UNLOCKING THE POTENTIAL OF DISTRIBUTED ENERGY RESOURCES IN ENMAX'S SECONDARY NETWORK SYSTEM

ELECTRICAL NETWORK SYSTEMS CONFERENCE – APRIL 25, 2023

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ACKNOWLEDGEMENT

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ALBERTA INNOVATES

OUTLINE

- Scope
- Secondary Network Systems
- Engineering Solution Overview
  - P&C Setting Modifications
  - P&C Cabinet Design
  - PQ Meter Design
- Fault Analysis
- Accomplishments & Lessons Learnt
- Summary

SCOPE

ENMAX Power Corporation (EPC) aims to develop the ability to enable Distributed Energy Resources (DERs) to export power onto the secondary network system.

Key objectives:

- Design a standardized engineering solution
- Maintain system reliability, security & safety in new solution
- Select a test site in EPC's secondary network system to deploy the engineering solution
- Data collection at the test site to evaluate, validate and measure system performance

SECONDARY NETWORK SYSTEMS

INTRODUCTION

Secondary Network Systems are special low voltage (below 600V) distribution system where multiple feeders operate in parallel to feed the load.

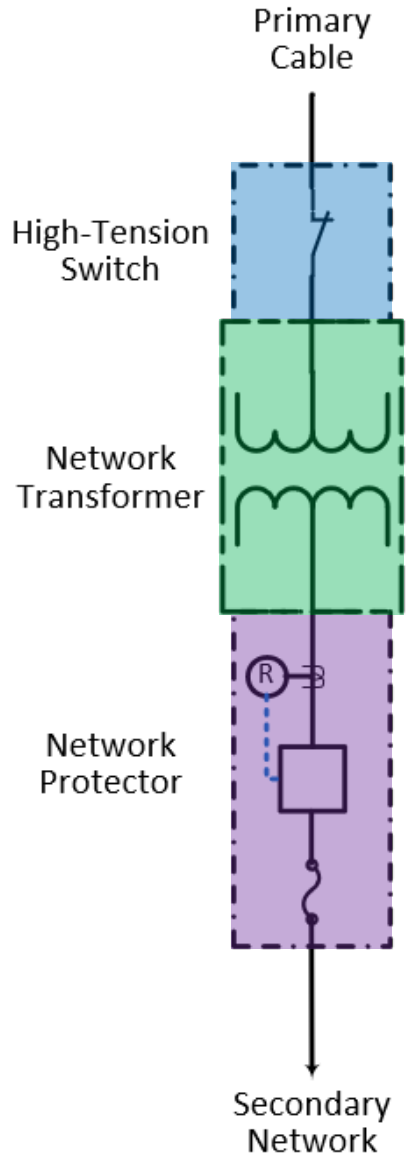
Key features:

- Highly reliable & redundant – multiple parallel sources
- Enhanced customer experience – service continuity
- High system efficiency – low losses
- Design does not allow reverse power flow – DERs not permitted to export

INTRODUCTION

Network Transformer Unit is a sealed unit designed to be completely submersible and has following key components

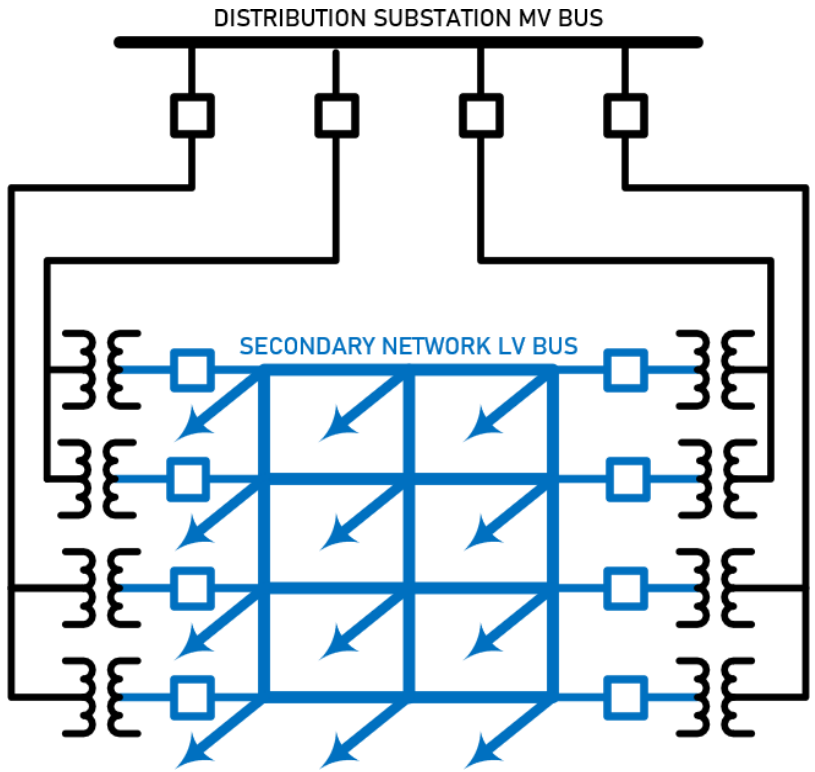
- High-Tension Switch (HTSW)
- Network Transformer (XFM)
- Network Protector (NWP)
- Fuses



INTRODUCTION

Grid Network is a secondary distribution system with

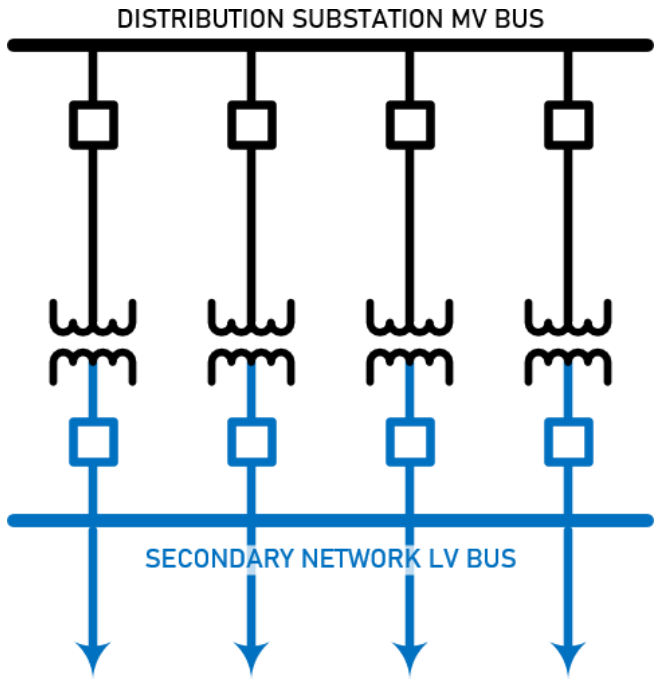
- Several network transformers installed in different vaults
- Secondary terminals of the NWPs connected by cables between vaults
- Secondary bus voltage level of 208V/120V
- Also referred to as Street Network or Street Grid



