DER Enabled Intelligent Network Protector

-ENSC Conference

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EATON

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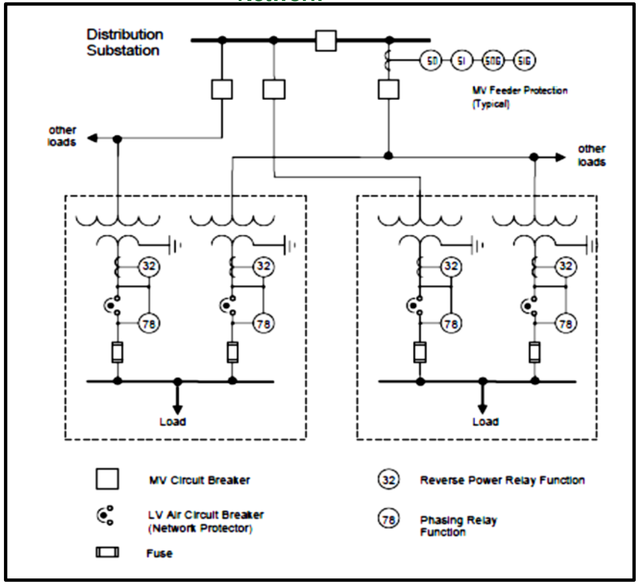
SECONDARY DISTRIBUTION SYSTEMS

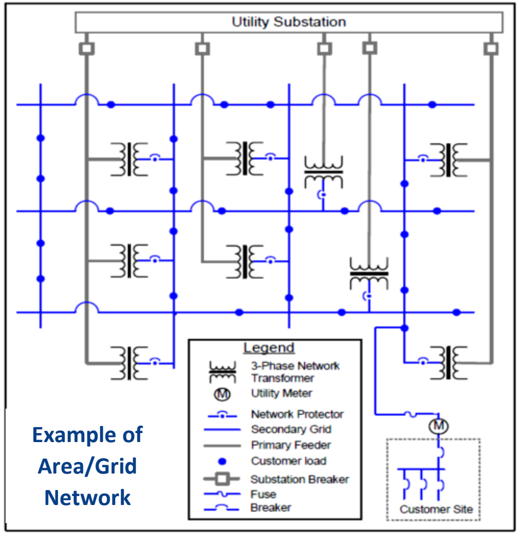
Example of Spot Network



- A **spot network** is commonly applied in high load-density areas such as metropolitan and suburban business districts.
- Spot networks frequently used to serve a single or multiple customers in a building.
- Spot networks will have two or more feeders and two or more network protectors that networked together at an electric consumer's site.

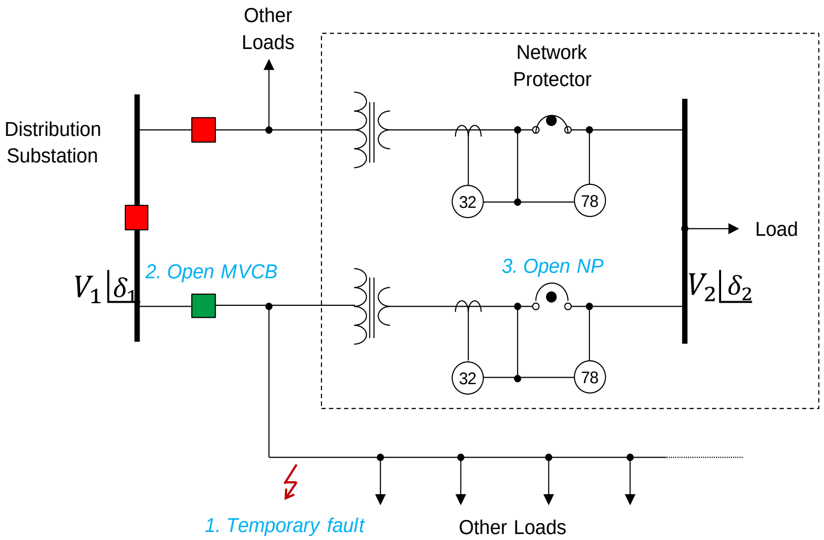
- **Area/Grid networks** serves downtown areas across U.S. , have redundant feeders and Network Protectors and may serve hundreds to thousands of customers.
- Area networks may include as many as ten network protectors to more than a thousand network protectors and served by three to thirty-five feeders.

