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A Comparative Study of the Reliability of Reverse Power and Directional Overcurrent Elements for Distribution Level Fault Identification

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Motivation

- Increasing penetration of DERs has led to bidirectional flow of power
- Conventional protection schemes need to undergo modifications in order to be able to trip DERs in the case of faults upstream of the PCC
- Out of step reclosing can create high electronic magnetic transients
  - Damage utility load
  - Safety hazard for utility personnel
- Feeder protection will need to be updated as DERs are integrated into the distribution system
  - Comparative analysis between the performance and feasibility of DOC and RP elements to identify faults at the PCC when DERs are present

Directional Overcurrent

- The DOC element, 67, combines directionality with the standard overcurrent element
- The directional element uses phase angle displacement between the current phasor of a particular phase and the reference variable to determine the directionality (forward or reverse)
- Usually single phase elements
- It is mostly used in the following conditions [1]:
    - Multi-source power distribution systems
    - Closed loop or parallel-cabled systems
    - Isolated neutral systems for the feedback of capacitive currents
    - To detect an abnormal direction of flow of active or reactive power

Reverse Power

- The RP element, 32R, is also a directional protection element that relies upon both voltage and current values to determine reverse power
- Measures 3 phase active or reactive power to detect reversal
- Normally, not used for single phases for fault detection due to availability of OC elements
- Detects reversal of power for a non-exporting DER at the PCC during sudden loss of generation at the utility side or Loss of Mains (LOM) situation