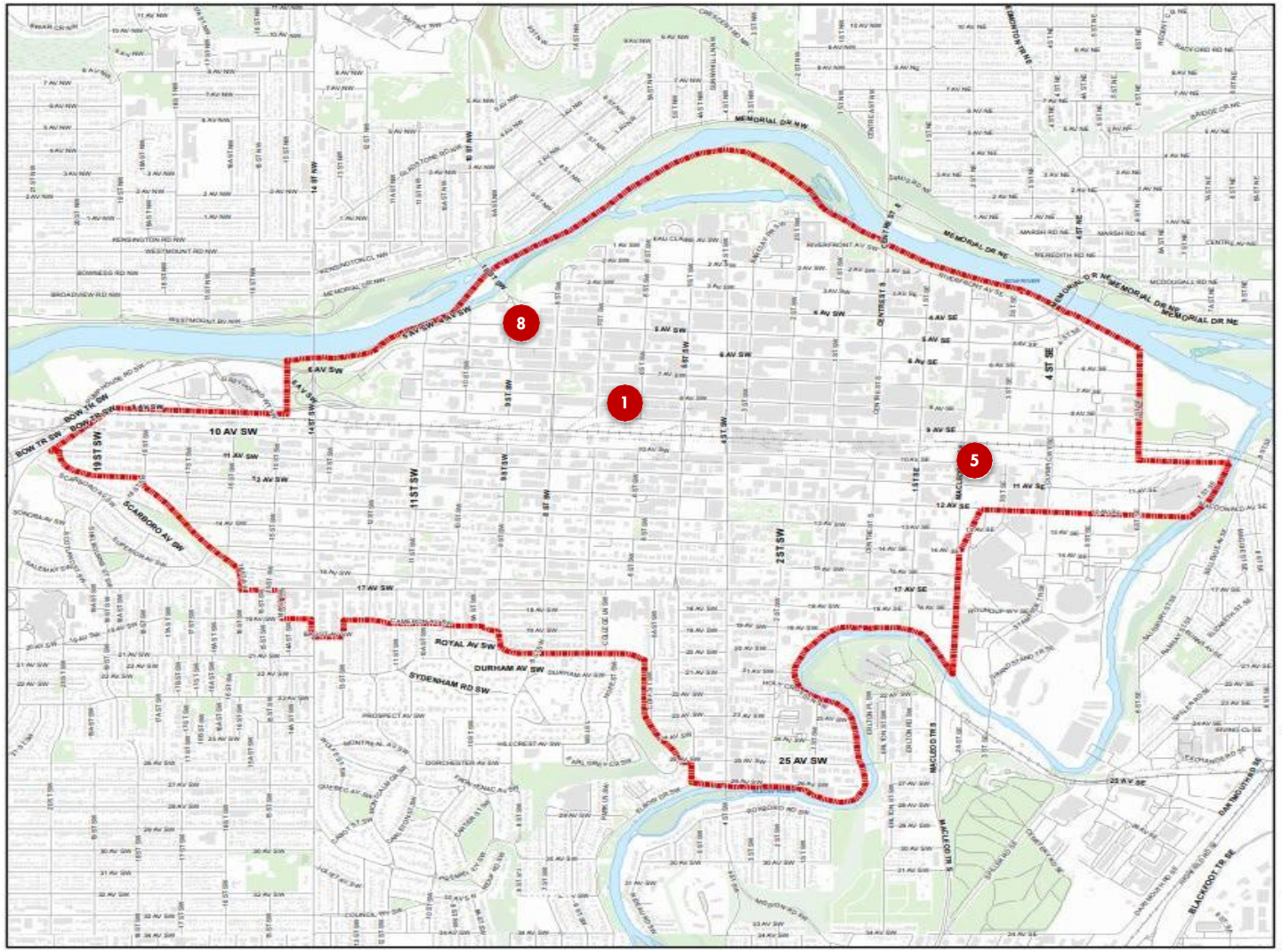
INTRODUCTION

Spot Network is a secondary distribution system with

- Two or more network transformers installed at a single site
- Secondary terminals of the NWPs are connected to a common bus
- Secondary bus voltage levels of 120/208V, 277/480V or 347/600V



CALGARY'S DOWNTOWN NETWORK



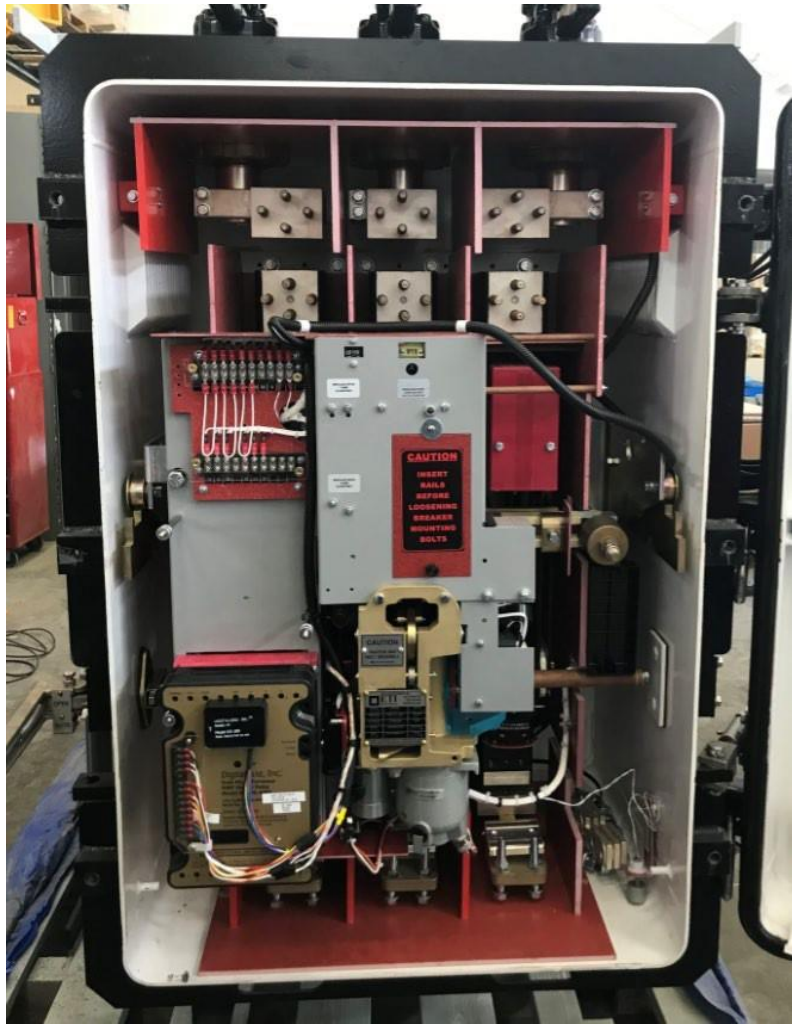
Downtown Network:

- ❑8 Square kilometers
- ❑Fed by 3 Substations:
  Sub 1, Sub 5 & Sub 8
- ❑8 Network bus zones:
  8 Feeders per zone
- ❑64 – 13.2kV Feeders
- ❑1050+ Transformers
- ❑420+ Vaults (Indoor & Street)
- ❑1300+ Manholes
- ❑3 Spot Networks outside downtown network area
- ❑18% ENMAX Load
- ❑29000+ Customers

https://www.enmax.com/generation-wires/transmission-and-distribution/our-system/distributed-generation/secondary-network-systems

EXISTING PROTECTION

- Sensitive Reverse Protection
- Phasing Check across NWP
- Automatic Close
- Anti-Pump Protection
- Safe Service Mode (SSM)
- SCADA Monitoring & Control – Ongoing project for fiber installation