Reverse Power is not Allowed in these systems according to IEEE standard and industrial practice due to the limitation of Network Protector device



Example of Area/Grid Network

Network Protector Existing logic



Network Protector job:

- Open when Medium Voltage circuit Breaker (MVCB) opens
- Close when Medium Voltage circuit Breaker (MVCB) closes

Network protector open logic:

- MVCB opening results in a back-feed and reverse power from the other feeder
- Reverse power equals to abnormal condition

Network protector reclose logic:

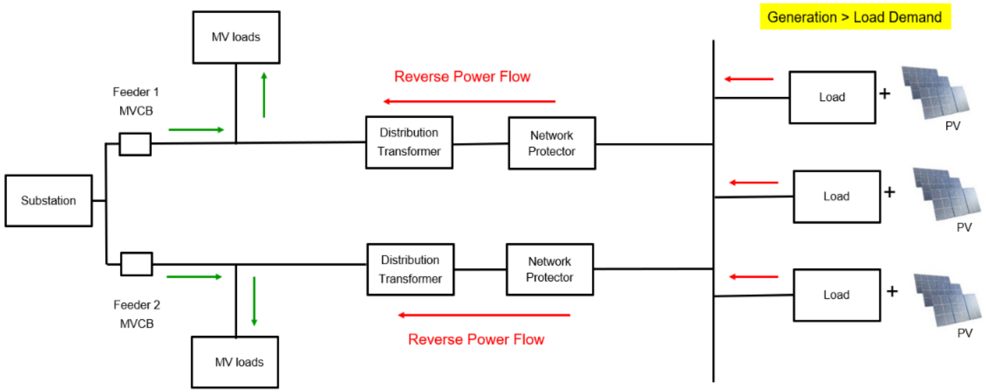
- If system recovers, no reverse power should exist:
- δ_1(substation side's Voltage angle) $>$ δ_2(Load side's Voltage angle)

Problem Statement 1 - Unintended Tripping

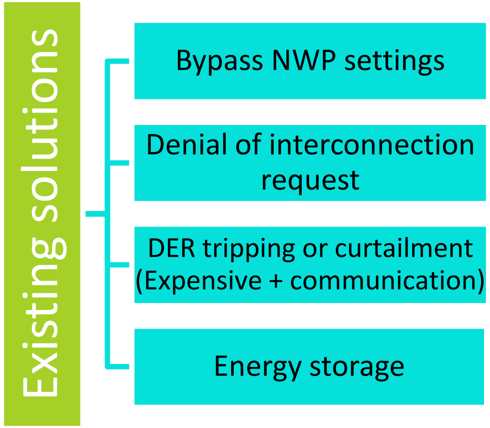
Problem:

- Network protector (NWP) logic requires tripping upon detecting a smallest reverse power to avoid back feeding a fault or a deenergized feeder. In other words, reverse power is equal to abnormal condition.