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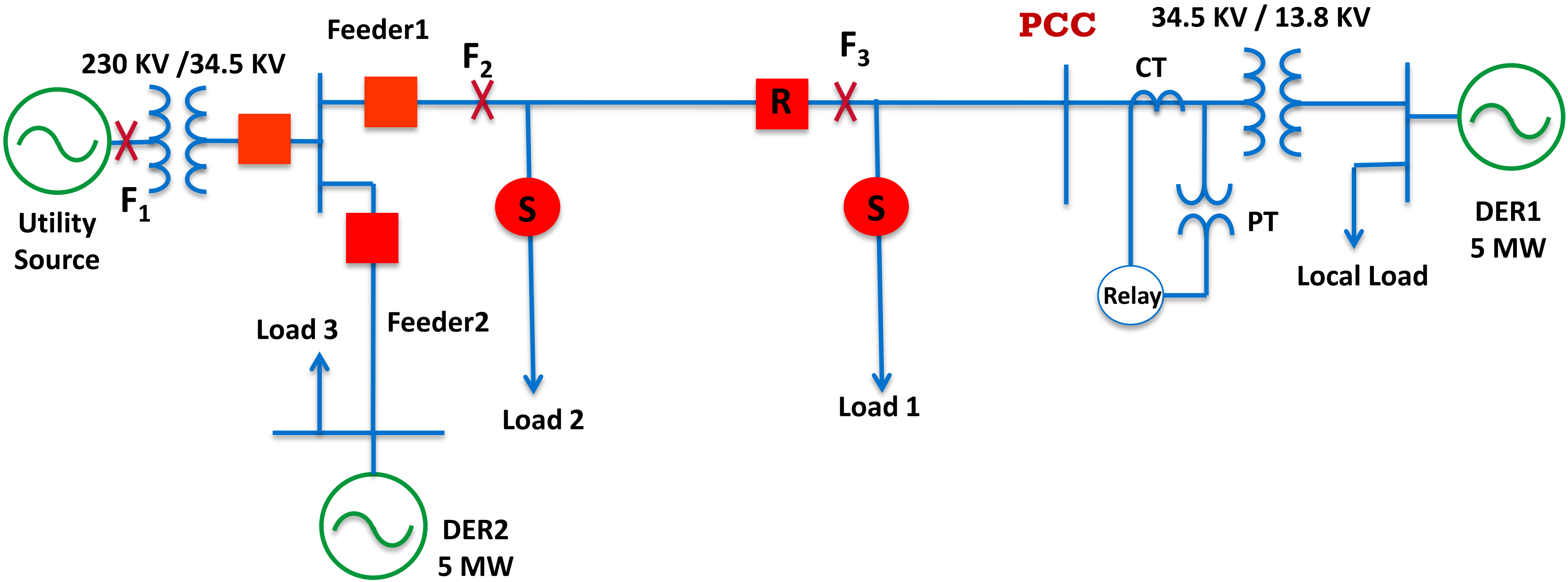
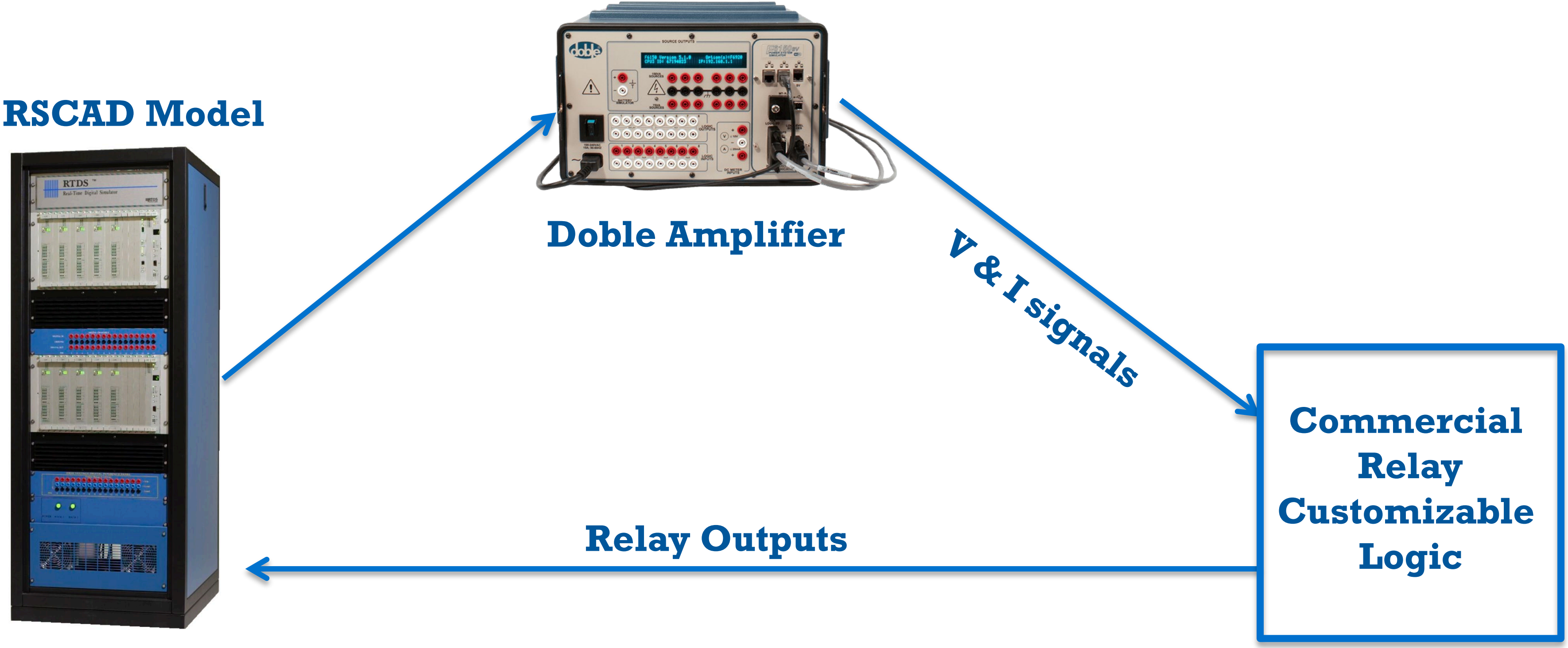
Test Bench Setup