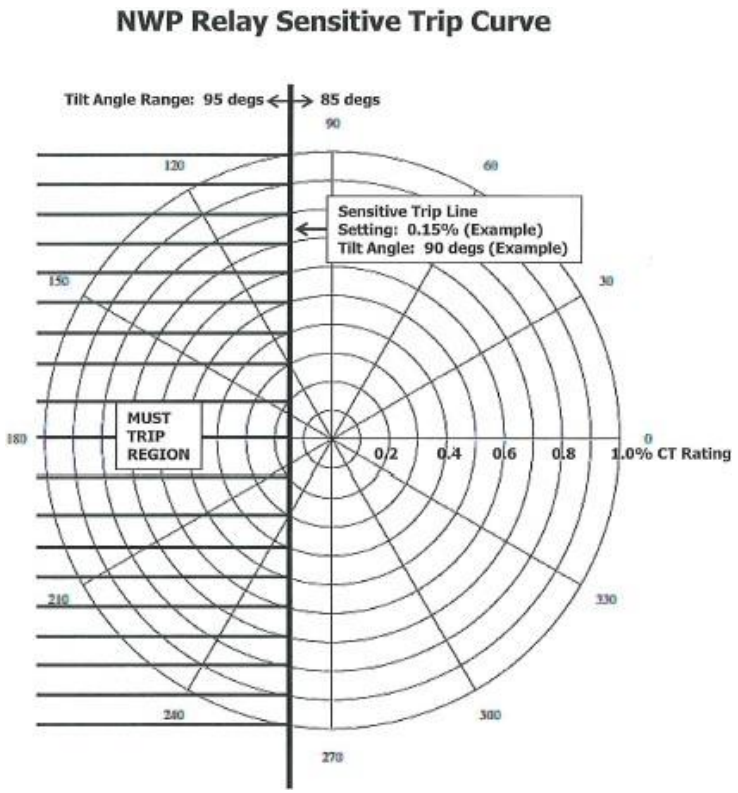
ENGINEERING SOLUTION OVERVIEW

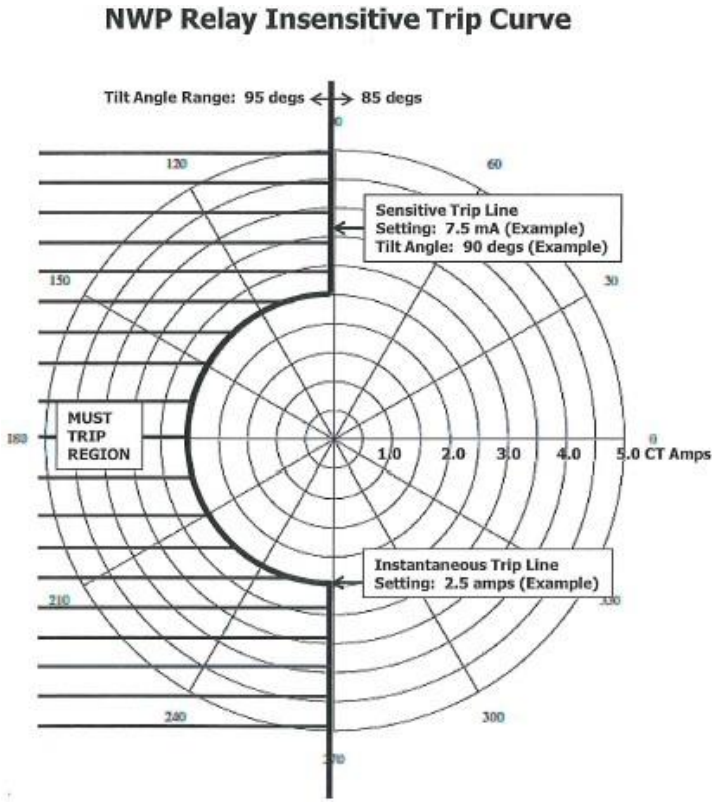
ENGINEERING CHALLENGES

- Existing network protection system does not permit reverse power flow by design
- Network systems reliability & safety must not be negatively impacted
- Automatic reclosing of NWP during DER export would not work
- Space limitation & water ingress concerns for new equipment installation
- Site selection, DER partner confirmation and Covid-19 Lockdown were added risks for the project

INSENSITIVE REVERSE PROTECTION

Insensitive reverse power is enabled in the existing protective device to allow export plus still detect & clear for a feeder fault





Insensitive element pickup is set to 100% full load current of network transformer

DIRECT TRANSFER TRIP (DTT) SCHEME

A communication assisted DTT protection scheme proposed for vault(s) with DER interconnection to resolve below concerns:

- Allowing reverse power flow may lead to slower fault clearing for some scenarios (reliability impacted)
- Allowing reverse power flow would cause back-feed during maintenance work (safety issue)

IEC 61850 communication protocol selected for the application using the existing fiber optic telecommunication network

AUTOMATIC CLOSE

Automatic close function of NWP relay is designed to close the breaker when current is flowing in the forward direction, hence:

- Automatic-close function of the relay would not work during DER export
- Modification to automatic-close function requires relay vendor to update firmware

Internal decision made to monitor the test site at this time and work with the relay vendor to update automatic close function (in future)

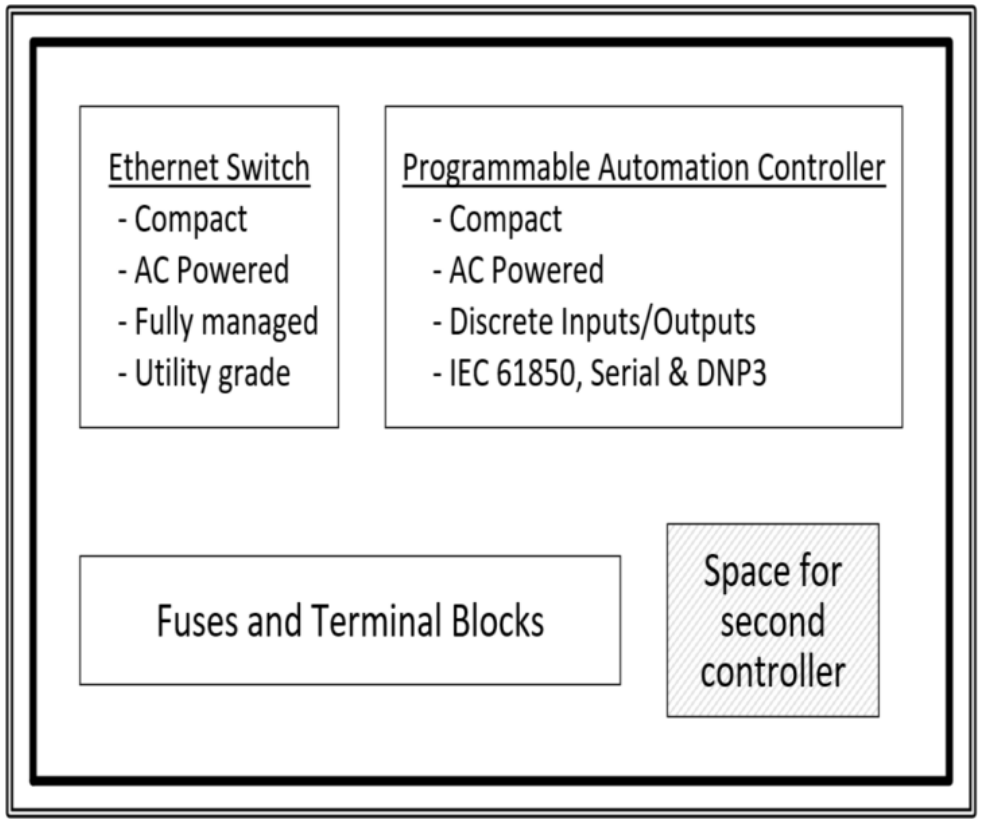
P&C CABINET DESIGN FEATURES

Design caters to the challenges noted during the project initiation:

- Compact design due to limited space in the network vaults
- Utilize existing assets & materials for low-cost solution
- New equipment cabinet design to prevent water ingress
- Equipment selection considerations included discrete inputs/outputs requirement, compact size, absence of a DC source in the vault and IEC 61850 protocol compliance

