Third Meeting of WG PC57.133

“Guide for Evaluating Transformer Performance under Reverse Power Flow”

IEEE PES Transformers Committee
Standards Subcommittee

3:15 PM to 4:30 PM MDT |March 25, 2025
Centennial DE (Floor 3)
Hyatt Regency Denver at Colorado Convention Center
Denver, CO

IEEE PES Power & Energy Society® IEEE

WG Leadership

Chair: Ryan Hogg |Bureau of Reclamation

rhogg@ieee.org

Vice Chair: Bruce Webb | Knoxville Utilities Board

bruce.webb@kub.org

Secretary: Drew Welton | Intellirent

dwelton@intellirentco.com

Recording

- Plan to record this meeting for purpose of meeting minutes only, delete after developed – any objections

Agenda

- Pull up PDF

Behavior/Copyright/Patent

- On next 12 slides

Participant behavior in IEEE-SA activities is guided by the IEEE Codes of Ethics & Conduct

- All participants in IEEE-SA activities are expected to adhere to the core principles underlying the:
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  - IEEE Code of Conduct
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- This rule applies equally to those participating in a standards development project and to that project's leadership group
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IEEE SA
STANDARDS
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IEEE SA COPYRIGHT POLICY

NOVEMBER 2019

IEEE

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At the beginning of each standards development meeting the chair or a designee is to:

- Show the following slides (or provide them beforehand)
- Advise the standards development group participants that:
- IEEE SA's copyright policy is described in Clause 7 of the IEEE SA Standards Board Bylaws and Clause 6.1 of the IEEE SA Standards Board Operations Manual;
- Any material submitted during standards development, whether verbal, recorded, or in written form, is a Contribution and shall comply with the IEEE SA Copyright Policy;
- Instruct the Secretary to record in the minutes of the relevant meeting:
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- Previously Published material (copyright assertion indicated) shall not be presented/submitted to the Working Group nor incorporated into a Working Group draft unless permission is granted.
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IEEE SA COPYRIGHT POLICY

- The IEEE SA Copyright Policy is described in the IEEE SA Standards Board Bylaws and IEEE SA Standards Board Operations Manual
  - IEEE SA Copyright Policy, see
    Clause 7 of the IEEE SA Standards Board Bylaws
    https://standards.ieee.org/about/policies/bylaws/sect6-7.html#7
    Clause 6.1 of the IEEE SA Standards Board Operations Manual
    https://standards.ieee.org/about/policies/opman/sect6.html
- IEEE SA Copyright Permission
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- IEEE SA Copyright FAQs
  - https://standards.ieee.org/faqs/copyrights/
- IEEE SA Best Practices for IEEE Standards Development

http://standards.ieee.org/content/dam/ieee-standards/standards/web/documents/other/best_practices_for_ieee_standards_development_051215.pdf

- Distribution of Draft Standards (see 6.1.3 of the SASB Operations Manual)
  - https://standards.ieee.org/about/policies/opman/sect6.html

INSTRUCTIONS FOR THE WG CHAIR

The IEEE SA strongly recommends that at each WG meeting the chair or a designee:

- **Show slides 1 through 4 of this presentation**
- **Advise the WG attendees that:**
  - The patent policy is described in Clause 6 of the *IEEE SA Standards Board Bylaws*;
  - Early identification of patent claims which may be essential for the use of standards under development is strongly encouraged;
  - There may be Essential Patent Claims of which IEEE is not aware. Additionally, neither IEEE, the WG, nor the WG Chair can ensure the accuracy or completeness of any assurance or whether any such assurance is, in fact, of a Patent Claim that is essential for the use of the standard under development.
- **Instruct the WG Secretary to record in the minutes of the relevant WG meeting:**
  - That the foregoing information was provided and that slides 1 through 4 (and this slide 0, if applicable) were shown;
  - That the chair or designee provided an opportunity for participants to identify patent claim(s)/patent application claim(s) and/or the holder of patent claim(s)/patent application claim(s) of which the participant is personally aware and that may be essential for the use of that standard
  - Any responses that were given, specifically the patent claim(s)/patent application claim(s) and/or the holder of the patent claim(s)/patent application claim(s) that were identified (if any) and by whom.
- The WG Chair shall ensure that a request is made to any identified holders of potential essential patent claim(s) to complete and submit a Letter of Assurance.
- It is recommended that the WG Chair review the guidance in *IEEE SA Standards Board Operations Manual* 6.3.5 and in FAQs 14 and 15 on inclusion of potential Essential Patent Claims by incorporation or by reference.