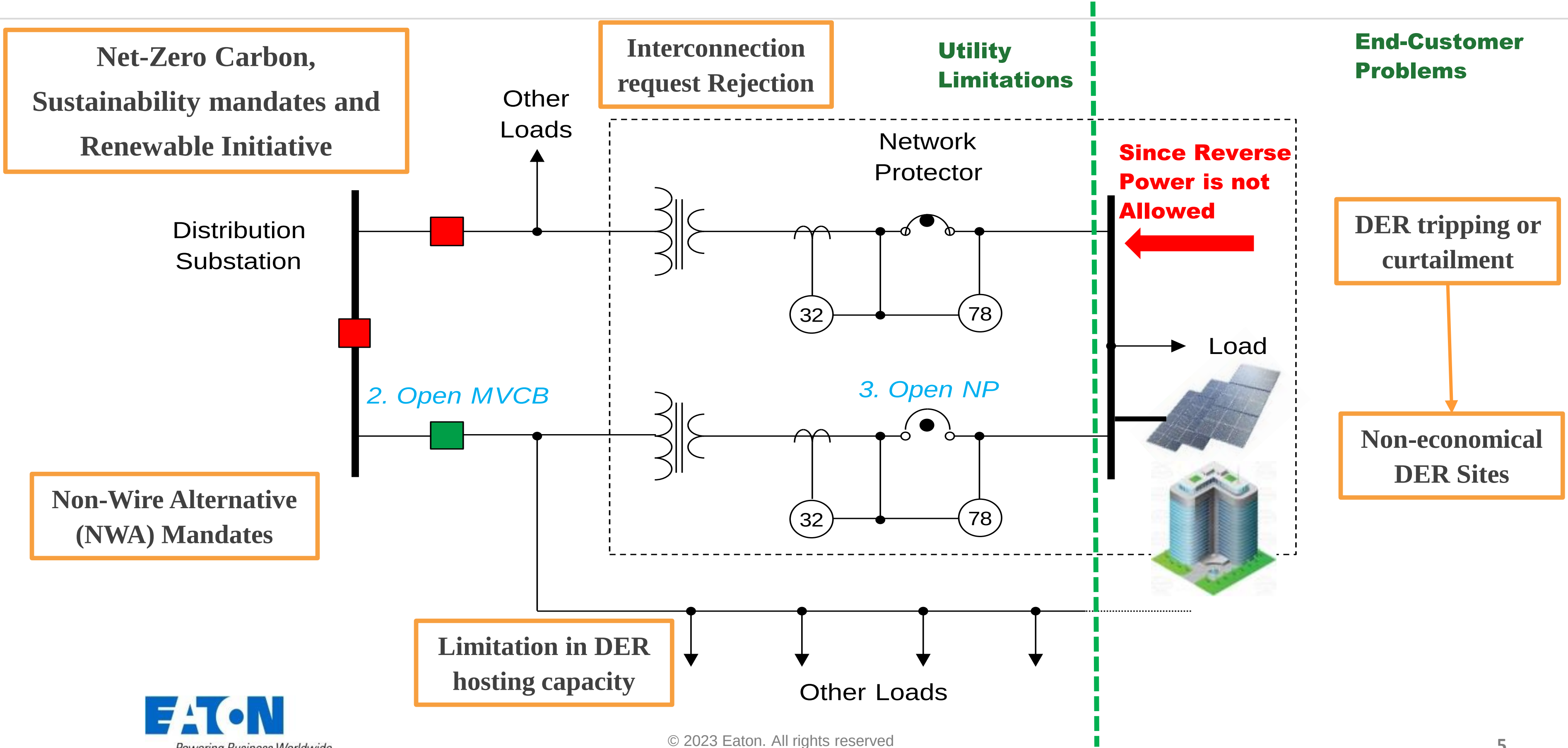
- Reverse power related to the more than adequate generation results to unintentional tripping and leads to interruption of service for thousands of highly critical loads



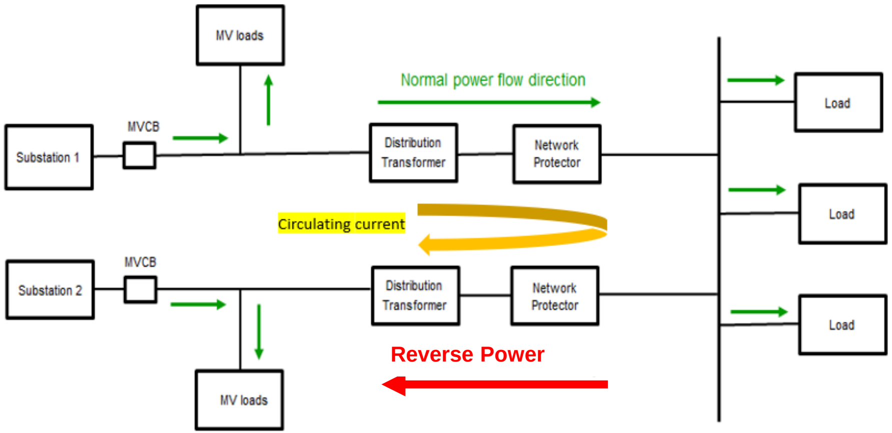
Current Solutions:



Value Proposition for Problem 1



Problem Statement 2 – Unintended tripping and Reclosing Problem On Systems Fed from Two Different Substations



Value Proposition:

- Increase reliability by using Spot Network and NWP.
- Cost reduction due to the elimination of the Transfer Switch and associated protection/communication.
- Ease of operation using Spot Network

Problem:

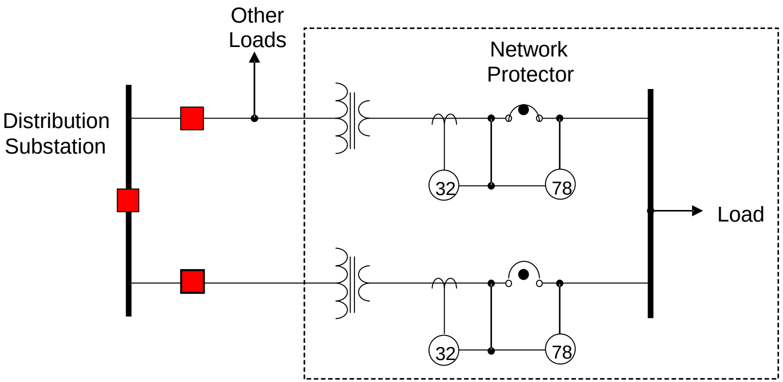
- After 9/11 the security requirements for critical infrastructure such as Hospitals, Data centers, and Airports requires feeding those loads from two separate substations.
- Voltage magnitude and angle difference due to the feeder head voltage difference will result in **circulating current** and unintended Tripping since one of the NWP will see reverse power!
- Because of the voltage angle difference in the systems fed from two substations, NWP also fails to reclose automatically!
- Currently, because of their limitations NWP and Spot system cannot be used for critical loads.

Eaton Solution

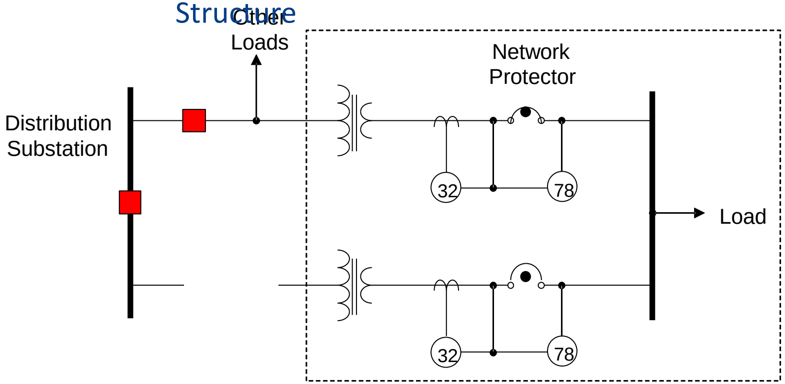
Fundamental concept of the new logic :

- System has Loop structure in normal condition, Radial structure in abnormal situation
- Electrons behave differently in Loop system compared to Radial system
- Detecting system structure is the indicator of normal vs. abnormal condition

Normal condition- Loop Structure



Abnormal condition- Radial Structure



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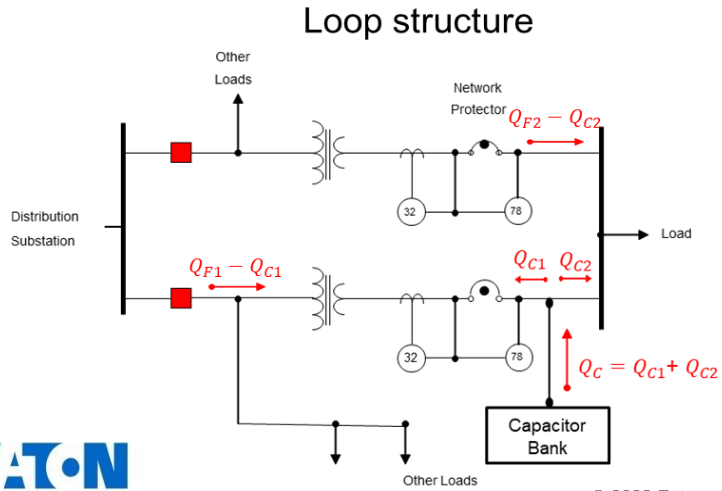
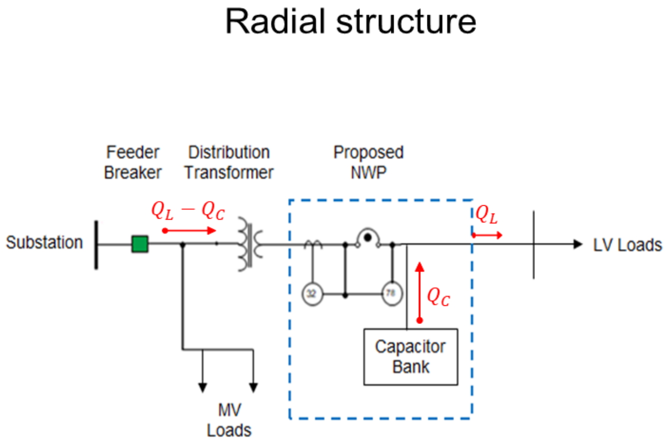
Eaton Solution (Cont.)