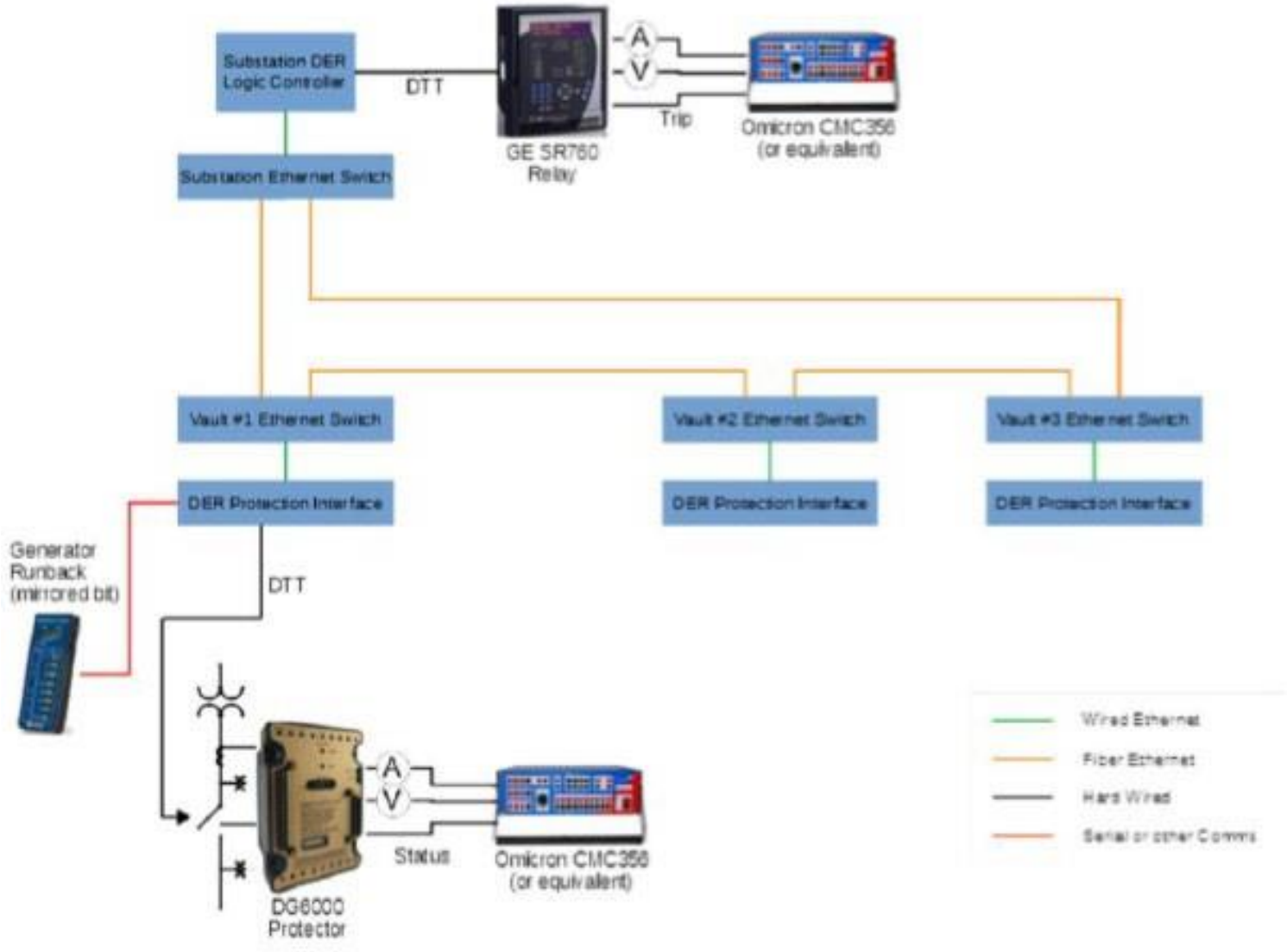
Submersible wall-mount IP67 enclosure chosen for the new cabinet design

P&C CABINET DESIGN FEATURES



Design supports upto 4 DERs interconnection in a vault

LAB TESTING BLOCK DIAGRAM



LAB TESTING RESULTS

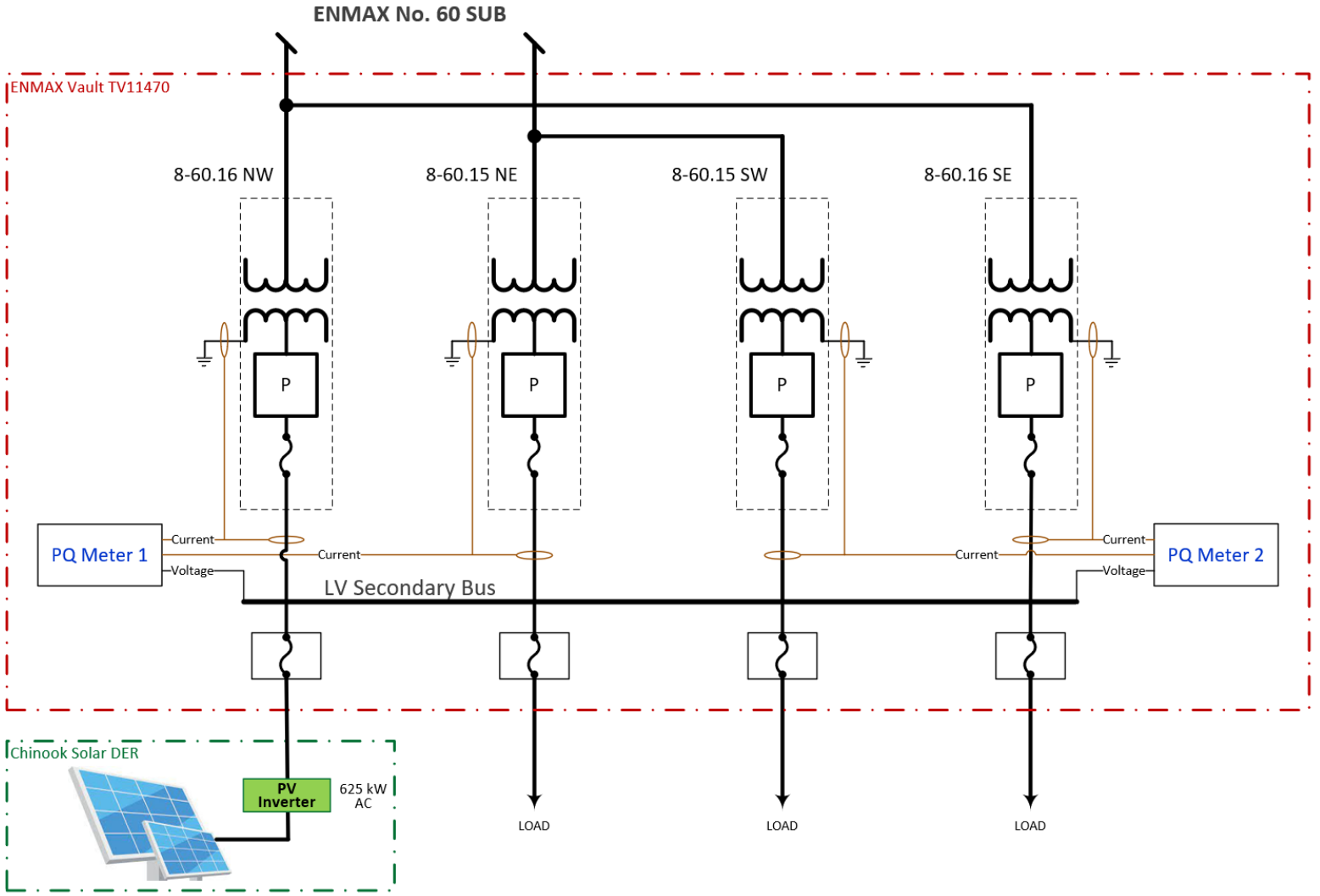
Following are results from Power Lab Testing:

- Coexistence of SCADA and protection traffic not an issue with prioritized GOOSE traffic
- Direct Transfer Trip performance : ~ 0.03s (1.8cyc)
- Insensitive reverse protection operated and tripped the NWP breaker for simulated feeder faults
- No Protection Coordination Concerns
- Protector automatic close was blocked during generation and NWP auto-closed as expected during DER non-export mode

SITE SELECTION

- Must be a Spot Network Vault
- DER owner interest in pilot
- Building requirements for Solar installation

PQ METER DESIGN



Metering Requirements:

- ❑ 16 Current Inputs
- ❑ 4 Voltage Inputs
- ❑ Remote Monitoring
- ❑ Internal Memory
- ❑ Compact size
- ❑ High-speed recording (512 samples/cycle)
- ❑ Revenue–Grade meter
- ❑ PQ monitoring capability

Two 3-phase PQ meters installed for monitoring and data collection

PERFORMANCE ANALYSIS

Microsoft Power BI performance analysis revealed following results:

- Multiple successful DER exports to the grid have been recorded since energization.
- The power generated by DER is consumed by the load on the secondary bus, reducing their energy consumption.
- Export power peaks before mall opening time in the morning.
- No problems with protection or operation have been observed in the pilot solution so far.