Note: **WG** includes Working Groups, Task Groups, and other standards-developing committees with a PAR approved by the IEEE SA Standards Board.

PARTICIPANTS HAVE A DUTY TO INFORM THE IEEE

- Participants <u>shall</u> inform the IEEE (or cause the IEEE to be informed) of the identity of each holder of any potential Essential Patent Claims of which they are personally aware if the claims are owned or controlled by the participant or the entity the participant is from, employed by, or otherwise represents

- Participants <u>should</u> inform the IEEE (or cause the IEEE to be informed) of the identity of any other holders of potential Essential Patent Claims

Early identification of holders of potential Essential Patent Claims is encouraged

WAYS TO INFORM IEEE

- **Cause an LOA to be submitted to the IEEE SA (patcom@ieee.org); or**
- **Provide the chair of this group with the identity of the holder(s) of any and all such claims as soon as possible; or**
- **Speak up now and respond to this Call for Potentially Essential Patents**

If anyone in this meeting is personally aware of the holder of any patent claims that are potentially essential to implementation of the proposed standard(s) under consideration by this group and that are not already the subject of an Accepted Letter of Assurance, please respond at this time by providing relevant information to the WG Chair

OTHER GUIDELINES FOR IEEE WORKING GROUP MEETINGS

- **All IEEE SA standards meetings shall be conducted in compliance with all applicable laws, including antitrust and competition laws.**
  - **Don't discuss the interpretation, validity, or essentiality of patents/patent claims.**
  - **Don't discuss specific license rates, terms, or conditions.**
    - Relative costs of different technical approaches that include relative costs of patent licensing terms may be discussed in standards development meetings.
      - **Technical considerations remain the primary focus.**
  - **Don't discuss or engage in the fixing of product prices, allocation of customers, or division of sales markets.**
  - **Don't discuss the status or substance of ongoing or threatened litigation.**
  - **Don't be silent if inappropriate topics are discussed. Formally object to the discussion immediately.**

For more details, see *IEEE SA Standards Board Operations Manual*, clause 5.3.10 and *Antitrust and Competition Policy: What You Need to Know* at http://standards.ieee.org/develop/policies/antitrust.pdf

PATENT-RELATED INFORMATION

The patent policy and the procedures used to execute that policy are documented in the:

- *IEEE SA Standards Board Bylaws*
  (http://standards.ieee.org/develop/policies/bylaws/sect6-7.html#6)
- *IEEE SA Standards Board Operations Manual*
  (http://standards.ieee.org/develop/policies/opman/sect6.html#6.3)

Material about the patent policy is available at
http://standards.ieee.org/about/sasb/patcom/materials.html

If you have questions, contact the IEEE SA Standards Board Patent Committee Administrator at patcom@ieee.org

PAR – Title, Scope, and Purpose

PAR expiration date: December 31st, 2028

Title: Guide for Evaluating Transformer Performance under Reverse Power Flow

Scope: This document provides guidance for the operation and performance evaluation of single- and three- phase transformers subjected to reverse power flow. This guide covers power and distribution transformers, both liquid-filled and dry-type.

Purpose: The purpose of this document is to provide guidance for transformers subjected to reverse power flow. This includes recommendations for specification and operation of new and existing transformers.

91 WG Members: Quorum ≥46

(slide 1 of 2)

First	Last
Kayland	Adams
Gilles	Bargone
Mats	Bernesjo
Daniel	Blaydon
William	Boettger
Garrett	Bradshaw
Jeffrey	Brooks
Alfredo	Carrizales
Thomas	Dauzat
Nikolaus	Dillon
Fernando	Duarte
Roger	Dugan
Eric	Elson
Miguel	Garcia
Eduardo	Garcia
David	Garcia-Paredes

