Electric Vehicles Charging Time Constrained Deliverable Secondary Frequency Regulation Provision

Jinning Wang[1], Fangxing Li[1],
[1] The University of Tennessee, Knoxville

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

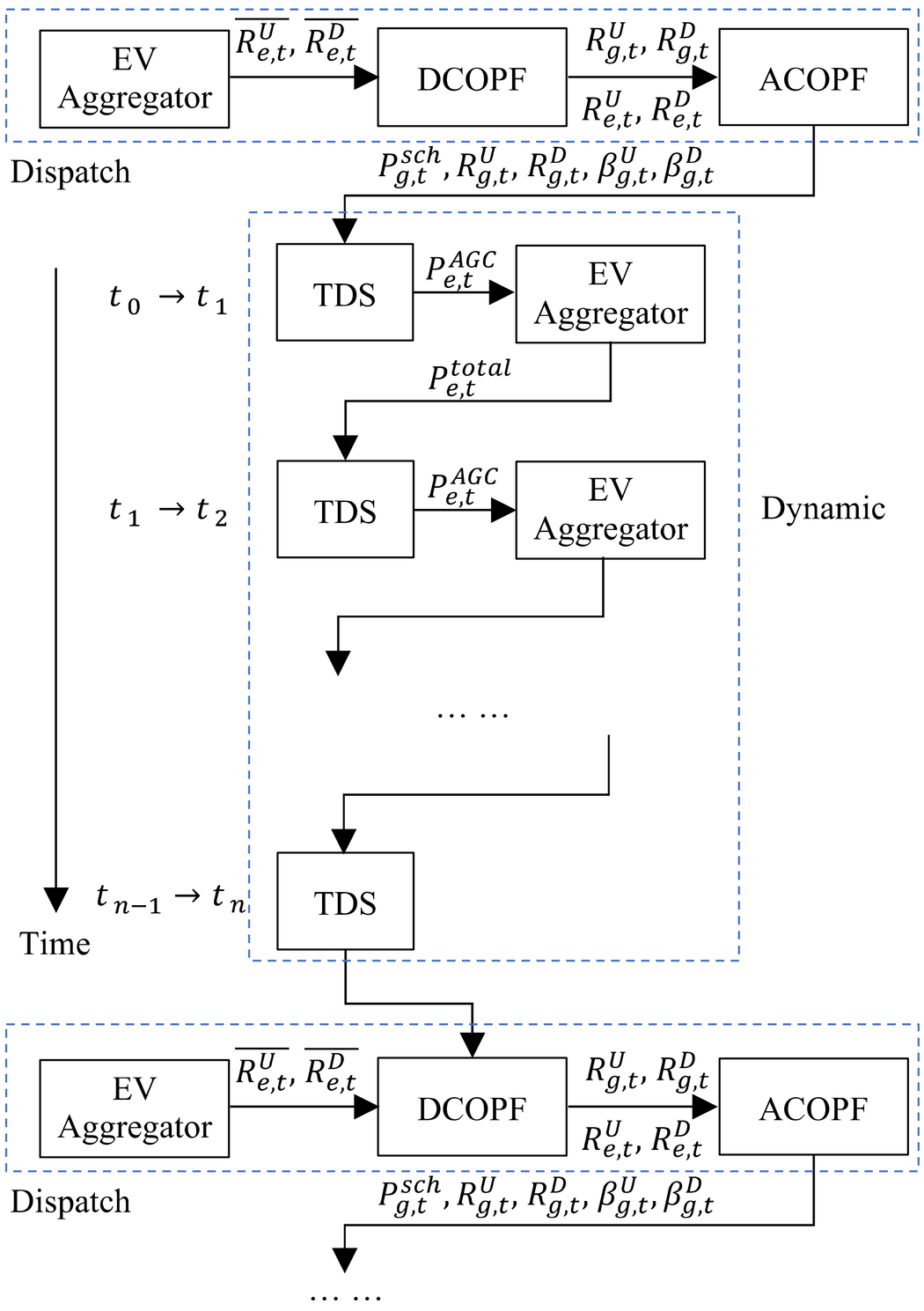
```
Initialize EV aggregator
for t in T_total
    if t = N · T_ed
        Estimate SFR capacities with Eqn (9);
    if t = N · T_p
        Record x and update A;
    if t = N · T_agc
        Compute signals with Eqns (10)-(14);
    Run Monte Carlo simulation;
    Switch EVs with Eqn (15);
    Estimate x and y with Eqn (1);
```