FAULT ANALYSIS

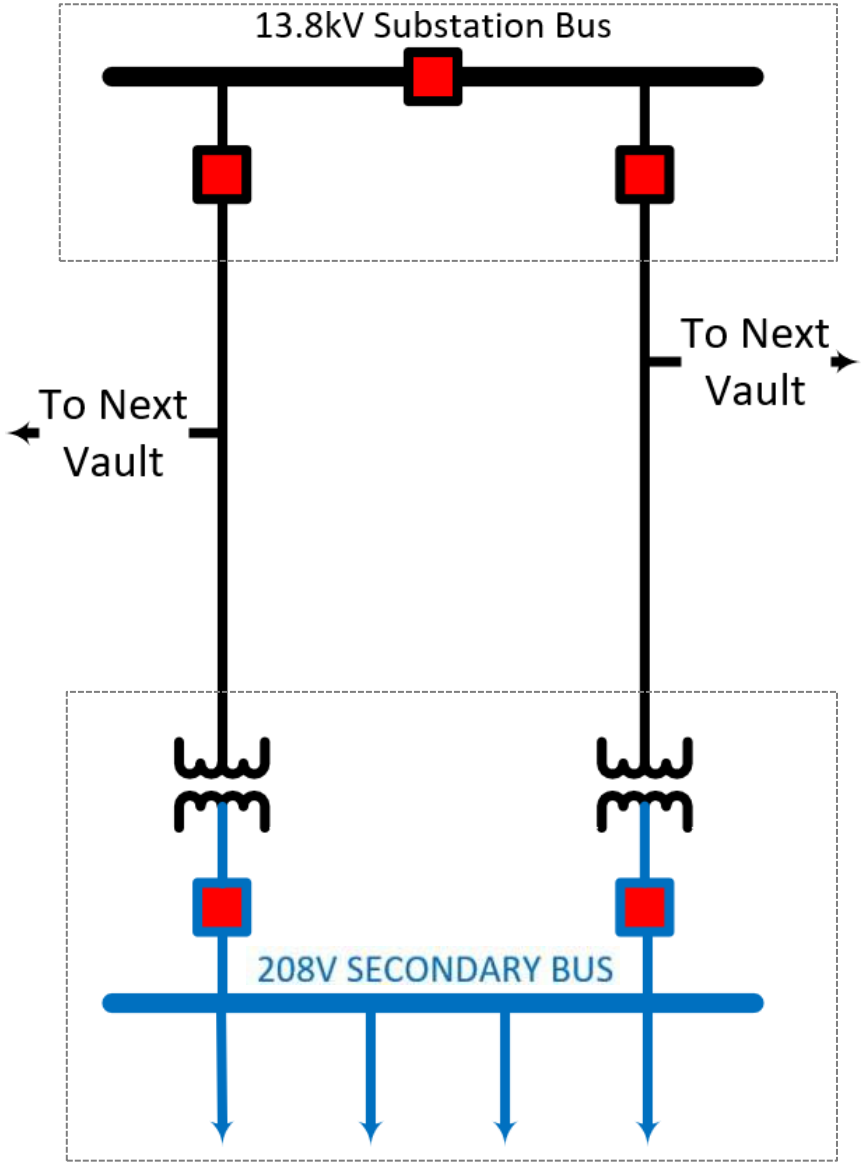
EXISTING SCHEME

Substation: Feeder Protection Relay

- Time Overcurrent Protection

Network Vault: NWP Relay

- Reverse Power (Sensitive)



EXISTING SCHEME

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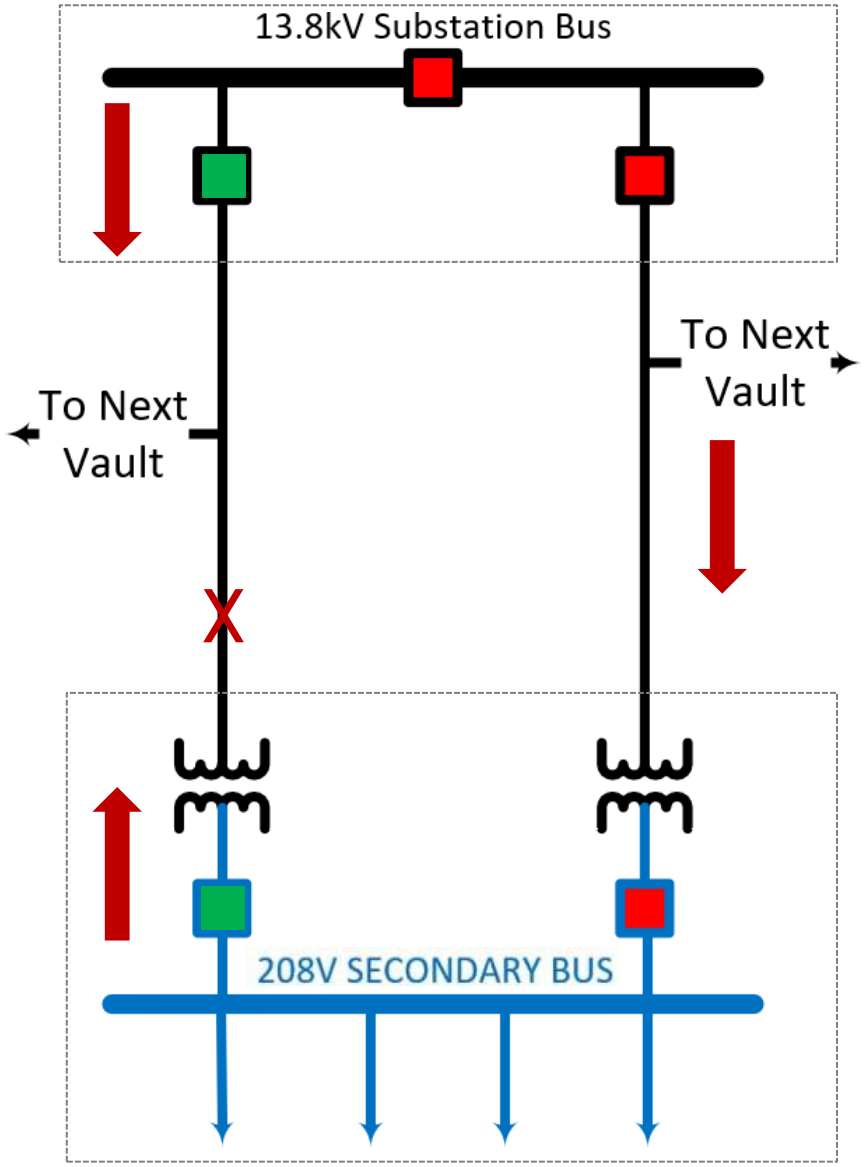
Consider a fault on feeder