First	Last
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Ramsis	Girgis
Jose Antonio	Gonzalez Ceballos
William	Griesacker
Jesse	Hall
Corey	Hanson
U	Hernandez Decanini
Saramma	Hoffman
Ryan	Hogg
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Thrinadha	Katapalli
Anton	Koshel
Mark	Lachman
Jihun	Lee
Junho	Lee
Kushal	Mahajan
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Daniel	Martinez
Katherine	Marulanda
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Tyler	Morgan

Attendance form→

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91 WG Members: Quorum ≥46

(slide 2 of 2)

First	Last
Dan	Mulkey
Ali	Naderian
Shankar	Nambi
Eduardo	Orozco
Sanjay	Patel
Vinay	Patel
Gustavo	Prado
Tim	Raymond
Yuri	Rossini
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Mark	Tostrud
Kannan	Veeran
Juan	Velasquez
Karsten	Viereck
Krishnamurthy	Vijayan

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Pragnesh	Vyas
David	Walker
Joe	Watson
Bruce	Webb
Drew	Welton
Joe	White
Jeffrey	Wright
Fei	Yang
Tim	Young
Guang	Yuan
Michael	Zarnowski
Hongzhi (Alan)	Zhang
Shibao	Zhang
Waldemar	Ziomek

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Agenda

- Approval of agenda
- Pull up PDF

Attendance form→

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Minutes

- Approval of first and second meeting minutes
  - October 29, 2024 (St Louis)
  - February 24, 2025 (virtual)
- Pull up PDFs

Attendance form→
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iMeet Central

https://ieee-sa.imeetcentral.com/ieeedashboard/

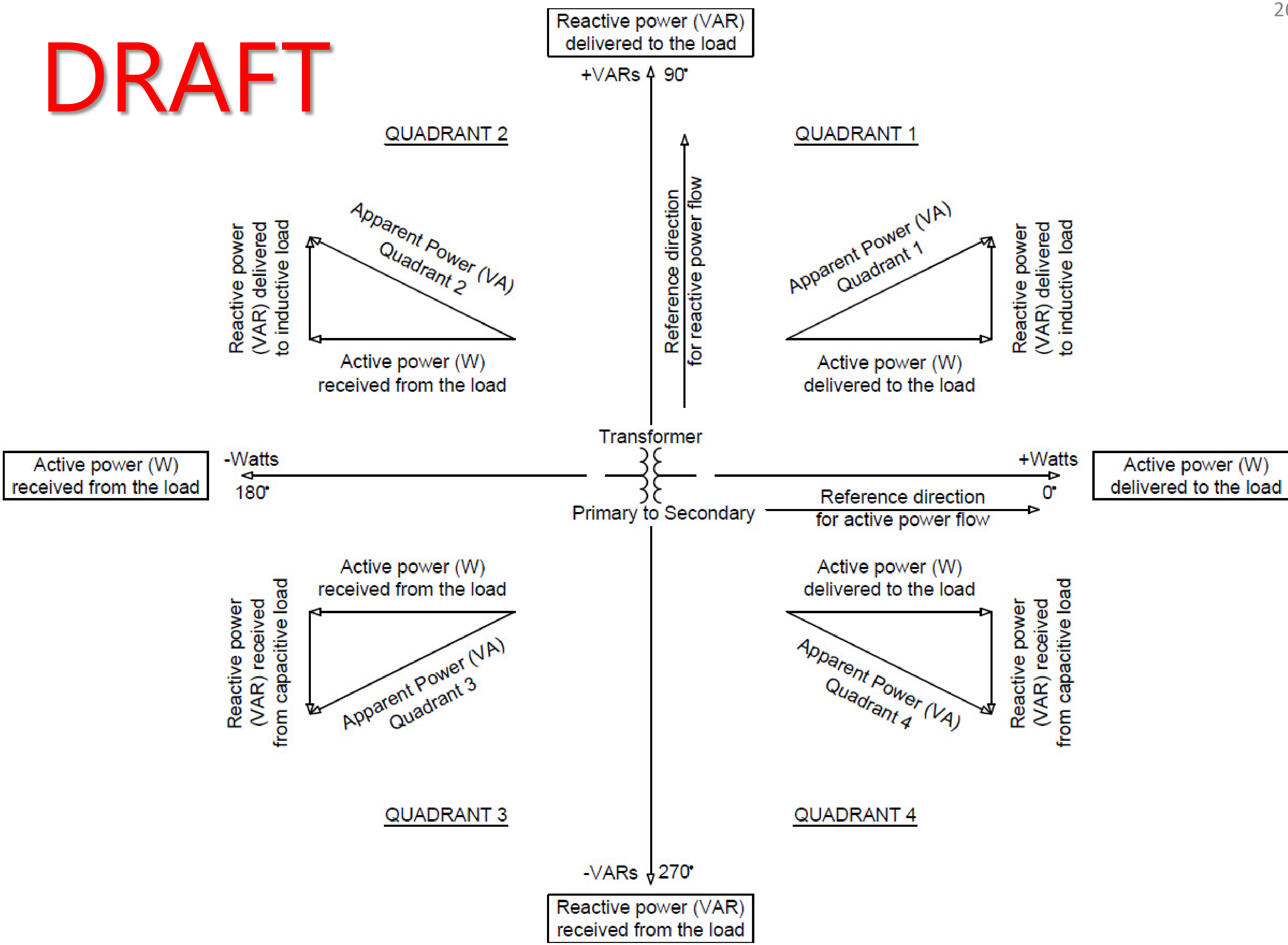
- Quick demo
- How to access to IEEE Transaction Paper