RTDS Testing – Hardware-in-the-Loop

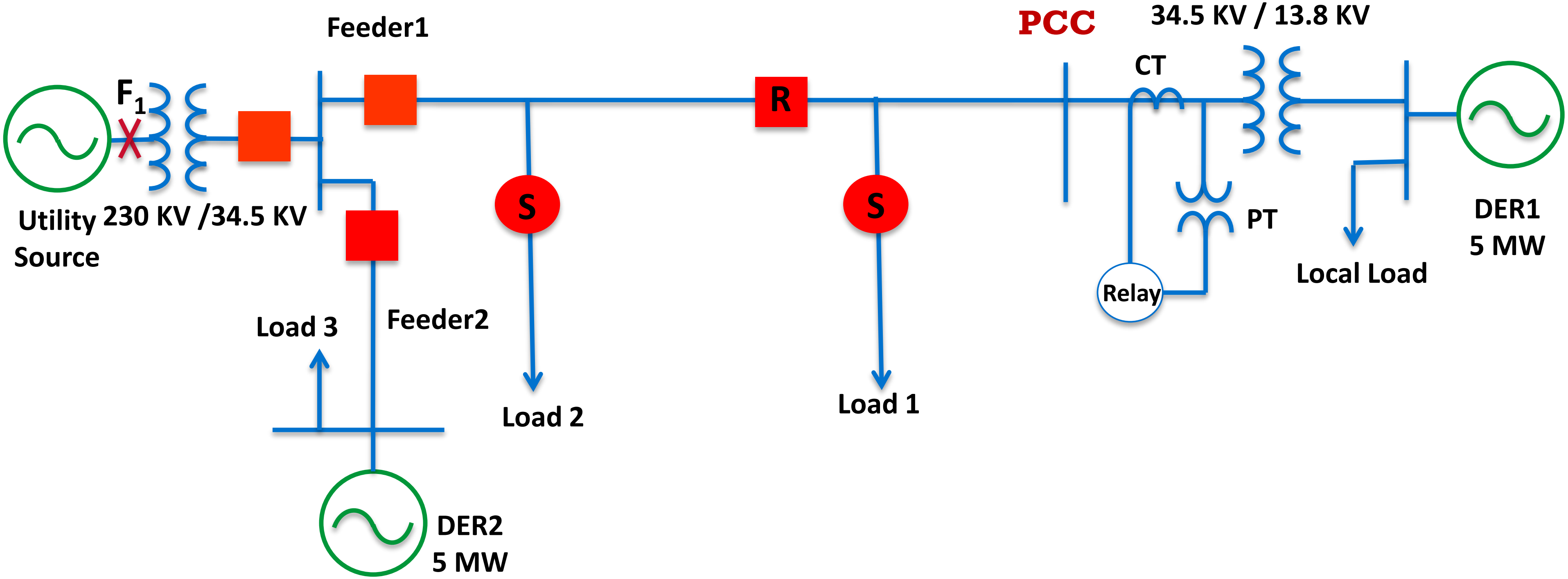


Results

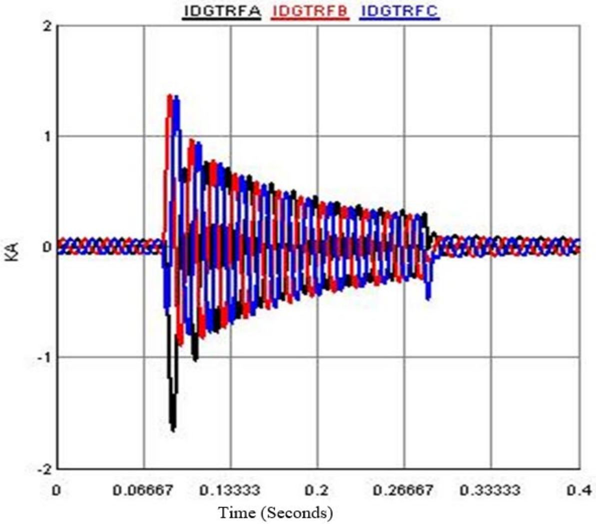
- Various scenarios and simulations were executed:
  - Various operating conditions - Heavy/light local load & with/without DER2
  - Faults at various locations - 3 phase/single phase (High Z/Low Z)
  - 12 scenarios in total in each case(with and without DER2)