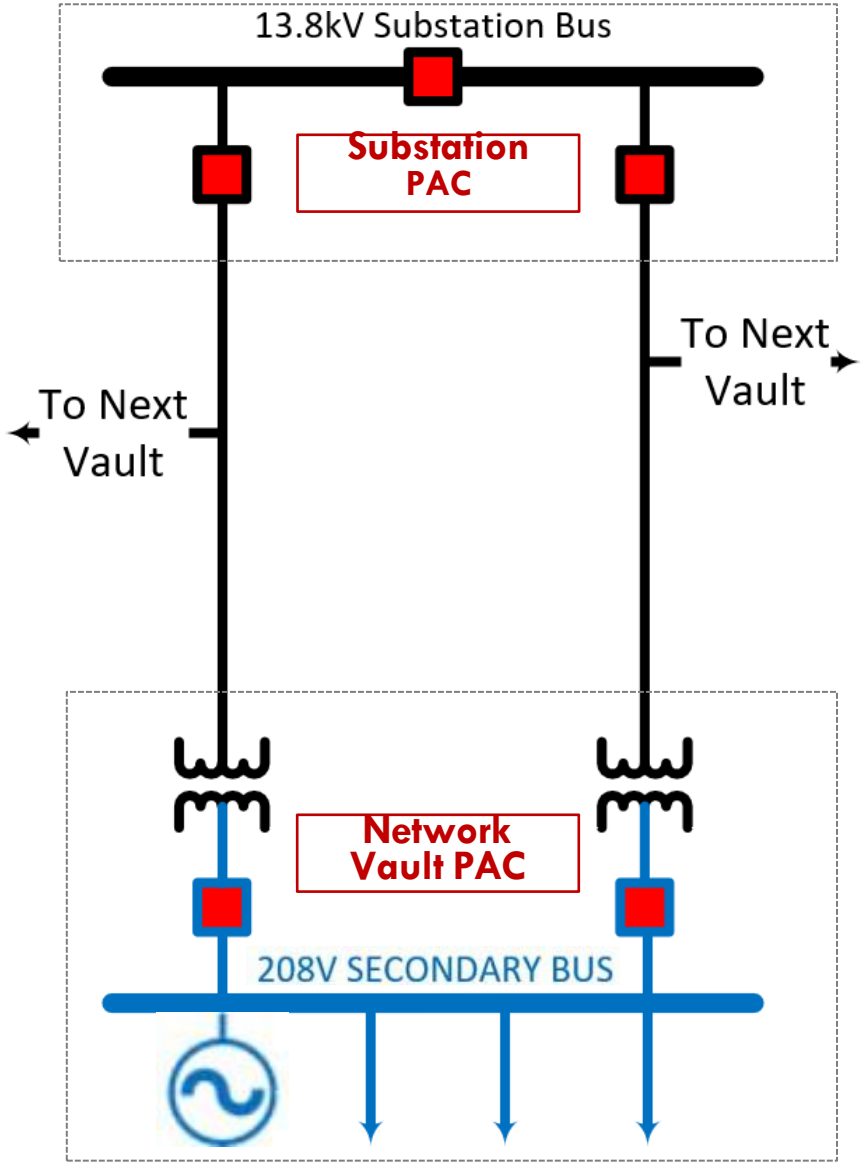
NEW PROTECTION SCHEME

Substation: Feeder Protection Relay

- Time Overcurrent Protection
- Programmable Automation Controller

Network Vault: NWP Relay

- Reverse Power (Insensitive)
- Programmable Automation Controller



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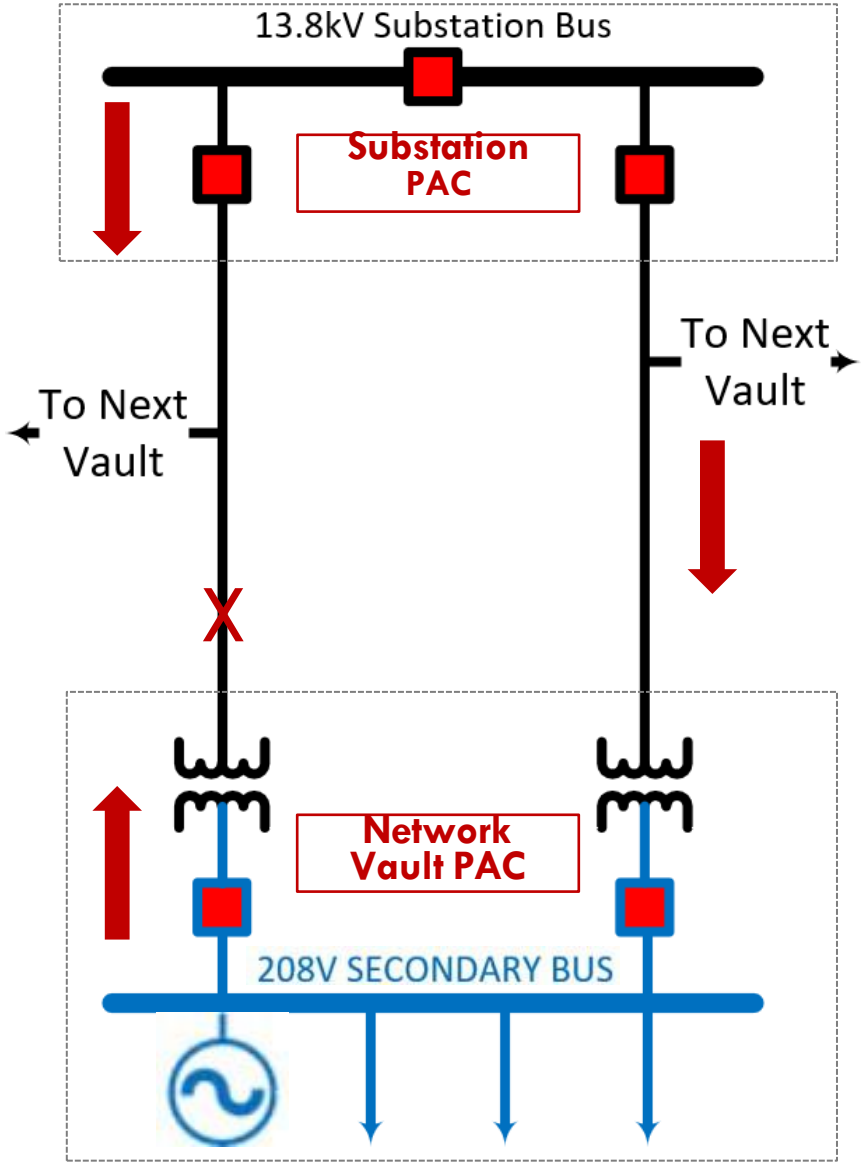

NEW PROTECTION SCHEME

Direct Transfer Trip performance :