New logic:

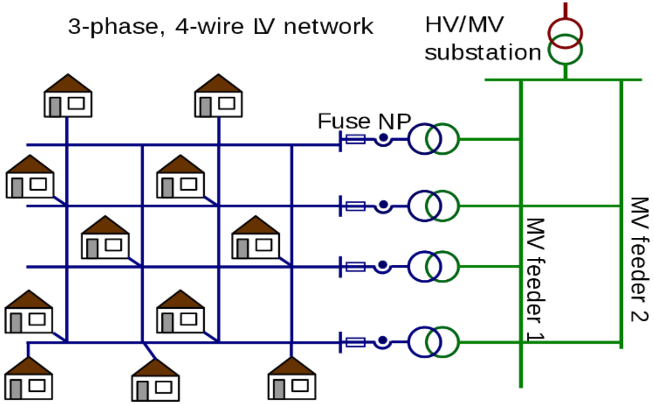
- When MVCB opens (Abnormal condition), system has a radial structure and according to the KCL, the entire reactive power injected by the capacitor will be the source of reactive power consumption on the network/load side. Therefore, the reactive power flow of the load side will remain constant while the reactive flow of the source/transformer side will change exactly by the amount injected by the capacitor bank (right figure).

- During normal condition where the feeder breaker is closed, system has a mesh structure, and based on the KCL ,the reactive power injected by the capacitor bank will be divided based on each side's impedance, so both side will see change in their power flow (left figure).



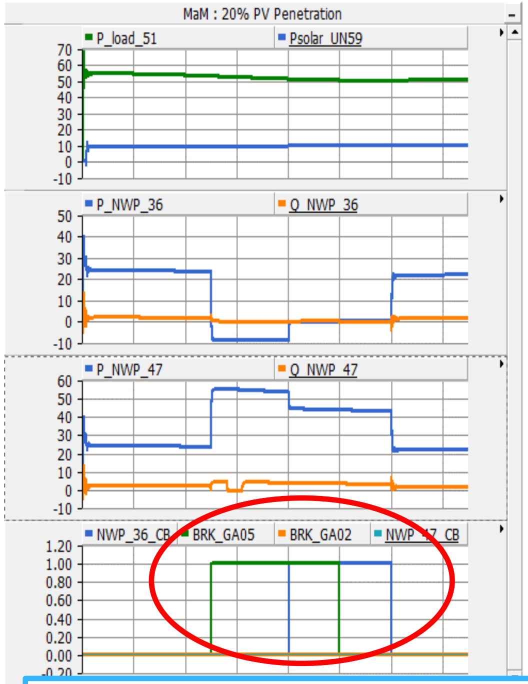


High DER Penetration (Problem 1)

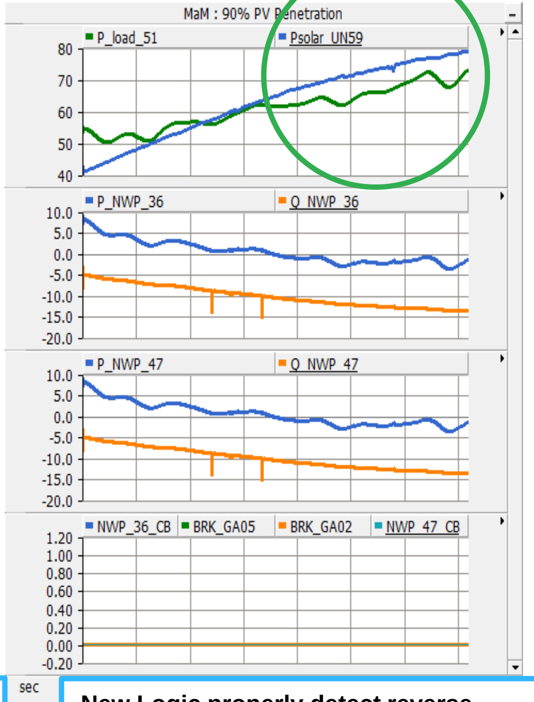


Learnings and take away:

- Loop detection logic successfully proven to be **effective** on **both area networks** and **spot networks**.
- Testing results proved the **robustness** and **scalability**.
- **Patent** application, **VOC** and **market study** is underway.