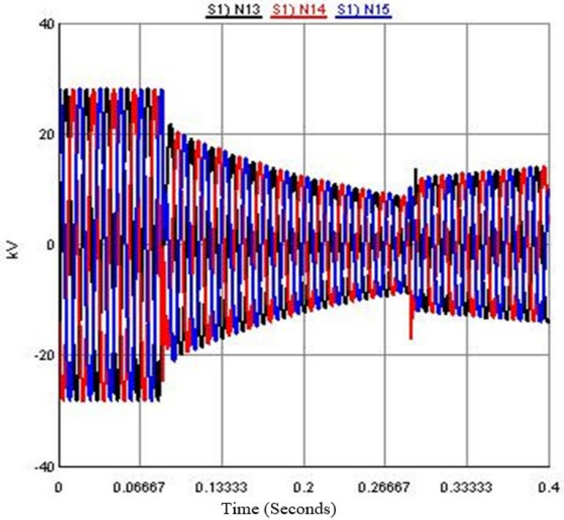
Operating Condition	Successful indication by DOC	Successful indication by RP
Without DER2	**12**	**3**
With DER2	**12**	**3**

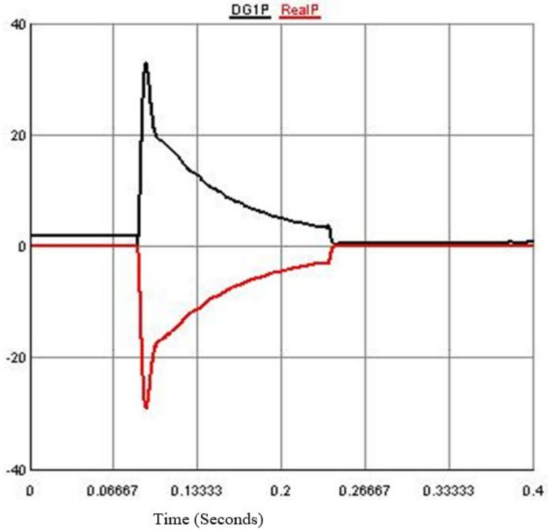
Scenario 1: High Z Three phase fault at F1

