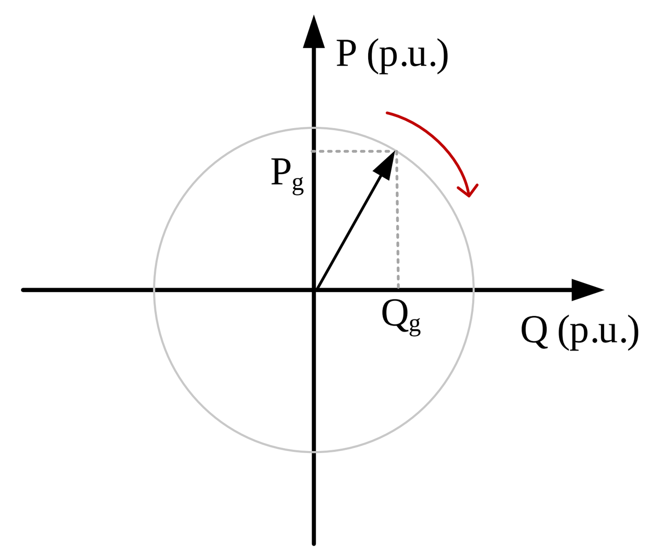

Fig. 2 constrained operation of inverters

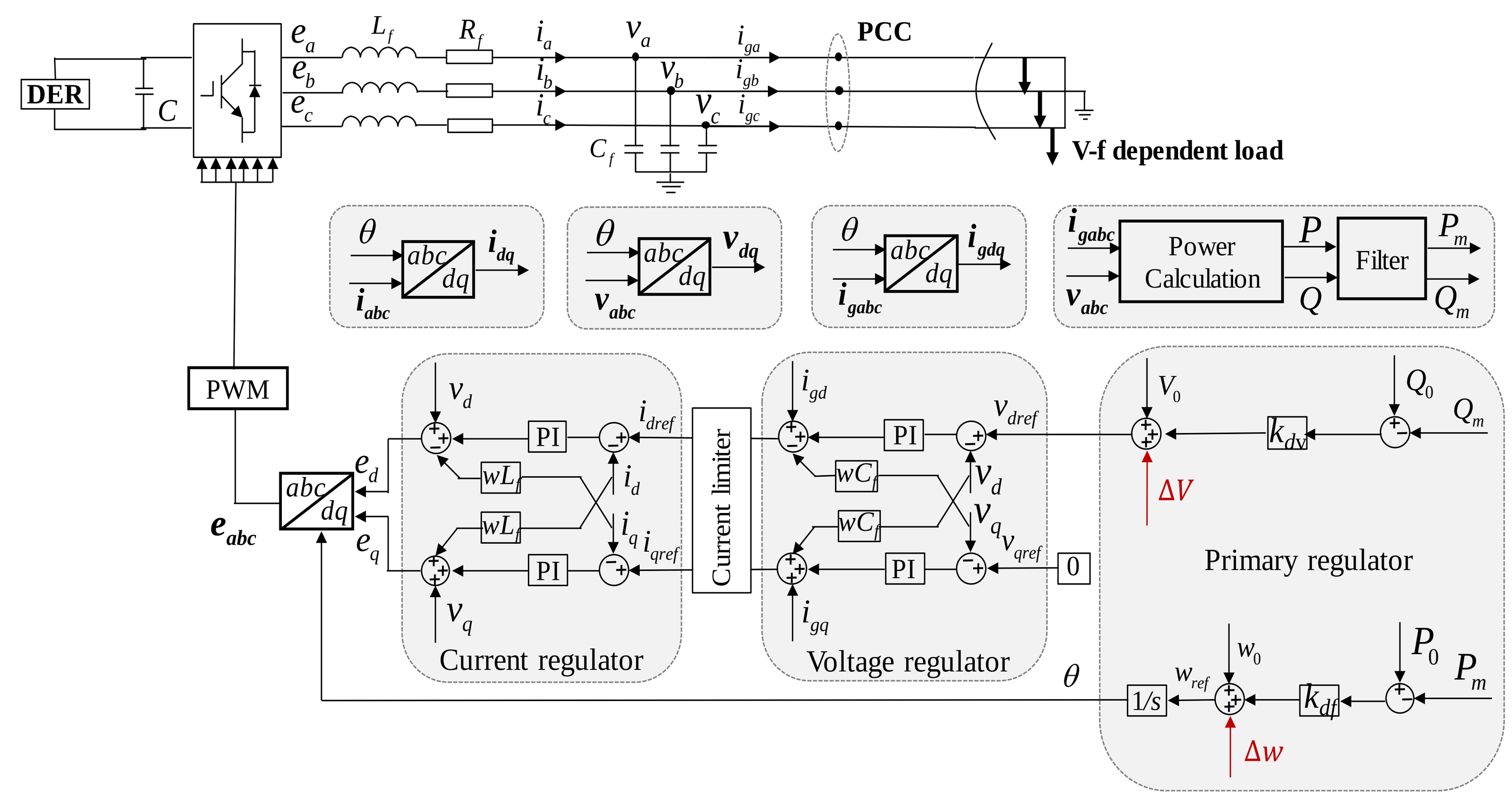

Fig. 3 Diagram of a droop-controlled GFM inverter supplying V-f dependent load

Decentralized and Coordinated control framework

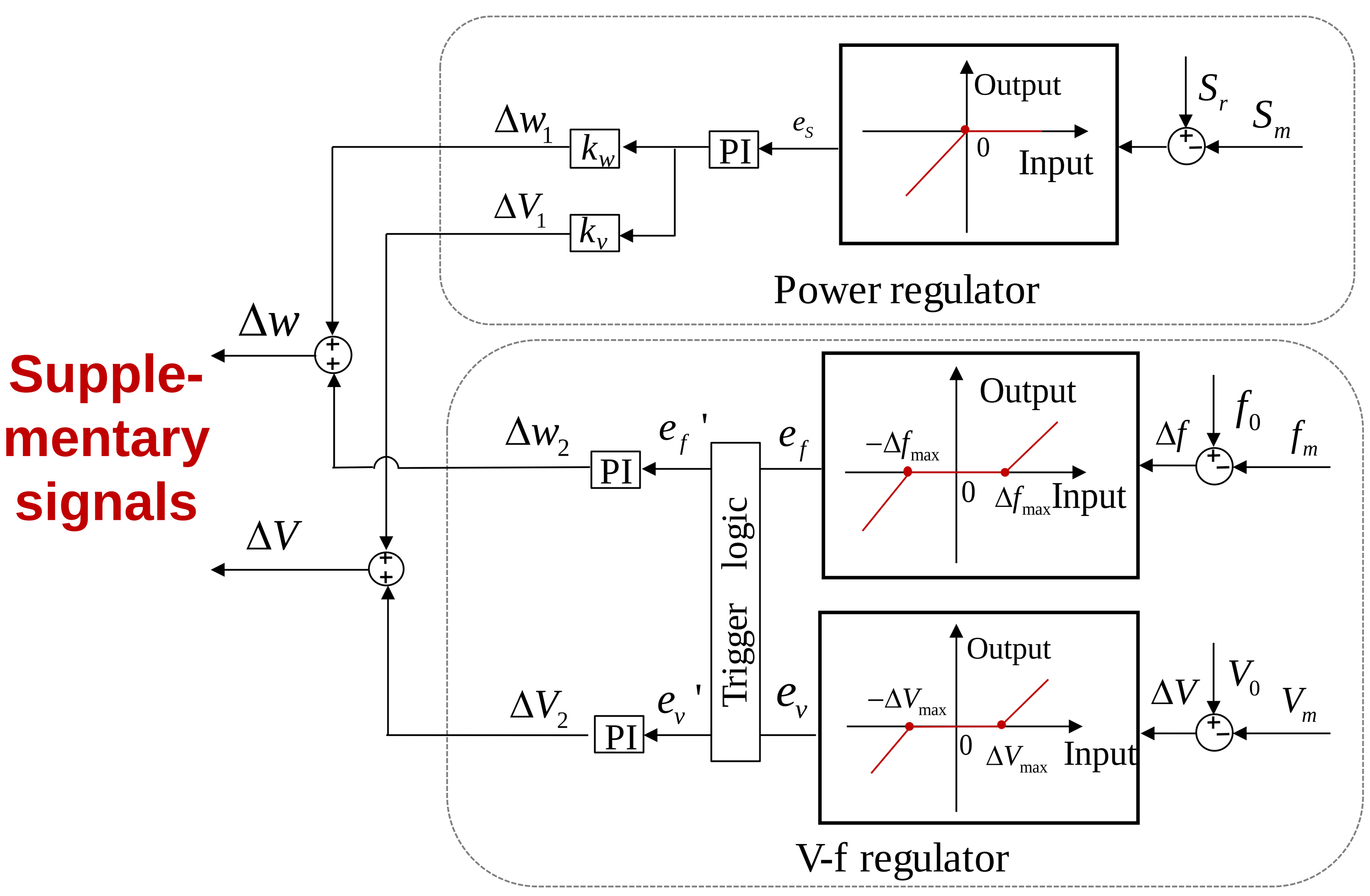

Fig. 4 Diagram of the proposed control framework

- **Power regulator** generates control signals based on the error between inverter output and DER capacity, which help limit the output of grid-forming inverters
- **V-f regulator** generates control signals based on voltage and frequency deviations, which reallocates limited generation for acceptable V-f deviations