- Procurement and delivery of EV SFR

Algorithm 2 RTED-TDS Co-Simulation

```
Initialize EV aggregator, DCOPF, ACOPF, TDS
for t in T_total
    if t = N · T_ed
        EV aggregator: estimate SFR with Eqn (9);
        DCOPF: update info from dynamic;
                solve RTED with Eqns (16)-(28);
        ACOPF: resolve with Eqns (29)-(30);
        TDS: assign schedule results from ACOPF;
    if t = N · T_agc
        TDS: assign AGC power;
        EV Aggregator: run with Algorithm 1;
    TDS: federate power from EV aggregator;
         run TDS;
         compute ACE with Eqn (31);
```

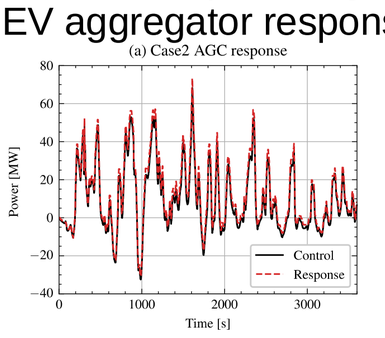
Framework of RTED-TDS co-simulation

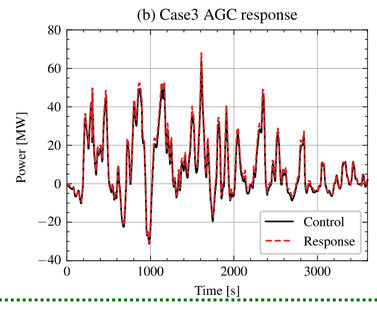


CASE STUDY

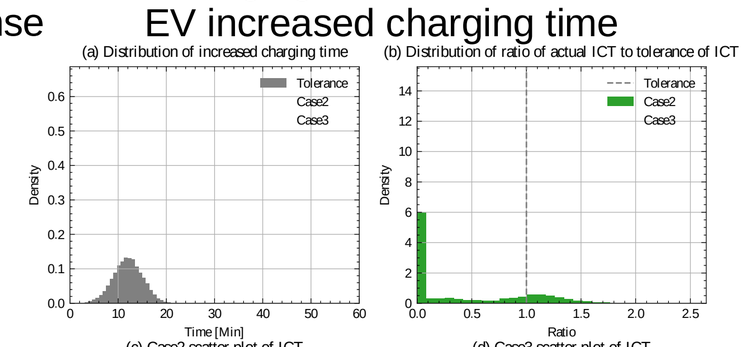
- Case1: EV not providing SFR
- Case2: EV providing SFR without charging time constraints
- Case3: EV providing SFR with charging time constraints

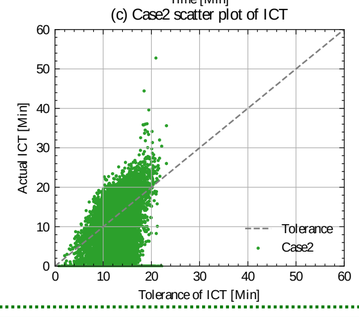
EV aggregator response

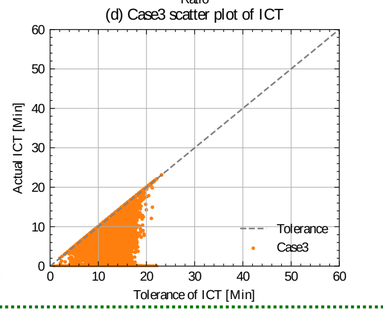




EV increased charging time







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

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