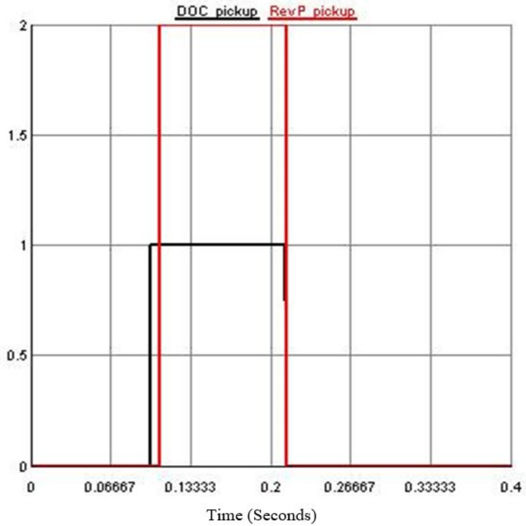


Scenario 1

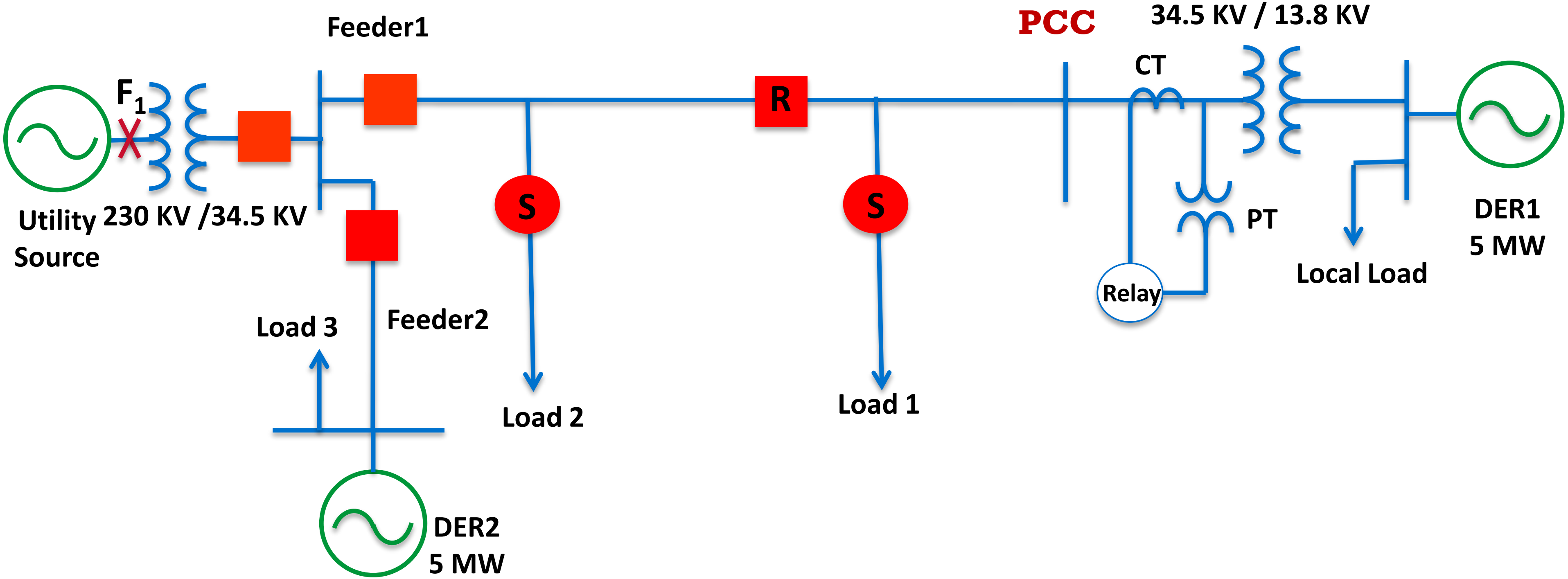

IDGTRFA IDGTRFB IDGTRFC
KA
2
1
0
-1
-2
0 0.06667 0.13333 0.2 0.26667 0.33333 0.4
Time (Seconds)


S1) N13 S1) N14 S1) N15
kV
40
20
0
-20
-40
0 0.06667 0.13333 0.2 0.26667 0.33333 0.4
Time (Seconds)

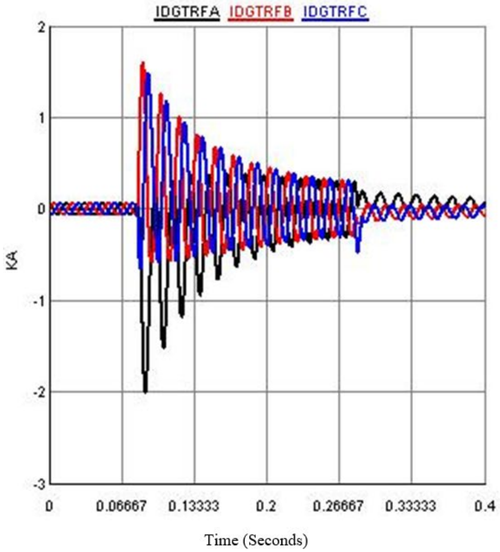

DG1P RealP
40
20
0
-20
-40
0 0.06667 0.13333 0.2 0.26667 0.33333 0.4
Time (Seconds)

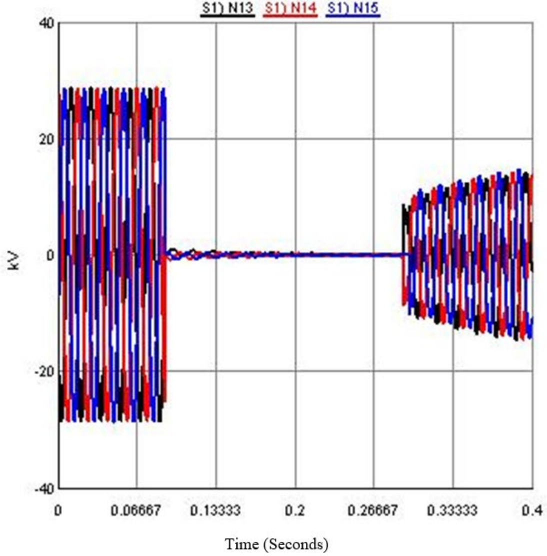

DOC_pickup RevP_pickup
2
1.5
1
0.5
0
0 0.06667 0.13333 0.2 0.26667 0.33333 0.4
Time (Seconds)