Action item for chair = add entire WG to iMeet

Status update:
TF Definition of Transformer Reverse Power

- Chair of TF = Ryan Hogg (TF has 29 members)
- Goal of TF = provide a definition for "transformer reverse power flow" back to WG
- Have held 2 virtual meetings, more planned
- Report on status of definition work
  - Have not finalized a definition, however the TF has made some great progress
  - Should hopefully have a definition by next in person PC57.133 meeting
- Developing a quadrants figure that standard could use (next slide)

DRAFT


Reactive power (VAR) delivered to the load
+VARs
90°
QUADRANT 2
QUADRANT 1
Reference direction for reactive power flow
Reactive power (VAR) delivered to inductive load
Apparent Power (VA) Quadrant 2
Active power (W) received from the load
Apparent Power (VA) Quadrant 1
Reactive power (VAR) delivered to inductive load
Active power (W) delivered to the load
Transformer
Active power (W) received from the load
-Watts
180°
Primary to Secondary
+Watts
0°
Reference direction for active power flow
Active power (W) delivered to the load
Active power (W) received from the load
Reactive power (VAR) received from capacitive load
Apparent Power (VA) Quadrant 3
Active power (W) delivered to the load
Apparent Power (VA) Quadrant 4
Reactive power (VAR) received from capacitive load
QUADRANT 3
QUADRANT 4
-VARs
270°
Reactive power (VAR) received from the load

Presentations

	Presenter	Affiliation	Presentation Title
1	Ramsis Girgis	Hitachi Energy	**Feasibility of Reverse Power Flow Scenarios in Step-Down Power Transformers**
2	Ryan Hogg	Bureau of Reclamation	**Dry Type GSU and Station Service Power**
3	Vinay Patel	Con Edison of New York	**Distributed generation**
4	Dan Blaydon	Baltimore Gas & Electric	**Solar DER**
5	Drew Welton	Intellirent	**Auto-determination OLTC controls**

Feasibility of Reverse Power Flow Scenarios in Step-Down Power Transformers

Ramsis Girgis
Hitachi Energy

Feasibility of operating Step-Down Power Transformers in a Reverse Power Flow Scenario (Step-Up)

Step-Down Operation

- ❑ Voltage @ Secondary = (System Voltage at HV terminals – Voltage Drop)

Reverse Power Flow Operation

- ❑ Voltage @ Primary = (Input Voltage at Secondary – Voltage drop)