Theoretical validation

- Droop equation

$$\begin{cases} f = f_{0,i} + k_{df}(P_{inv,i} - P_{inv0,i}) \\ V_i = V_{0,i} + k_{dv}(Q_{inv,i} - Q_{inv0,l}) \end{cases} \Rightarrow \boxed{P_{g,i}'^2 + Q_{g,i}'^2 = S_i^2}$$

- V-f dependent load

$$\begin{cases} P_{l,i} = P_{l0,i}(p_1V_i^2 + p_2V_i + p_3)\left[1 + K_{pf}(f - f_0)\right] \\ Q_{l,i} = Q_{l0,i}(q_1V_i^2 + q_2V_i + q_3)\left[1 + K_{pf}(f - f_0)\right] \end{cases} \Rightarrow \begin{cases} P_{l0,i}' = P_0 + \Delta P \\ Q_{l0,l}' = Q_0 + \Delta Q \end{cases}$$

- Grid power flow

$$\begin{cases} P_i = P_{inv,i} + P_{l,ii} = G_{ij}V_i^2 - G_{ij}\sum_{i\neq j} V_iV_j\cos\theta_{ij} - B_{ij}\sum_{i\neq j} V_iV_j\cos\theta_{ij} \\ Q_i = Q_{inv,i} + Q_{l,i} = G_{ij}V_i^2 - G_{ij}\sum_{i\neq j} V_iV_j\cos\theta_{ij} - B_{ij}\sum_{i\neq j} V_iV_j\cos\theta_{ij} \end{cases}$$