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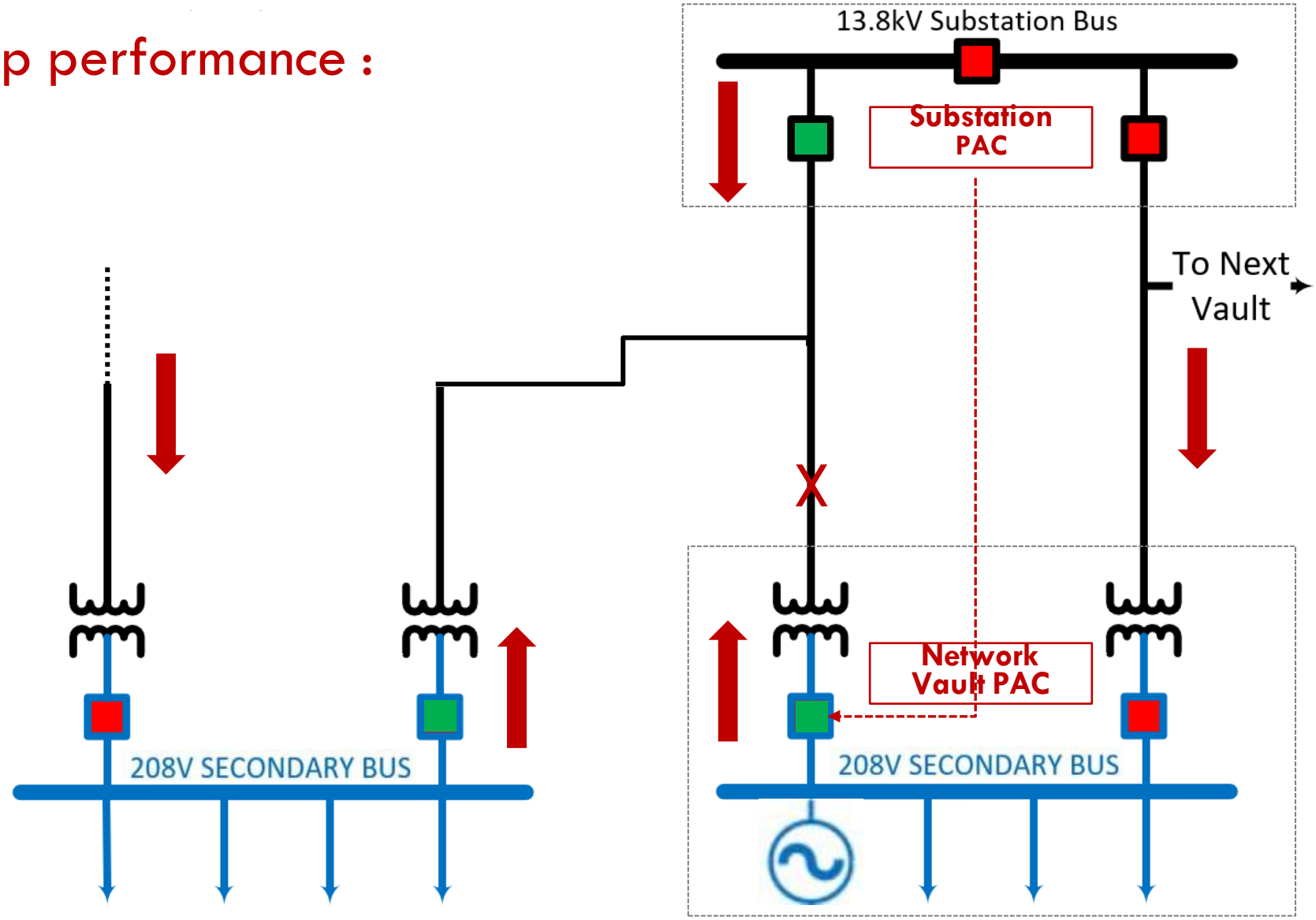
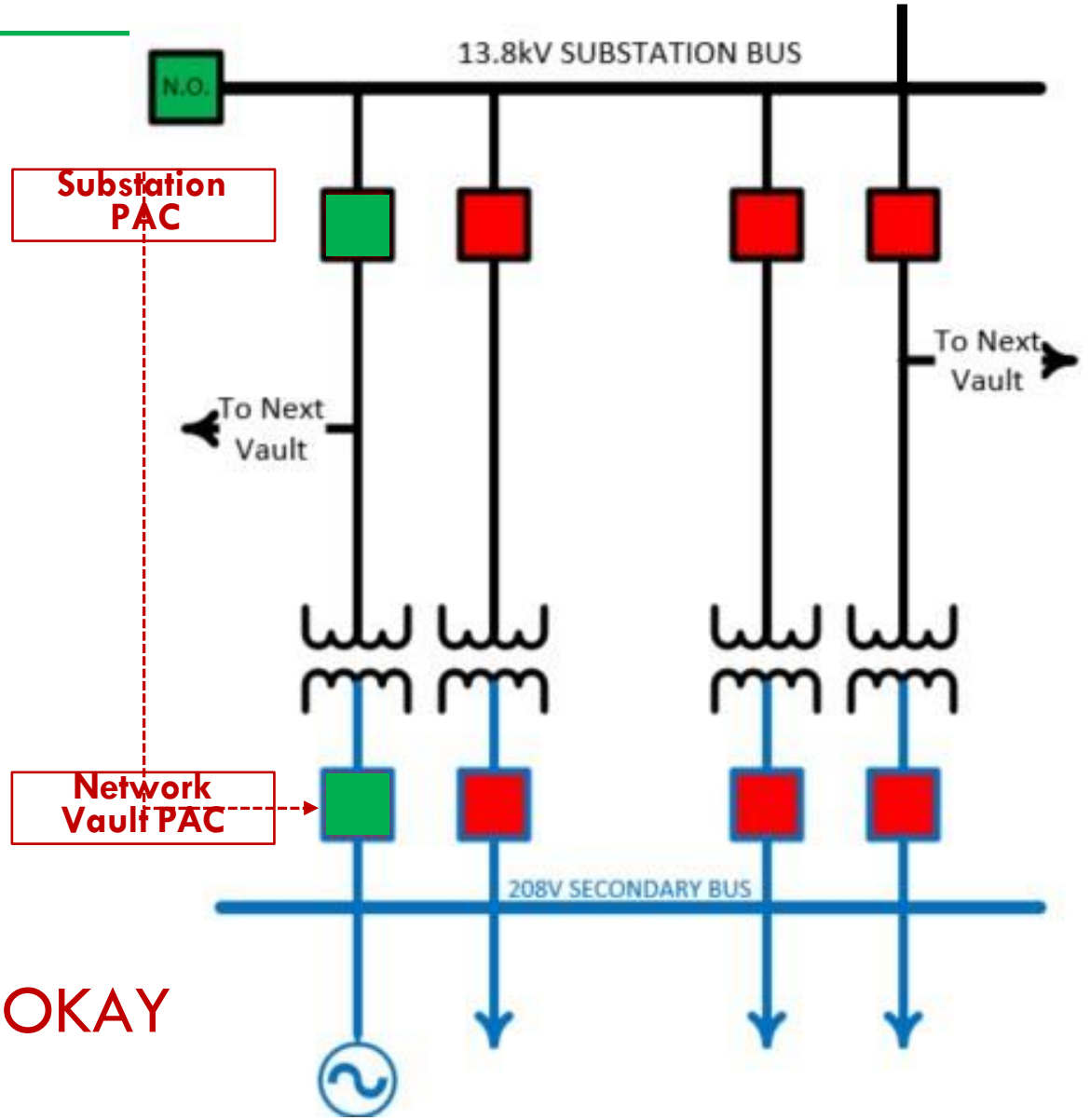


