Conservation Voltage Reduction with Distributed Energy Resource Management System, Grid-Edge, and Legacy Devices

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Background

Distribution utilities use conservation voltage reduction (CVR) to obtain energy savings and lower peak demand by reducing bus voltages. Traditionally, the CVR is accomplished by controlling the legacy assets such as load tap changers, voltage regulators, and capacitor banks. The deployment of the advanced distribution management system (ADMS) and distributed energy resource management system (DERMS) enables the integration of distributed energy resources into the distribution networks and provide the grid services including CVR. This paper studies the coordinated operation of an ADMS and a DERMS in achieving CVR and voltage regulation. A commercial ADMS uses legacy devices and Edge-of-Network Grid Optimization (ENGO) devices to obtain energy savings through CVR. A prototype DERMS dispatches the photovoltaic smart inverters based on real-time optimal power low to ensure voltage regulation across the feeder. The results show that the coordinated operation of ADMS and DERMS is effective in achieving CVR and voltage regulation. Specifically, energy savings of up to 4.7% are observed in the real utility distribution system used in this study.

Feeder Characteristics

- 12.47-kV system with a peak load of 35 MW
- One substation load tap changer, 13 capacitor banks for voltage regulation
- Large system with > 13,000 buses
- Added distributed PV generation of ~200% relative to the minimum load for the study

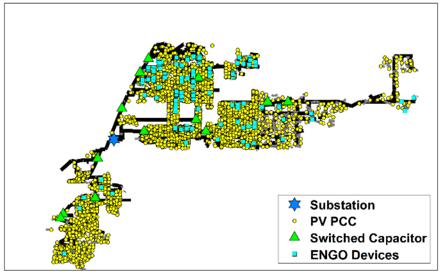

Figure. 1. Topology of Xcel Energy's distribution system.

Experimental Setup

- Schneider Electric's ADMS
- Real-time Optimal Power Flow (RT-OPF)-based prototype DERMS
- Grid model: OpenDSS & OPAL-RT
- HELICS co-simulation

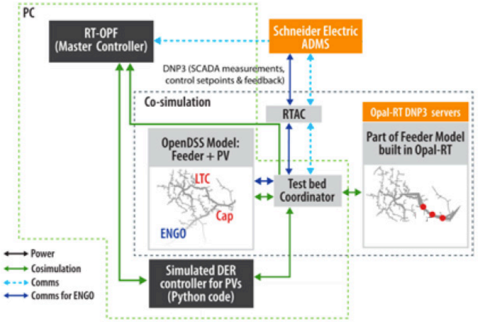

Figure 2. ADMS test bed setup.

Results

Table 1. Simulation Scenarios

Scenario	Legacy Devices	ENGO units	PV Smart Inverters
Baseline	Local control	-	Unity power factor
S1	ADMS	ADMS	Local Volt-VAR-Watt control mode
S2	ADMS	ADMS	RTOPF

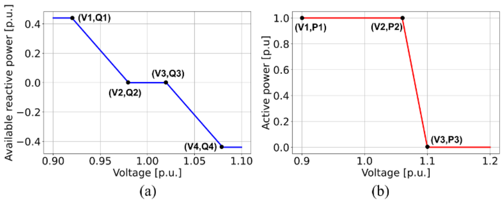

Figure. 3. (a) Volt-VAR curve, and (b) Volt-Watt curve.

Table 2. Volt-VAR Curve Settings

Curve	V1	Q1	V2	Q2	V3	Q3	V4	Q4
Volt-VAR	0.92	0.44	0.98	0	1.02	0	1.08	-0.44

Table 3. Volt-WATT Curve Settings

Curve	V1	P1	V2	P2	V3	P3
Volt-Watt	0.9	1	1.05	1	1.1	0

Baseline Results

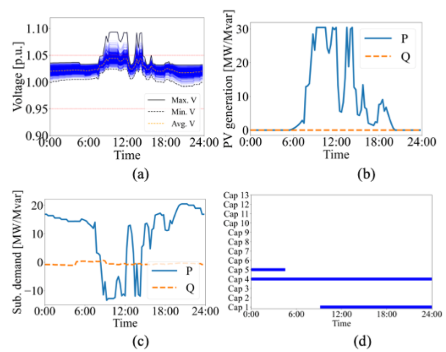

Figure. 4. (a) bus voltages, (b) total PV generation, (c) substation demand, and (d) capacitor statuses.

S1 Scenario Results

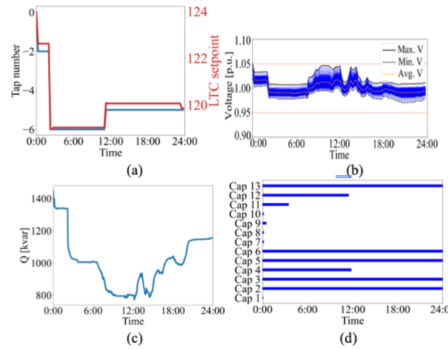

Figure. 5. (a) LTC tap changes, (b) bus voltages, (c) Q output of ENGO units, and (d) capacitor statuses.

S2 Scenario Results

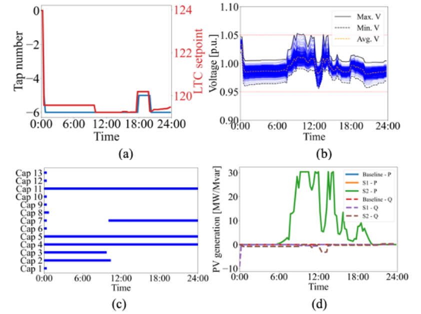

Figure. 6. S2 results: (a) LTC tap changes, (b) bus voltages, (c) capacitor statuses, and (d) PV generation.

Metrics

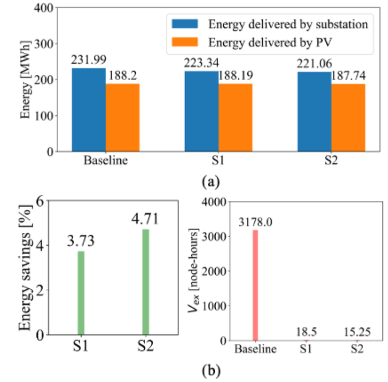

Figure. 7. Metrics for minimum load day.

Conclusion

We evaluated the coordinated operation of an ADMS and a prototype DERMS in achieving CVR while ensuring voltage regulation with high PV penetration. Our findings show that the ADMS lowers system voltages to achieve CVR by lowering the LTC taps which reduce the feeder head voltage. To ensure voltage regulation, ADMS uses dynamic reactive power support from ENGO devices and capacitor banks. The DERMS complements the ADMS through active and reactive power control of the PV smart inverters. Energy savings of up to 4.7% with a significant improvement in the voltage profile and minimal PV energy export curtailment (0.25%) are observed in the studied system with these controls.

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