Electric Vehicles Charging Time Constrained Deliverable Provision of Secondary Frequency Regulation

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MOTIVATION

❖ EV randomness involves not only the procurement stage but also the delivery stage
❖ Increased charging time should be constrained to secure the EV owners' preference
❖ Comprehensive assessment of EV SFR provision involves economic perspective and dynamic performance

CONTRIBUTION

❖ The problem of EVs participating in the RTED to provide SFR is decoupled into dispatch modeling and EV aggregator modeling
❖ The increased charging time caused by the SFR services is constrained by the EV owner's tolerance.
❖ A hybrid OPF structure is proposed in the RTED-TDS co-simulation for the frequency regulation studies
❖ EV providing deliverable SFR is verified using the proposed RTED-TDS co-simulation

METHODS

❖ Charging time constrained EV aggregation

Algorithm 1 EV Aggregator Control

1: Initialize EV aggregator
2: **for** t in T_{total}
3:     **if** $t = N \cdot T_{\text{ed}}$
4:         Estimate SFR capacities with Eqn (9);
5:     **if** $t = N \cdot T_p$
6:         Record $\mathbf{x}$ and update $\mathbf{A}$;
7:     **if** $t = N \cdot T_{\text{agc}}$
8:         Compute signals with Eqns (10)-(14);
9:     Run Monte Carlo simulation;
10:    Switch EVs with Eqn (15);
11:    Estimate $\mathbf{x}$ and y with Eqn (1);

