Electric Vehicles Charging Time Constrained Deliverable Secondary Frequency Regulation Provision

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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} do
3:   if t = N \cdot T_{p}
4:     Compute SFR capacities with Eqn (9);
5:     Record x and update A;
6:     Compute signals with Eqns (10)-(14);
7:     Switch EVs with Eqn (15);
8: end if
9: end for

Algorithm 2 RTED-TDS Co-Simulation
1: Initialize EV aggregator, DCOPF, ACOPF, TDS
2: for t in T_{total} do
3:   if t = N \cdot T_{p}
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: end if
10: end for

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

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 proposed RTED-TDS co-simulation framework on IEEE 39-bus system