New Logic trip and reclose properly with the opening of substation CB



New Logic properly detect reverse power due to DER and won't trip

The concept has been proved in simulation and the robustness of the solution is under study

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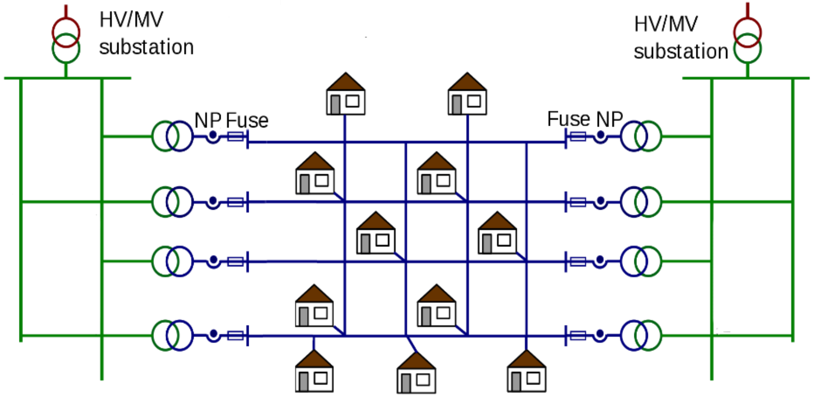
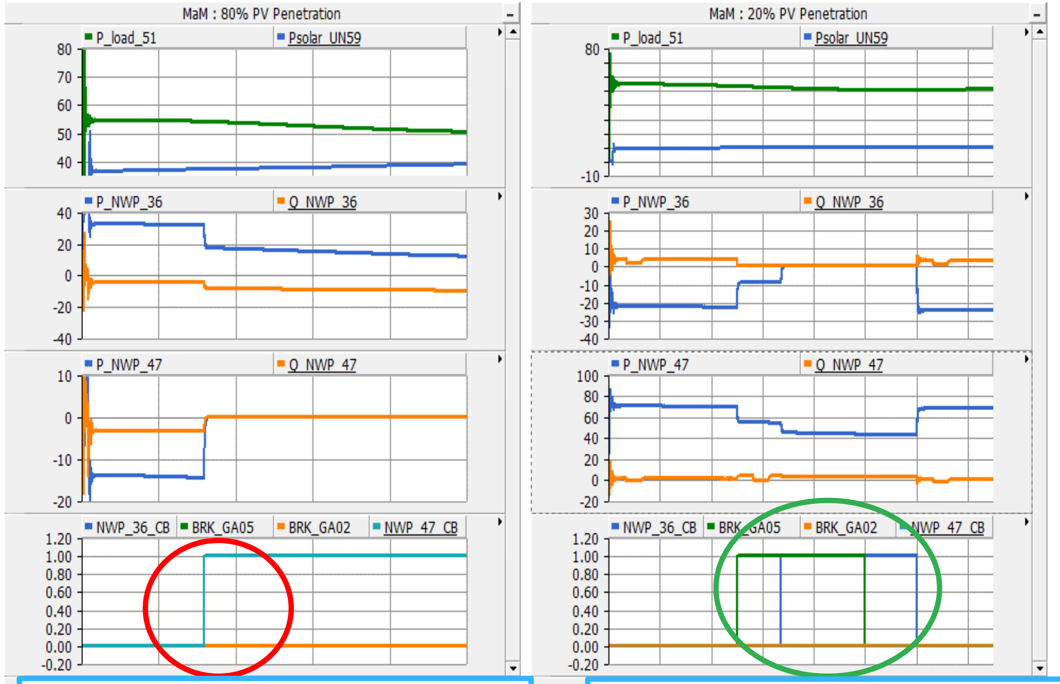
Systems Fed by Two Substations (Problem 2)





Old Logic fails to reclose due to the voltage angle difference of its two sides

New Logic properly trip and reclose voltage angle difference of its two sides

Learnings and take away:

- Loop detection logic successfully proven to be **effective** on **both area networks** and **spot networks** fed by **two substations**.
- Testing shows promising results for **robustness** and **scalability validation**.
- **Patent** application, **VOC** and **market study** is underway.