Feasibility

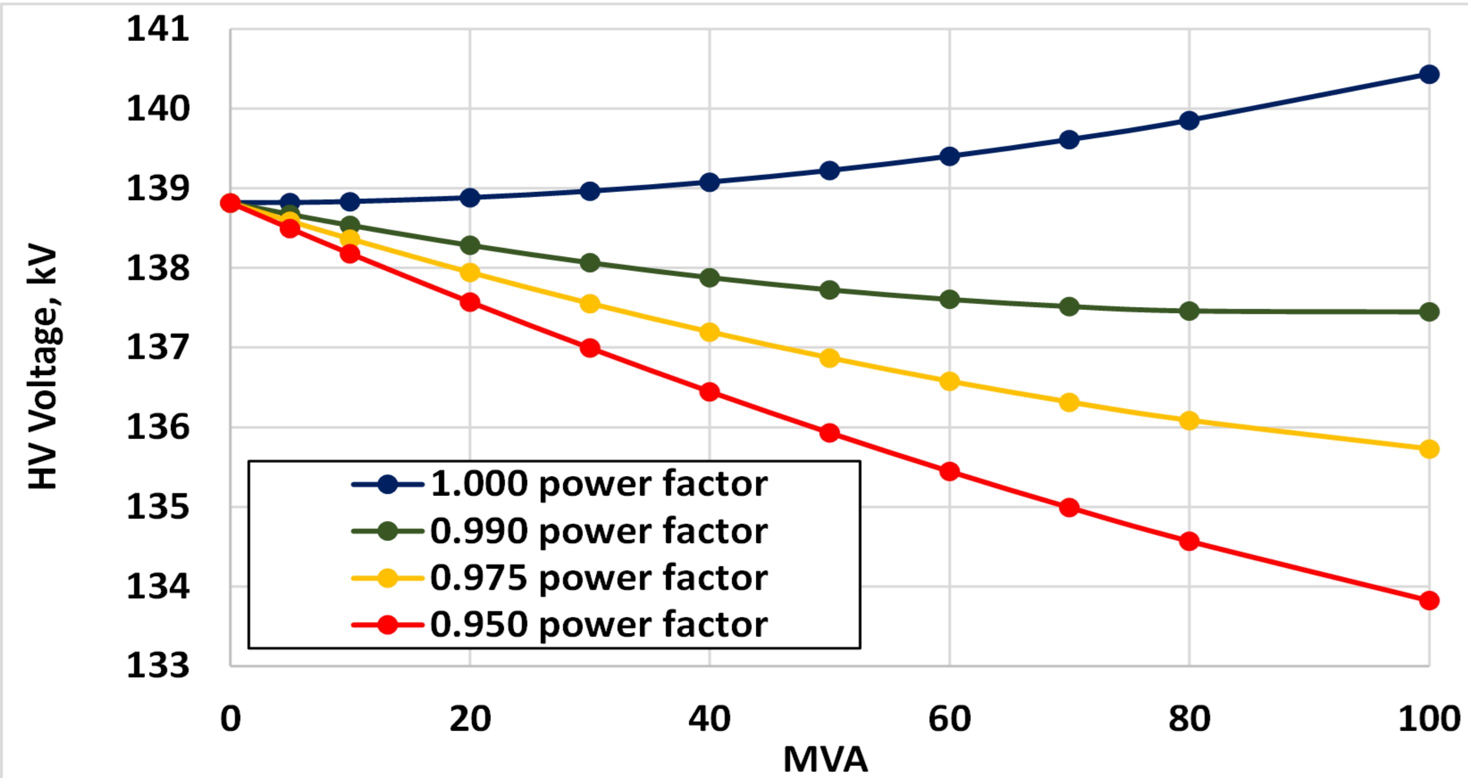
❑How much Power can be delivered in a Reverse Power Scenario, while ensuring that the output voltage is sufficiently close to the Nominal Voltage of the Power System that the Transformer is connected to.

Variables associated with operating Step-Down Power Transformers in a Reverse Power Flow Scenario (Step-Up)

- Magnitude of the voltage applied to the Low Voltage terminals of the Transformer, versus its rated voltage
- Magnitude of the Nominal voltage of the Power System at the High Voltage terminals of the Transformer, versus the rated High Voltage of the Transformer
- Power Factor at the Low Voltage terminals of the Transformer
- Availability of means of voltage regulation (De-Energized Tap Changer, On-Load Tap Changer, Voltage regulators)
- Winding regulated by OLTC (HV, or LV)
- Two-Way Power Flow Scenario