❖ Procurement and delivery of EV SFR

Algorithm 2 RTED-TDS Co-Simulation

1: Initialize EV aggregator, DCOPF, ACOPF, TDS
2: **for** t in T_{total}
3:     **if** $t = N \cdot T_{\text{ed}}$
4:         EV aggregator: estimate SFR with Eqn (9);
5:         DCOPF: update info from dynamic;
6:             solve RTED with Eqns (16)-(28);
7:         ACOPF: resolve with Eqns (29)-(30);
8:         TDS: assign schedule results from ACOPF;
9:     **if** $t = N \cdot T_{\text{agc}}$
10:        TDS: assign AGC power;
11:        EV Aggregator: run with Algorithm 1;
12:        TDS: federate power from EV aggregator;
13:           run TDS;
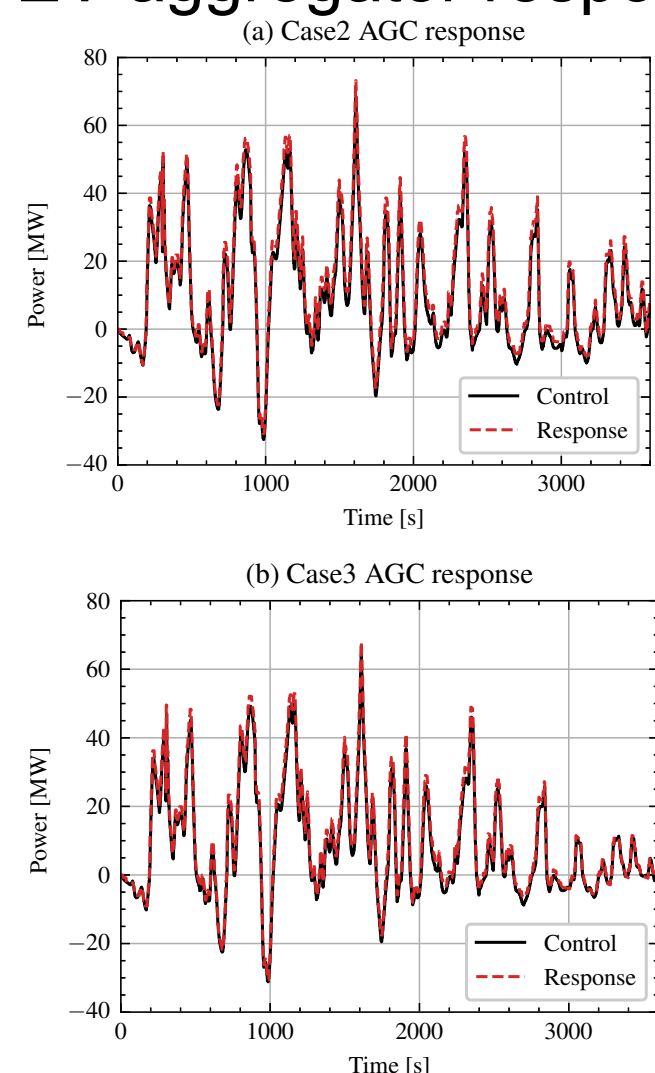14:   compute ACE with Eqn (31);
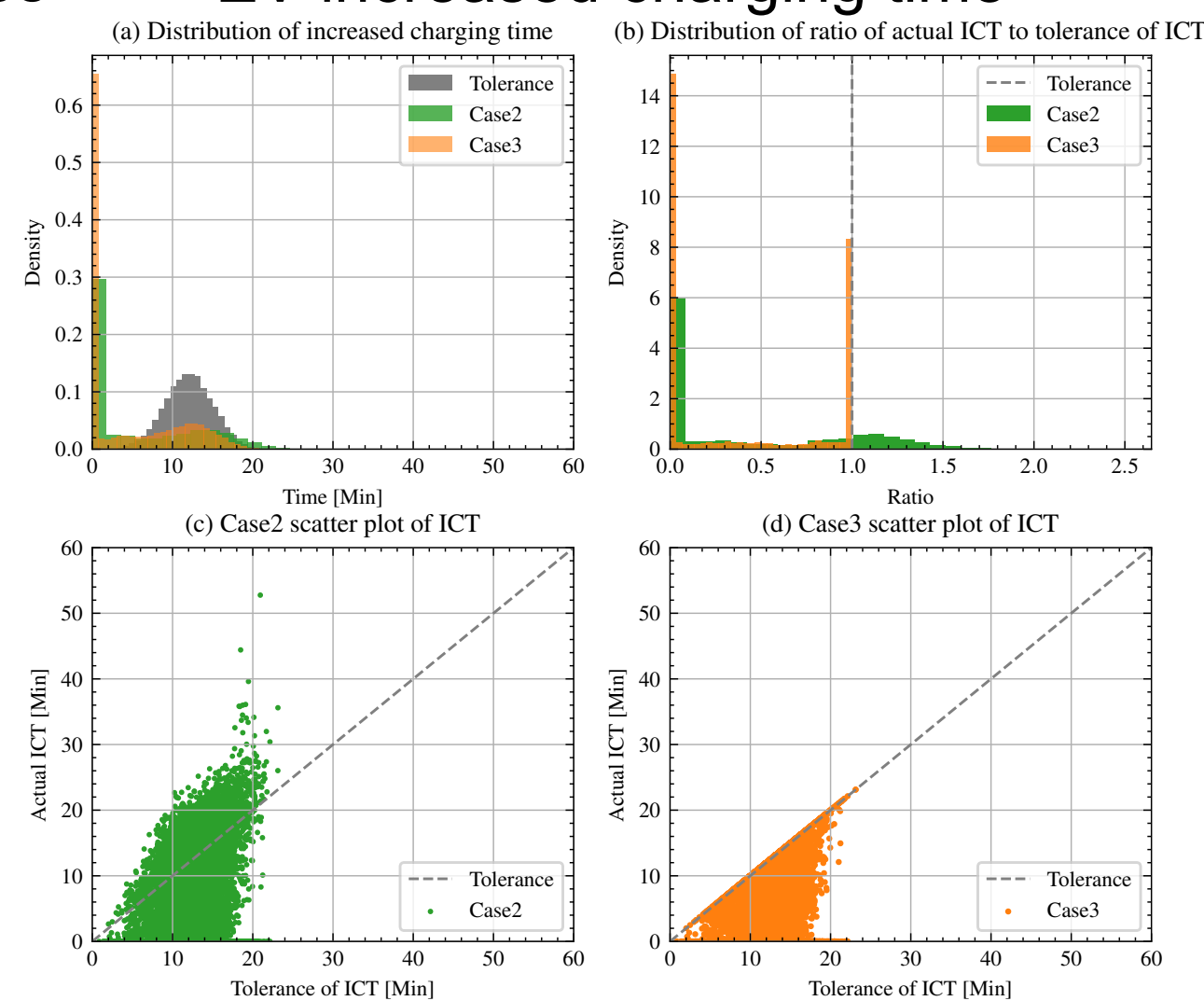