The concept has been proved in simulation and the robustness of the solution is under study

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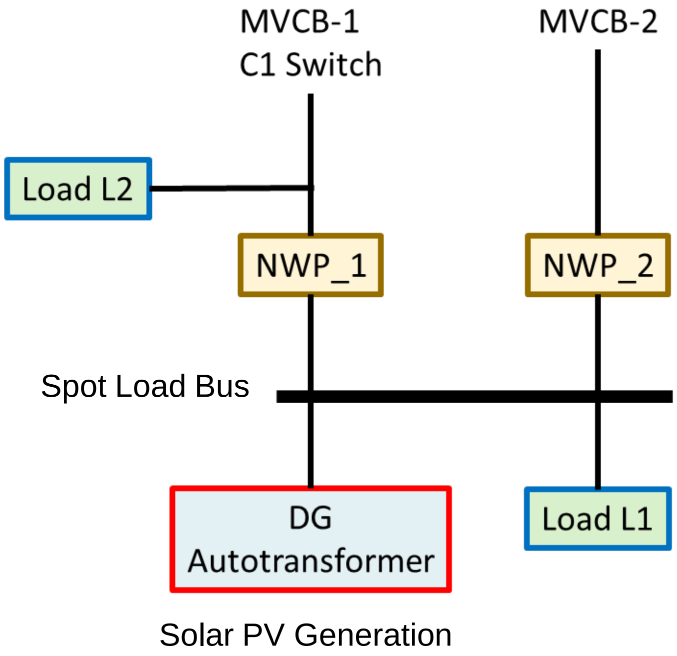
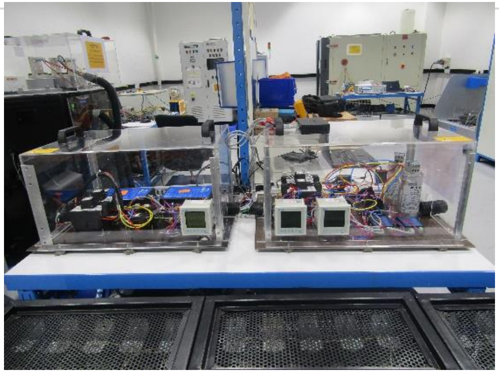
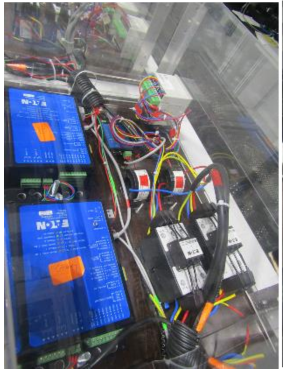
Eaton Solution Validation in the Lab

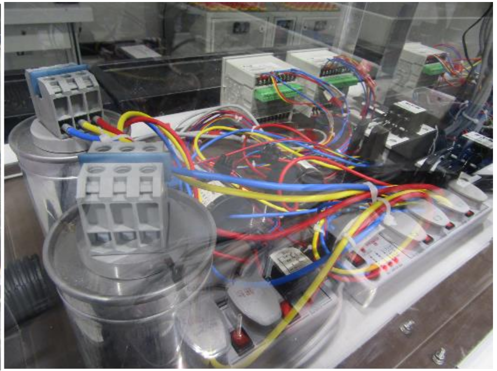
- Network Protector rating
  - 10 / 29 A , 415V (L-L)
- Load rating
  - L2 = 40kW, L1 = 1.5 kW
- Capacitor Bank rating:
  - 5kVAR, 415V(L-L)
- Autotransformer – 415V, 40A
  - Used as Source to create reverse power flow



Eaton Solution Validation in the Lab (Pictures)