DER COMMUNICATION SCHEME

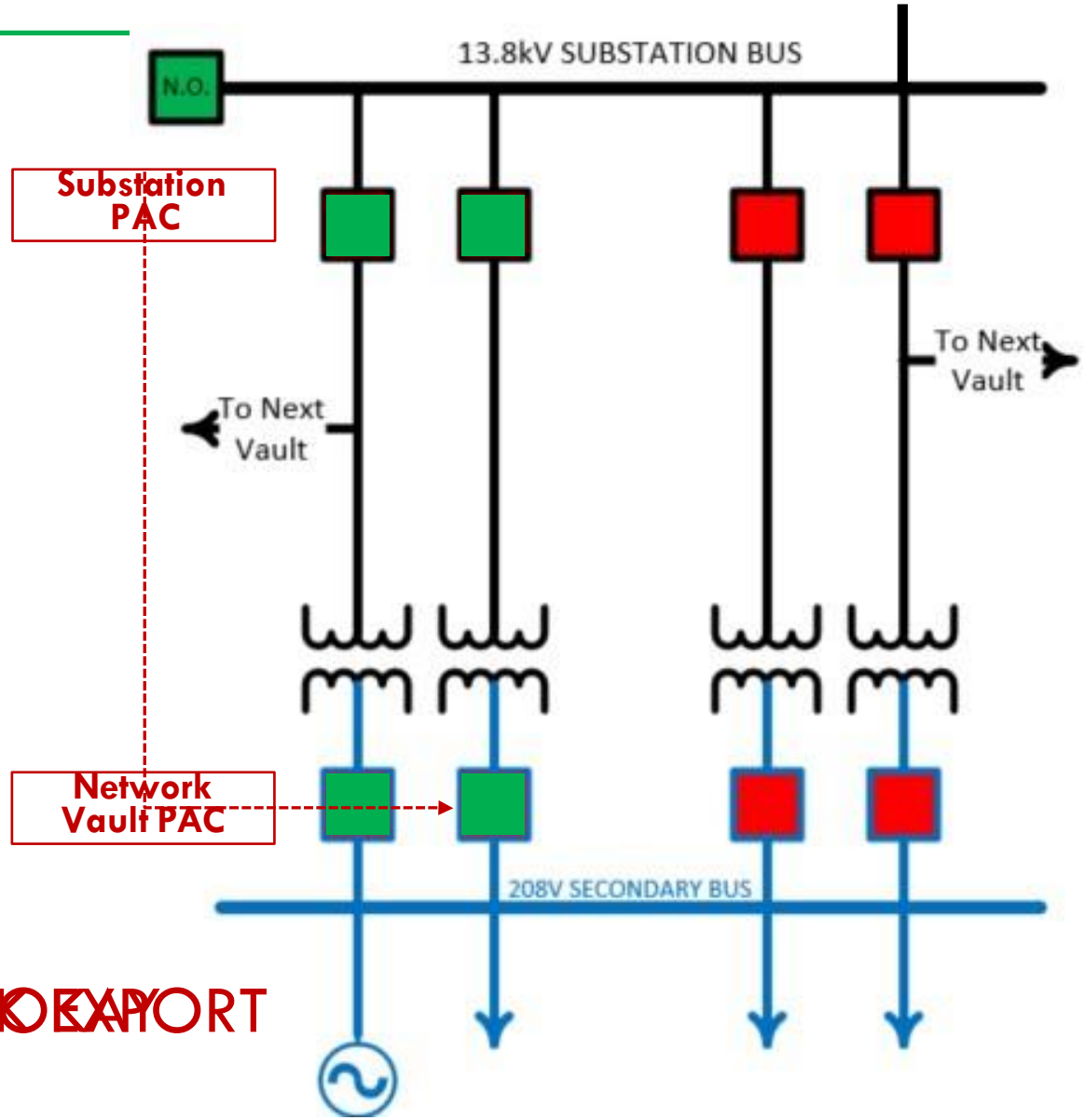
- Healthy GOOSE Communication
- Feeding Substation is in normal configuration
- Network Vault
  - Normal
  - N-1 Configuration



EXPORT OKAY

DER COMMUNICATION SCHEME

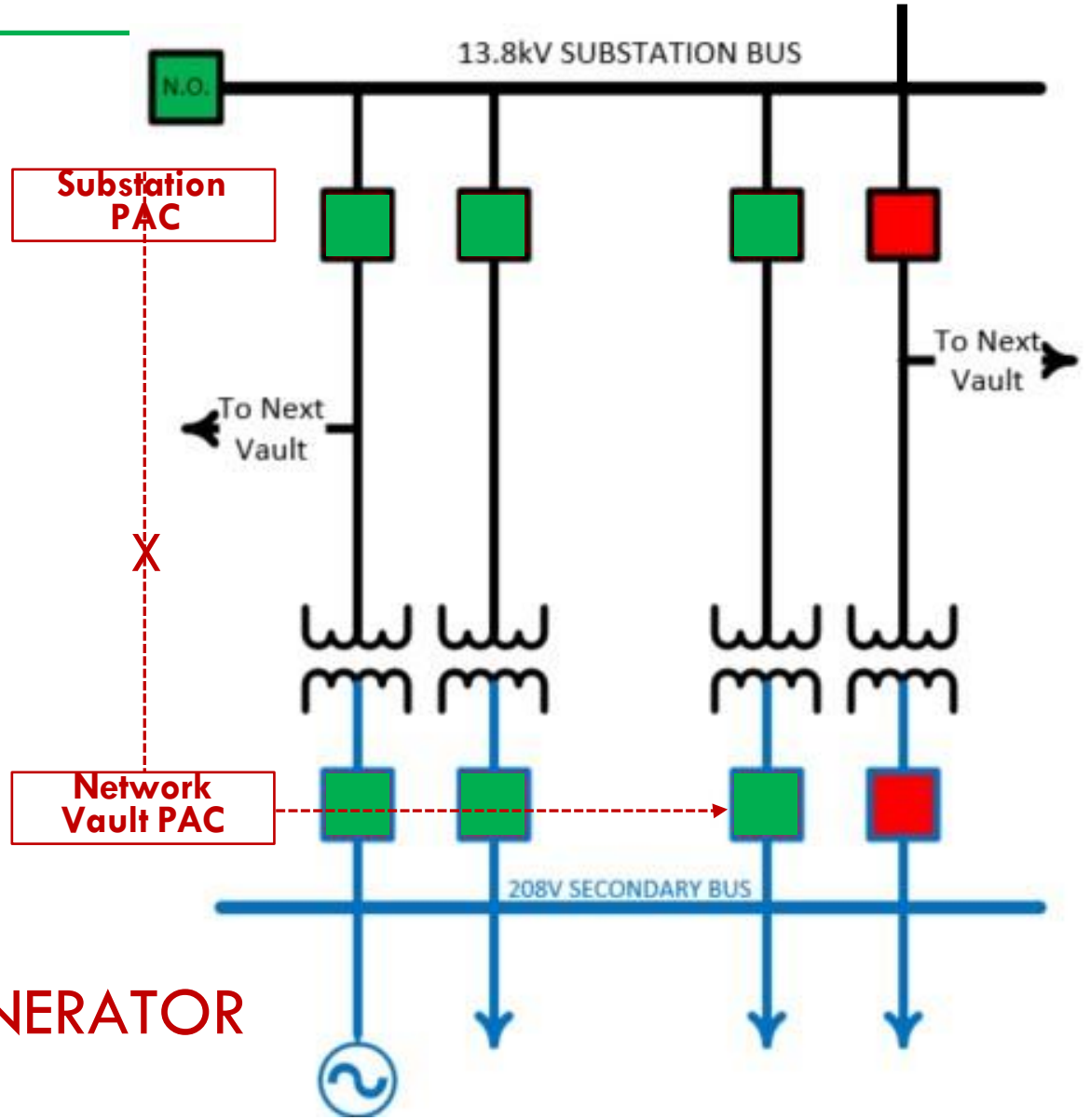
- Healthy GOOSE Communication
- Feeding Substation is in normal configuration
- Network Vault
  - N-2 Configuration



DER COMMUNICATION SCHEME

DER tripped for below conditions:

- Local control for maintenance
- Network Vault
  - N-3 Configuration
- Loss of GOOSE Communication
  - DNP Custom Logic
- Feeding Substation in emergency mode



MILESTONES, LESSONS LEARNT &SUMMARY

ENGINEERING MILESTONES

- Equipment Selection – Completed
- Site Selection – Completed
- Preliminary Engineering Design – Completed
- Protector Relay & Automation Controller Settings – Completed
- Power Lab Testing – Completed
- PQ Meter Design & Installation – Completed
- Testing and Commissioning – Completed
- End-to-End System Testing with DER – Completed
- Site Energized – April 04, 2022
- Data collection, analysis and system monitoring – Ongoing

LESSONS LEARNT

- Accurate sizing of the Solar plant was essential for achieving the desired export level.
- Planning, research and budgeting are necessary for a successful project.
- Collaborating with DER owners is essential for effective communication, defining roles and responsibilities.
- Third-party power laboratory testing was beneficial in addressing concerns & verifying assumptions.
- Carrying out site commissioning in an iterative manner aided in enhancing system performance.
- Using high-precision PQ meters and Power BI for data processing ensured accurate performance analysis.

SUMMARY

- Completed pilot project as proof of concept
  - Performed network system modelling and coordination studies
  - Standardized engineering solution is scalable to support multiple DERs Direct
  - Transfer Trip performance : ~ 0.03s (1.8cyc)
  - Data from PQ meters is being analyzed
- Leveraging the use of fiber optic cables in secondary network system makes this an economically viable solution for the customer
- EPC to expand the engineering solution to enable DER export on Street Grids

Thank You.

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Cadillac Fairview