Evaluating the Effect of Four-Quadrant Electric Vehicle Charging Station Operation on Distribution System Protection

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❖ Introduction

The rapid integration of electric vehicles (EVs) into power systems is transforming the traditional roles of distribution networks, not only as energy delivery channels but also as interactive platforms for bidirectional power flow. Among the advanced charging technologies, four-quadrant EV charging stations (EVCSs) capable of sourcing and sinking both real and reactive power introduce new operational capabilities that can support grid flexibility and stability. However, this functionality also presents challenges to existing distribution system protection schemes, which were originally designed for unidirectional, radial power flows.

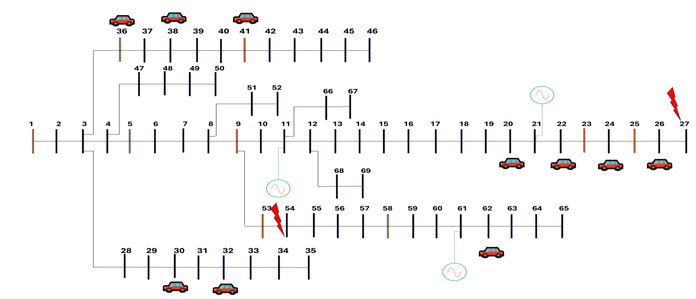
❖ Objective

Study the impact of EVCSs on distribution network by observing fault currents at key locations during three-phase bolted faults

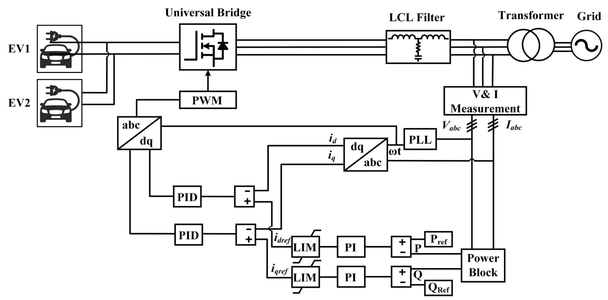
❖ Methodology

- **Test system:** EVCSs distributed across 10 locations in IEEE 69 bus system, with penetration levels ranging from 4% to 30%.
- **Detailed EVCS modelling:** Modelled EVCS as power electronic converters rather than lumped loads for realistic system representation.
- **Four-quadrant operation:** Evaluated V2G, G2V, and all four-quadrant operating modes to characterize their impact on fault currents.
- **DER–EVCS interaction:** Investigated the combined impact of DER integration and EVCS operation.
- **Comprehensive protection assessment:** Examined diverse fault and relay locations relative to EVCS placement to characterize fault current responses.

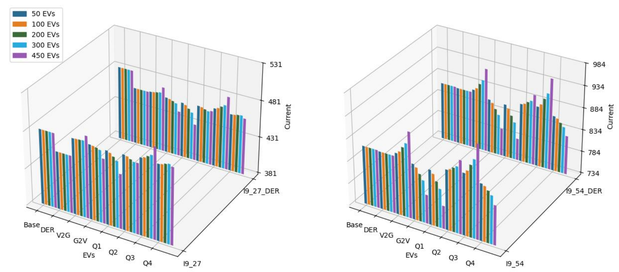
❖ Test System

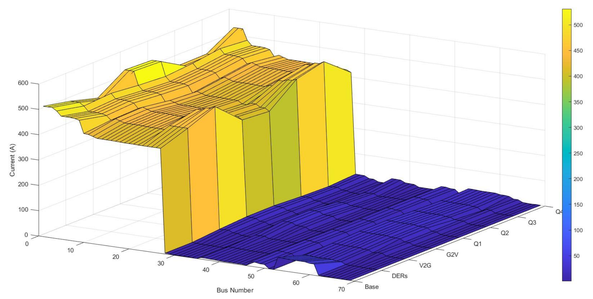


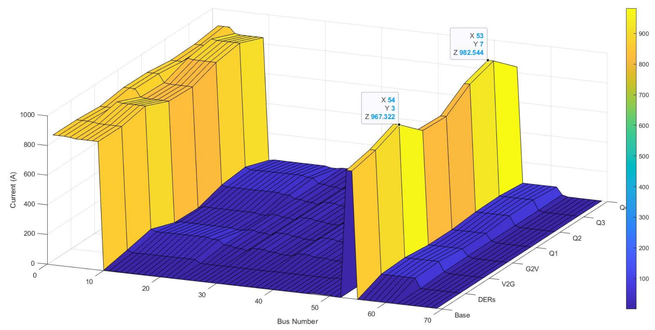
❖ EVCS Modelling



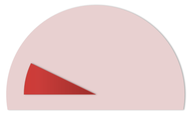
❖ Observed Fault Currents







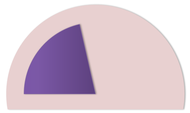
❖ Key Takeaways



G2V and Q1/Q4 modes generally reduce fault currents across downstream buses, helping alleviate system stress.



Upstream buses experience opposite effects, although the variations are relatively insignificant.



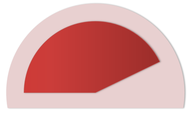
DERs increase fault currents at their connection points but dampen currents at upstream fault locations.



Remote buses exhibit smaller but noticeable fault current variations due to DER integration and EVCS operating modes.



Four-quadrant EVCS operation introduces reverse power flow, necessitating directional protection for relays upstream of EVCS.



Fault current variations can approach 30%, challenging conventional protection coordination under intermittent DER operation.



High EV penetration in G2V and Q1/Q4 modes can reduce fault currents below base-case levels, potentially compromising fault detection at remote buses.

❖ Conclusion

Varying levels of EVCS penetration and operating modes in the distribution network under fault conditions, introduce both change in the magnitude and direction of fault currents and they are highly sensitive to the positioning, sizing, and operational state of EVCS and DERs.