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Distribution Feeder Fault Comparison Utilizing a Real-Time Power Hardware-in-the-Loop Approach for Photovoltaic System Applications

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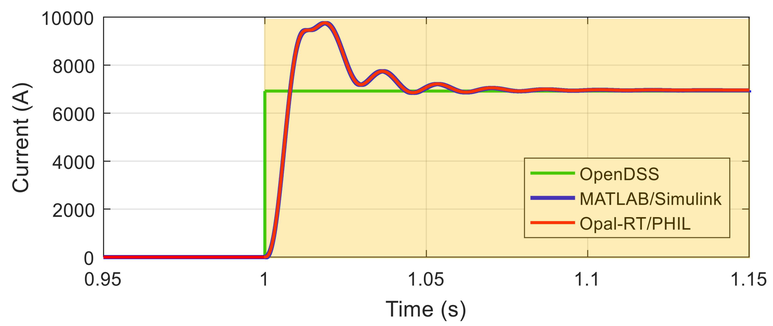
Introduction

Power outages are a challenge that utility companies must face, with the potential to affect millions of customers and cost billions in damage. For this reason, there is a need for ***developing approaches that help understand the effects of fault conditions on the power grid***. In distribution circuits with high renewable penetrations, the fault currents from DER equipment can impact coordinated protection scheme implementations so it is critical to accurately analyze fault contributions from DERs.

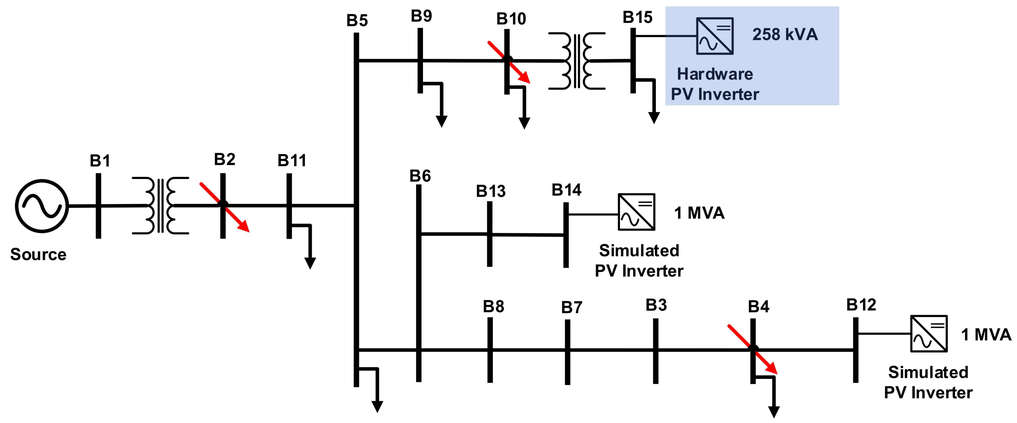
Fault Current Dynamics

A comparison between ***OpenDSS, MATLAB/Simulink*** *and* ***PHIL/Opal-RT*** fault currents was conducted to determine the steady-state and dynamic accuracy of each method as well as the response of using simulated and hardware PV inverters. This figure show the fault current of a line to line fault at bus 2.



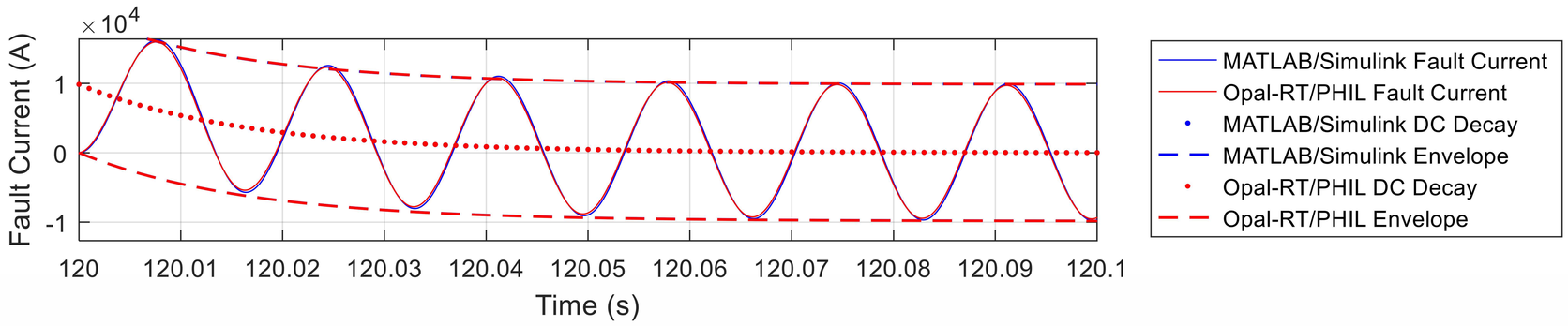
Distribution Feeder Model

MATLAB/Simulink was used to simulate the reduced-order distribution system with different faults applied at different bus locations. The use of Real-Time (RT) Power Hardware-in-the-Loop (PHIL) simulations was also used to further improve the fidelity of the model.

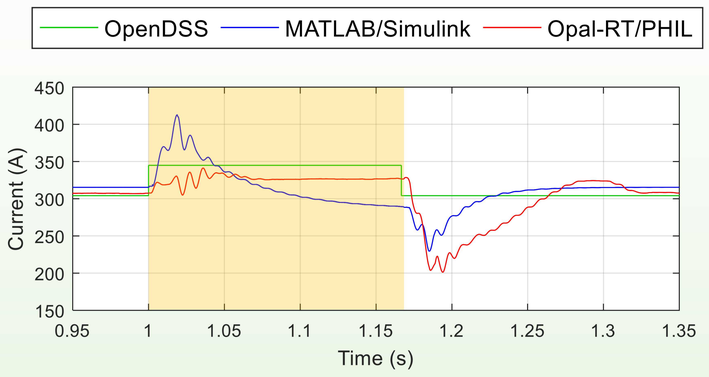


DC Decay Comparison

- In any system with inductive components, instantaneous changes in current are not possible, resulting in a **DC current** being present.
- These results show that there is a correlation between the envelop calculated from ***MATLAB/Simulink*** and the ***PHIL/Opal-RT*** fault currents.



PV Inverter Dynamics



Introducing a 3-phase Fault at Bus 4, showed that all methods were closely correlated in steady-state, but the transient response of the inverter was difficult to capture with a PV model and the physical device behavior could not be represented completely without incorporating it through ***PHIL/Opal-RT***.

Observations

- ***OpenDSS*** can perform short circuit analysis and protection studies in the frequency domain with phasor analysis, ***speeding computational time***.
- ***MATLAB/Simulink*** includes time-domain simulations, including ***transients, so protection studies can be performed at a much higher resolution***. However, if an average *dq* PV inverter model is used, the dynamics, switching transients, and output filter capacitor discharge are also not captured.
- ***PHIL/Opal-RT*** simulations with a physical PV inverter allowed for ***detailed circuit study under fault conditions***.

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