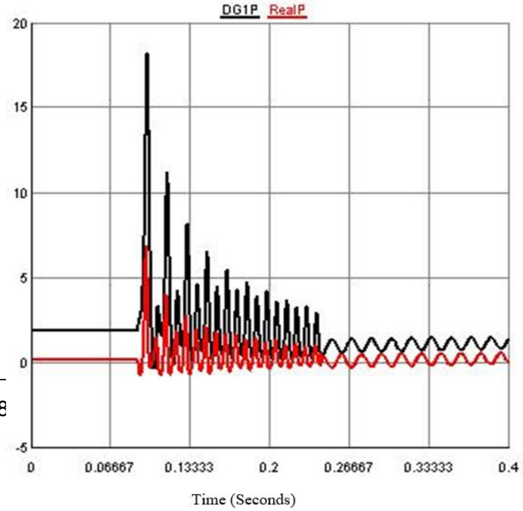
Scenario 2: Bolted 3 phase fault at F1

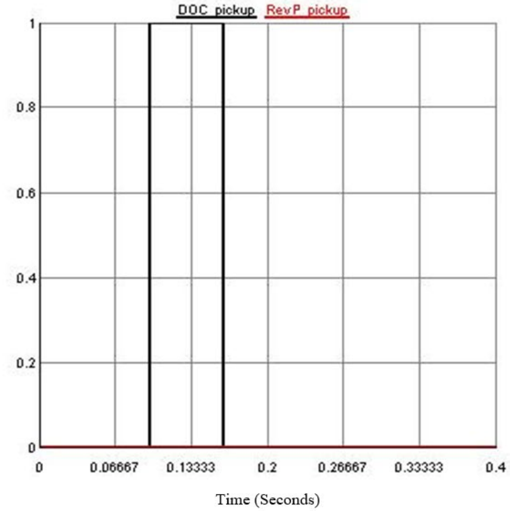


Scenario 2

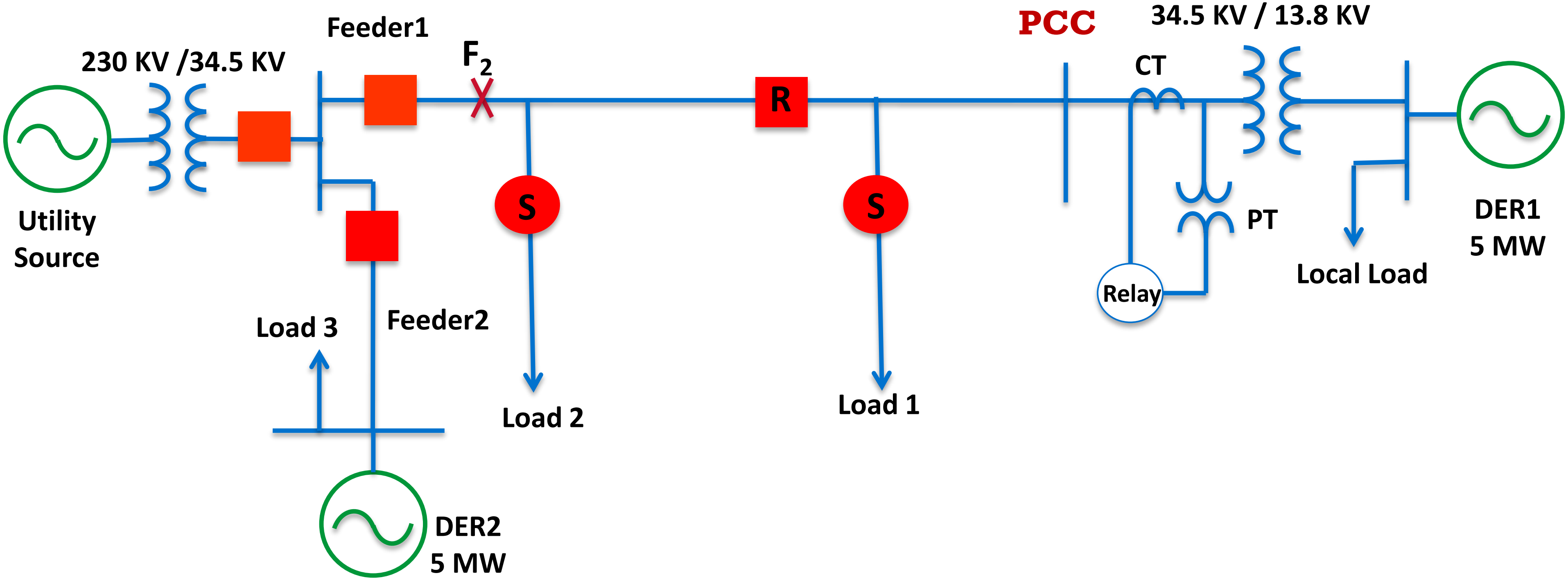

IDGTRFA IDGTRFB IDGTRFC
KA
2
1
0
-1
-2
-3
0 0.06667 0.13333 0.2 0.26667 0.33333 0.4
Time (Seconds)


S1) N13 S1) N14 S1) N15
kV
40
20
0
-20
-40
0 0.06667 0.13333 0.2 0.26667 0.33333 0.4