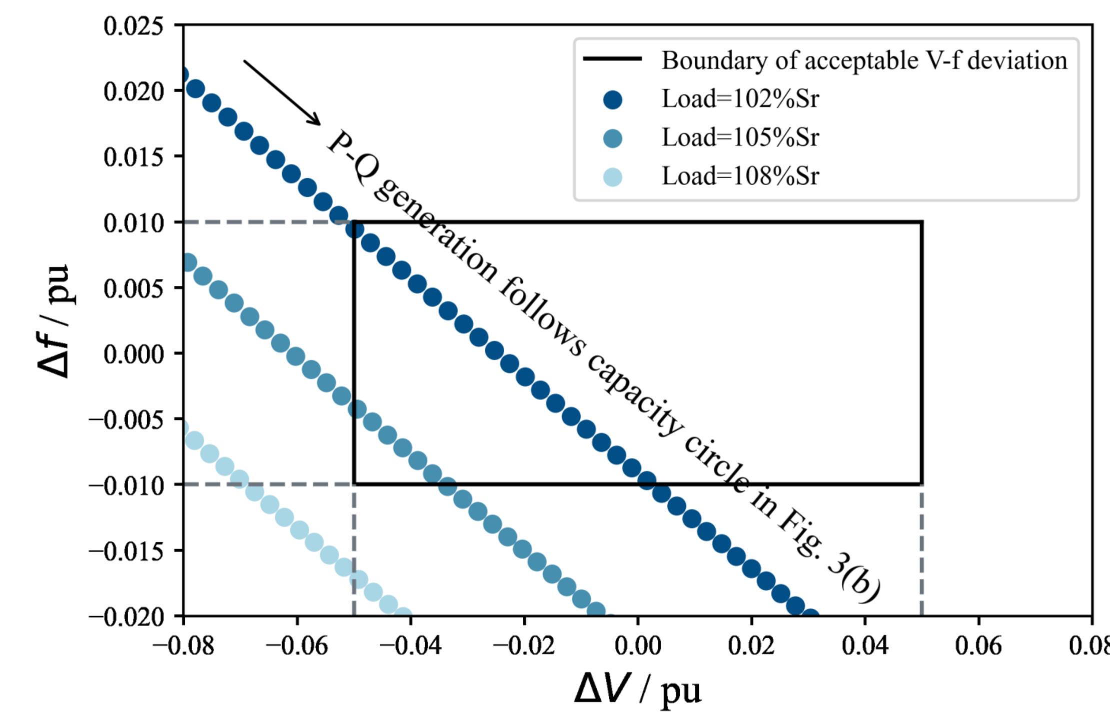

Fig. 5 V-f deviation under bounded generation constraints

Case study

Basic settings

a) Before 8 s, G1-G3 are controlled with the conventional droop method represented in Fig. 1.
b) At 8 s, load C2 increases.
c) At 12 s, the reference capacities of G1-G3 are set as 1.2MVA, 0.6MVA, and 1.2MVA, respectively. The power regulator starts working.
d) At 16 s, the V-f regulator starts working.