Study Case 1: 100 MVA, 141 ± 1 x 2.5 % / 36.2 ± 16 x 0.625 % kV

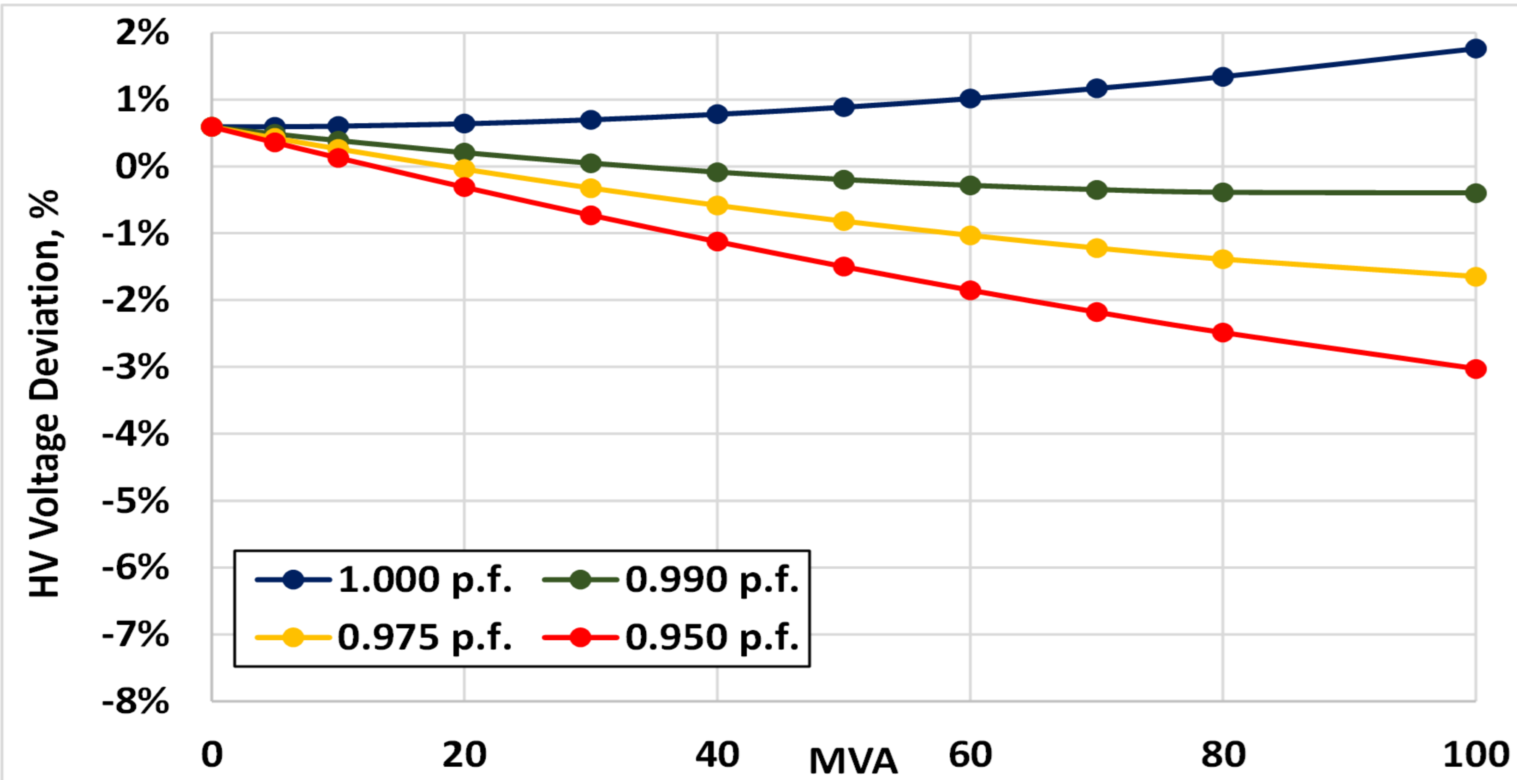
- Input Voltage: 35.65 kV, @ Rated DETC & OLTC Tap Positions
- System Voltage: 138 kV