Time (Seconds)

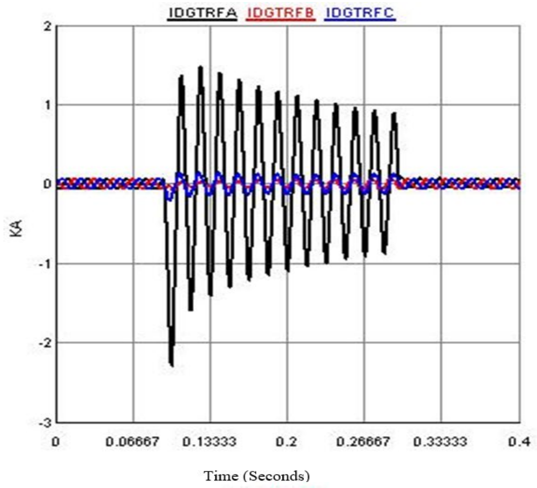

DG1P RealP
20
15
10
5
0
-5
0 0.06667 0.13333 0.2 0.26667 0.33333 0.4
Time (Seconds)


DOC_pickup RevP_pickup
1
0.8
0.6
0.4
0.2
0
0 0.06667 0.13333 0.2 0.26667 0.33333 0.4
Time (Seconds)

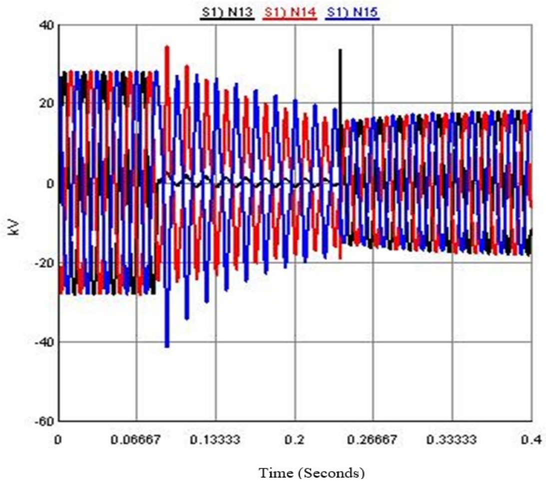
Scenario 3: High Z single phase to Ground fault at F2