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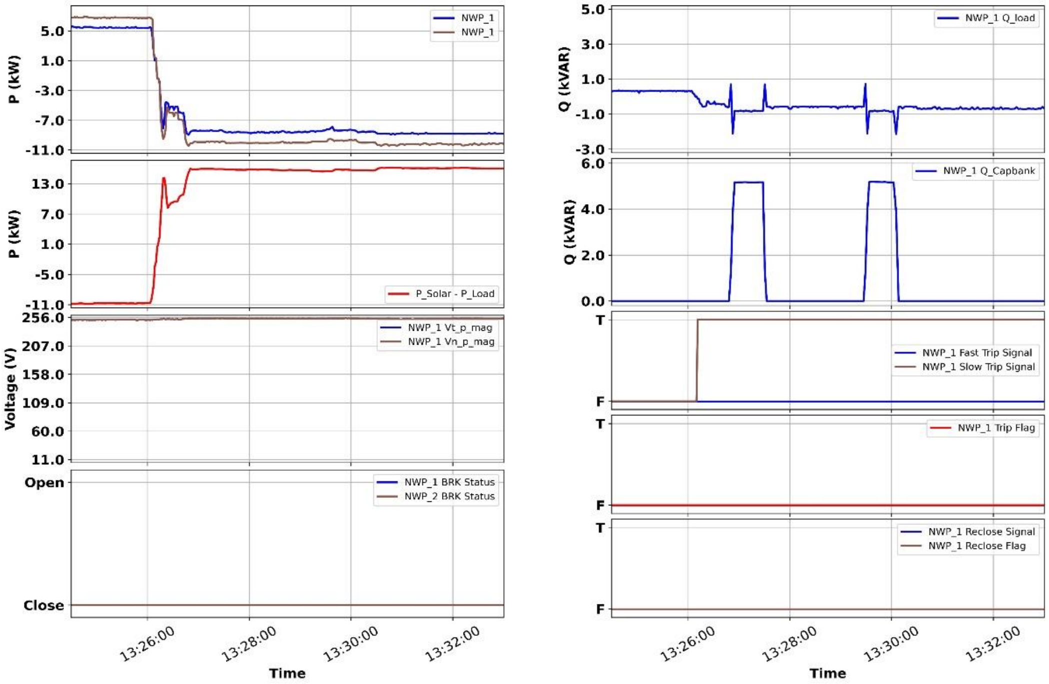
Eaton Solution Validation in the Lab (Results)



PV based reverse current testing:

- 13:24:30 – Start, Both device ON, Feeder 1 is ON
- 13:26:30 – PV power increased
  - both device see the change
  - Test activated, No trip

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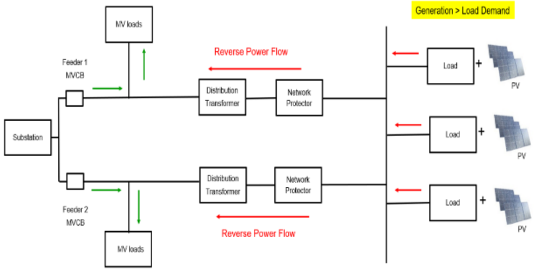
Smart Low-Carbon Urban Networks

Problem 1:



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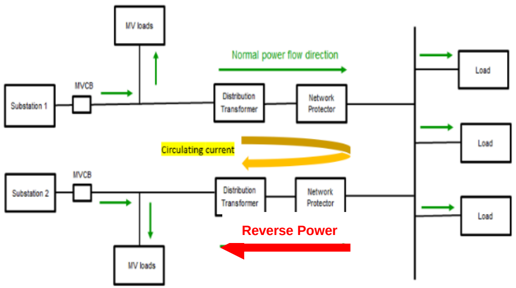
Reverse power related to the more than adequate generation results to unintentional tripping and leads to interruption of service for thousands of highly critical loads

Problem 2:



After 9/11 the security requirements for critical infrastructure such as Hospitals, Data centers, and Airports requires feeding those loads from two separate substations.

Voltage magnitude and angle difference due to the feeder head voltage difference will result in **circulating current** and unintended Tripping since one of the NWP will see reverse power!

Because of the voltage angle difference in the systems fed from two substations, NWP also fails to reclose automatically!

Currently, because of their limitations NWP and Spot system cannot be used for critical loads.

Eaton Solution:

- New logic that differentiate between normal reverse and reverse due to system abnormal events
- Cost-effective and easy to implement
- Allow up to 100% reverse power in system
- Help utilities to meet their Sustainability, DER integration and Low-Carbon initiative mandates.
- Retrofittable to existing equipment
- Increase reliability by expanding use of Spot Networks.
- Applicable for MV feeders and critical infrastructure such as Hospitals, Data centers, and Airports.

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