Framework of RTED-TDS co-simulation
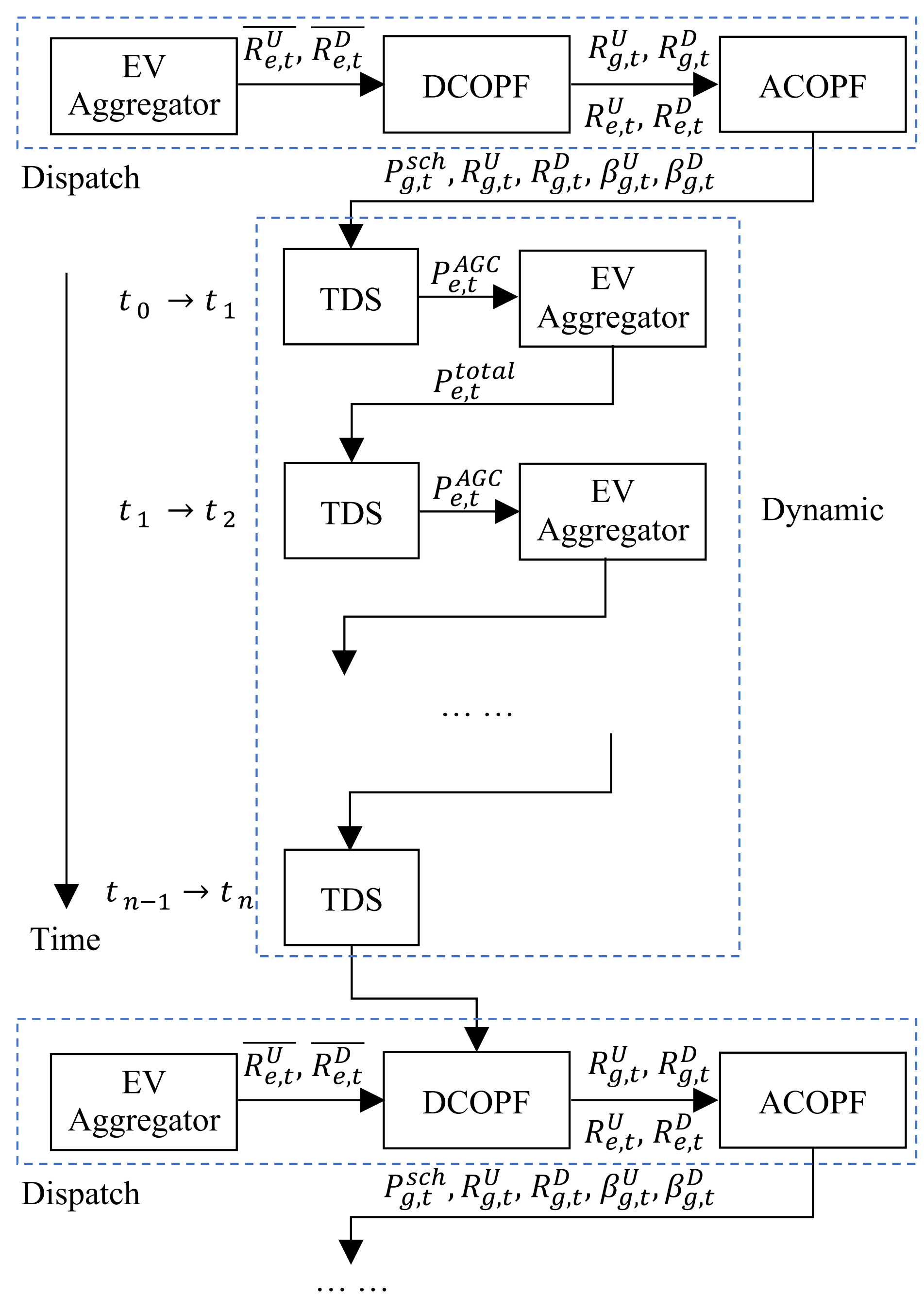
CASE STUDY

❖ Case1: EV not providing SFR
❖ Case2: EV providing SFR without charging time constraints
❖ Case3: EV providing SFR with charging time constraints

EV aggregator response   EV increased charging time

CONCLUSION

In conclusion, this paper proposes an EV charging time-constrained deliverable SFR provision model.

❖ Charging time constrained EV aggregation based on state space modeling
❖ Inter-interval SFR reserve procurement and reliable delivery real-time intra-interval AGC response from EV aggregation
❖ Hybrid OPF structure for RTED-TDS co-simulation to secure the broadcasting dispatch results into the dynamic simulation, reducing the overall co-simulation modeling complexity
❖ the proposed charging time-constrained EV aggregation is verified using the RTED-TDS co-simulation framework on IEEE 39-bus system