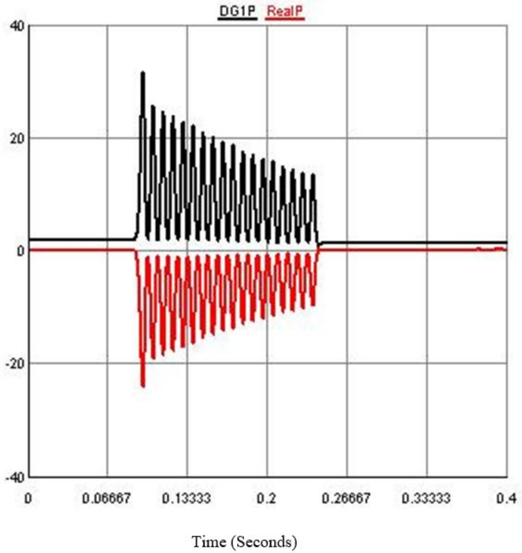
Scenario 3



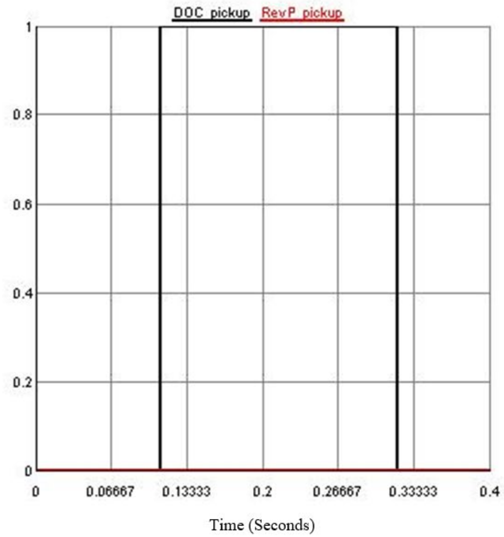
IDGTRFA IDGTRFB IDGTRFC
2
1
0
-1
-2
-3
KA
0 0.06667 0.13333 0.2 0.26667 0.33333 0.4
Time (Seconds)



S1) N13 S1) N14 S1) N15
40
20
0
-20
-40
-60
kV
0 0.06667 0.13333 0.2 0.26667 0.33333 0.4
Time (Seconds)



DG1P RealP
40
20
0
-20
-40
0 0.06667 0.13333 0.2 0.26667 0.33333 0.4
Time (Seconds)



DOC_pickup RevP_pickup
1
0.8
0.6
0.4
0.2
0
0 0.06667 0.13333 0.2 0.26667 0.33333 0.4
Time (Seconds)

Conclusion

- A comparative analysis was carried out to evaluate the capability of DOC and RP elements to detect various faults
- A custom model was built to test consider multiple fault types and locations and Hardware-in the loop technology was used to execute real time simulations
- Low fault impedance causes the voltage to collapse, which leads to a negligible power magnitude
- During phase to ground faults power in one phase might reverse direction, however the three phase power is not considered in the reverse direction as the other two phases increase power to compensate
- Reverse power is not a reliable indicator of fault identification, and the DOC element should be considered instead for feeder protection

References

[1] Pierre Bertrand , "Directional protection equipment", Schneider Electric, Cahier Technique no.181.

[2] A. Moore, "Distributed Generation (DG) Protection Overview", University of Western Ontario.

[3] J. Simms, G. Johnson, " Protection Considerations for Installation of Distributed Energy Resources", 2015 68th Annual Conference for Protective Relay Engineers

[4] T. Medalel Masaud, R. Deepak Mistry, "Fault Current Contribution of Renewable Distributed Generation: An Overview and Key Issues", 2016 IEEE Conference on Technologies for Sustainability, 2016.

[5] David Costello, Martin Moon, and Greg Bow, "Use of Directional Elements at the Utility-Industrial Interface", 31st Annual Western Protective Relay Conference, October 2004.

[6] Abhisek Ukil; Bernhard Deck; Vishal H Shah, "Current-Only Directional Overcurrent Protection for Distribution Automation: Challenges and Solutions", 2012 IEEE Transactions on Smart Grid.

Questions?