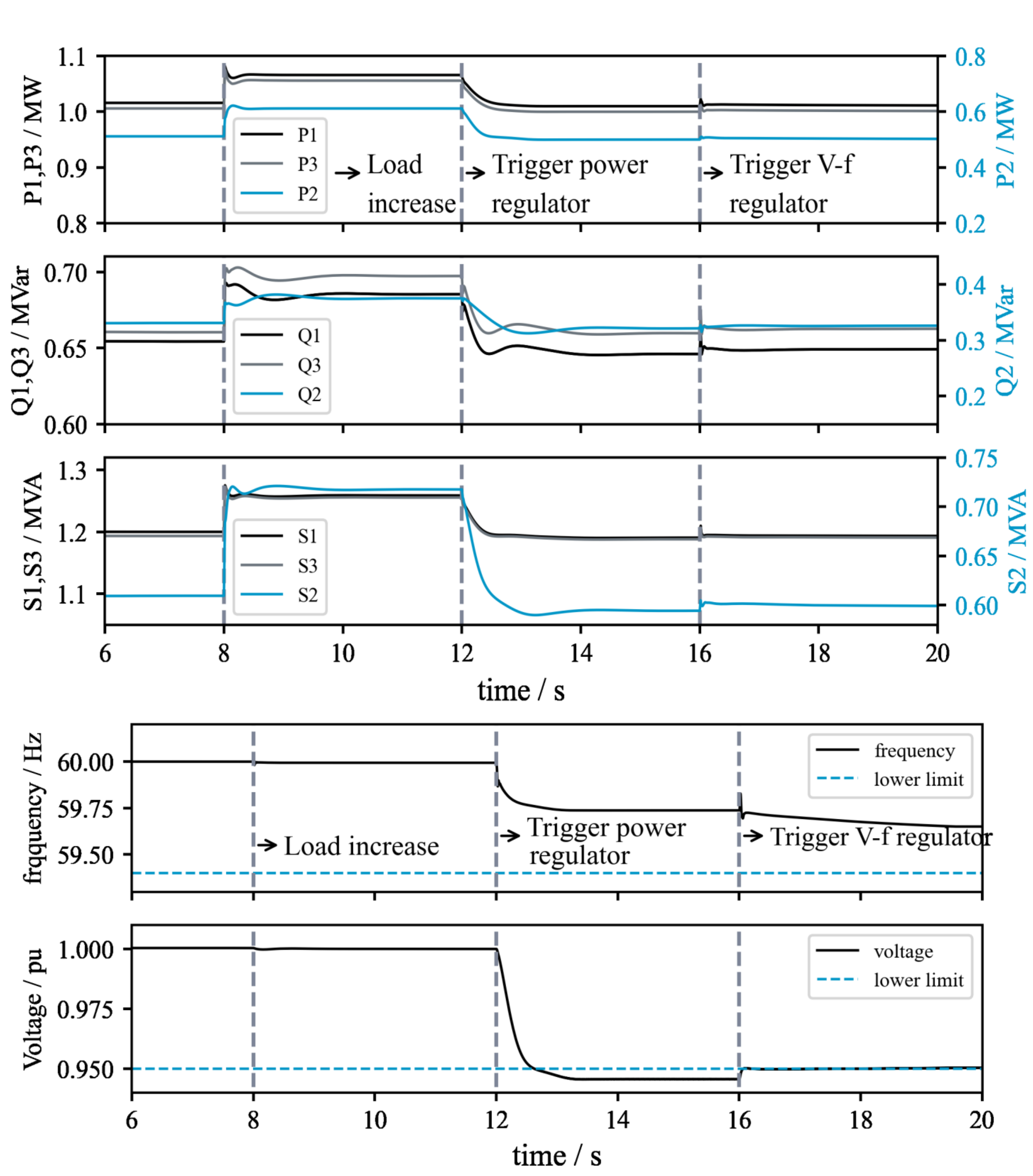

Fig. 6: Scenario 1: Over voltage dip and recovery

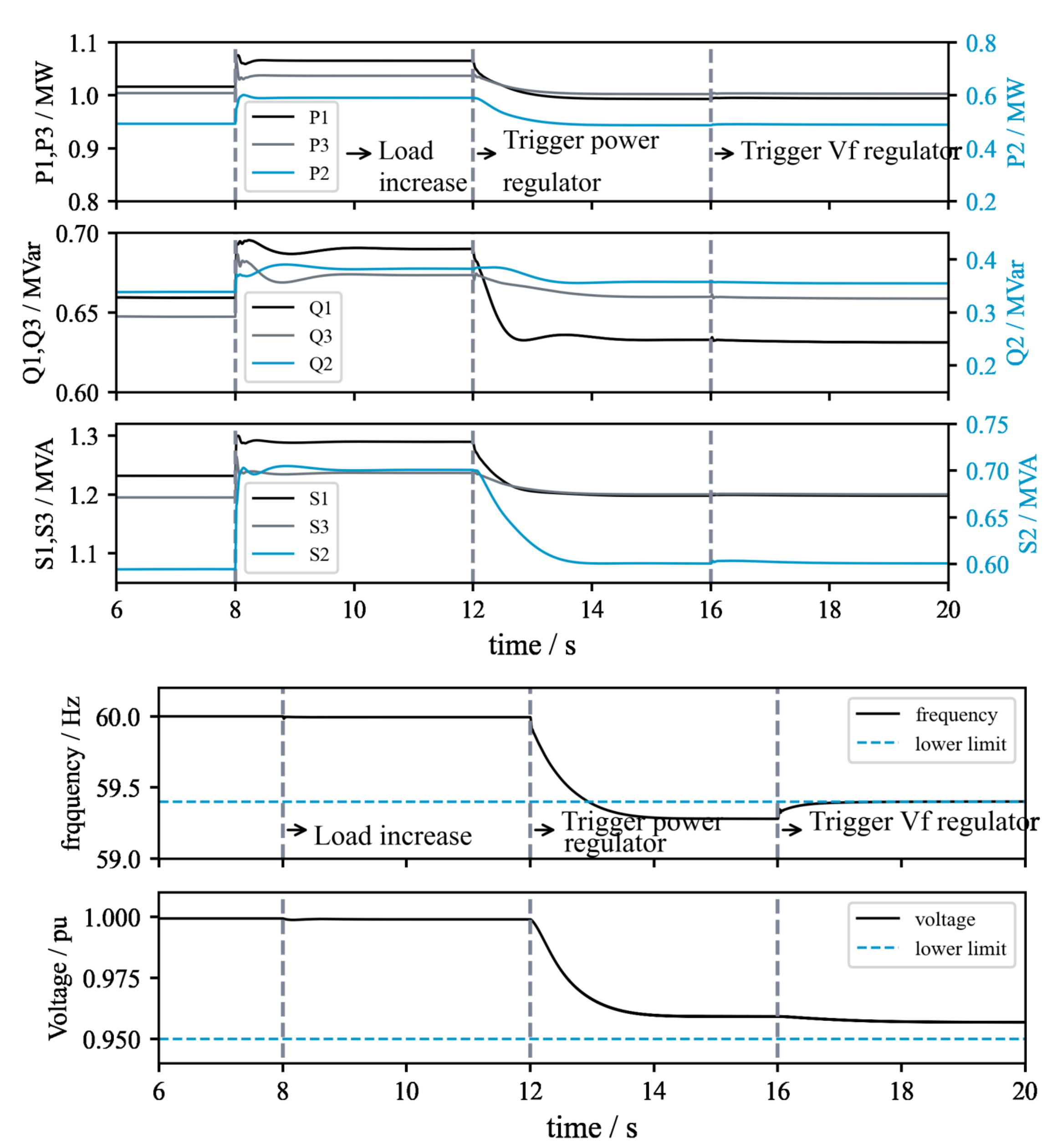

Fig. 7. Scenario 2: Over frequency dip and recovery

Conclusions

- The power regulator regulates the output of GFM inverters, while the V-f regulator improves the V-f deviation by leveraging the load response to voltage and frequency.
- Three-level coordination is achieved within the proposed control framework, : 1). Generation and load, 2). V regulation and f regulation, and 3). P generation and Q generation.

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