Output voltage: 133.8 to 140.4 kV

Study Case 1: 100 MVA, 141 ± 1 x 2.5 % / 36.2 ± 16 x 0.625 % kV, cont'd

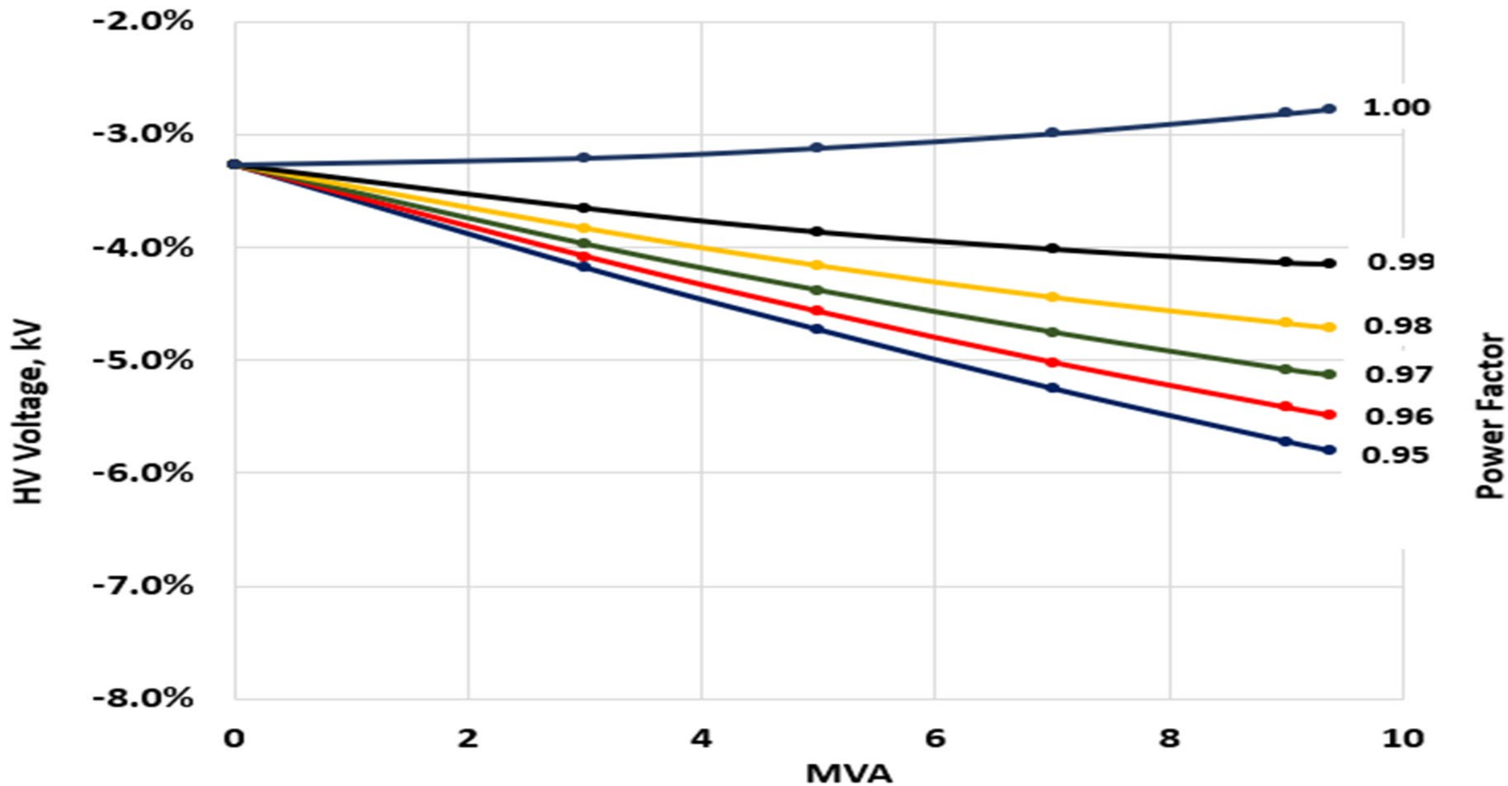
- Input Voltage: 35.65 kV, @ Rated DETC & OLTC Tap Positions
- System Voltage: 138 kV



Voltage deviation: +1.8 to -3%

Study Case 2: 9.375 MVA, 67 (+3 x 2.69 % / -1 x 2.69 %) / 13.09 kV

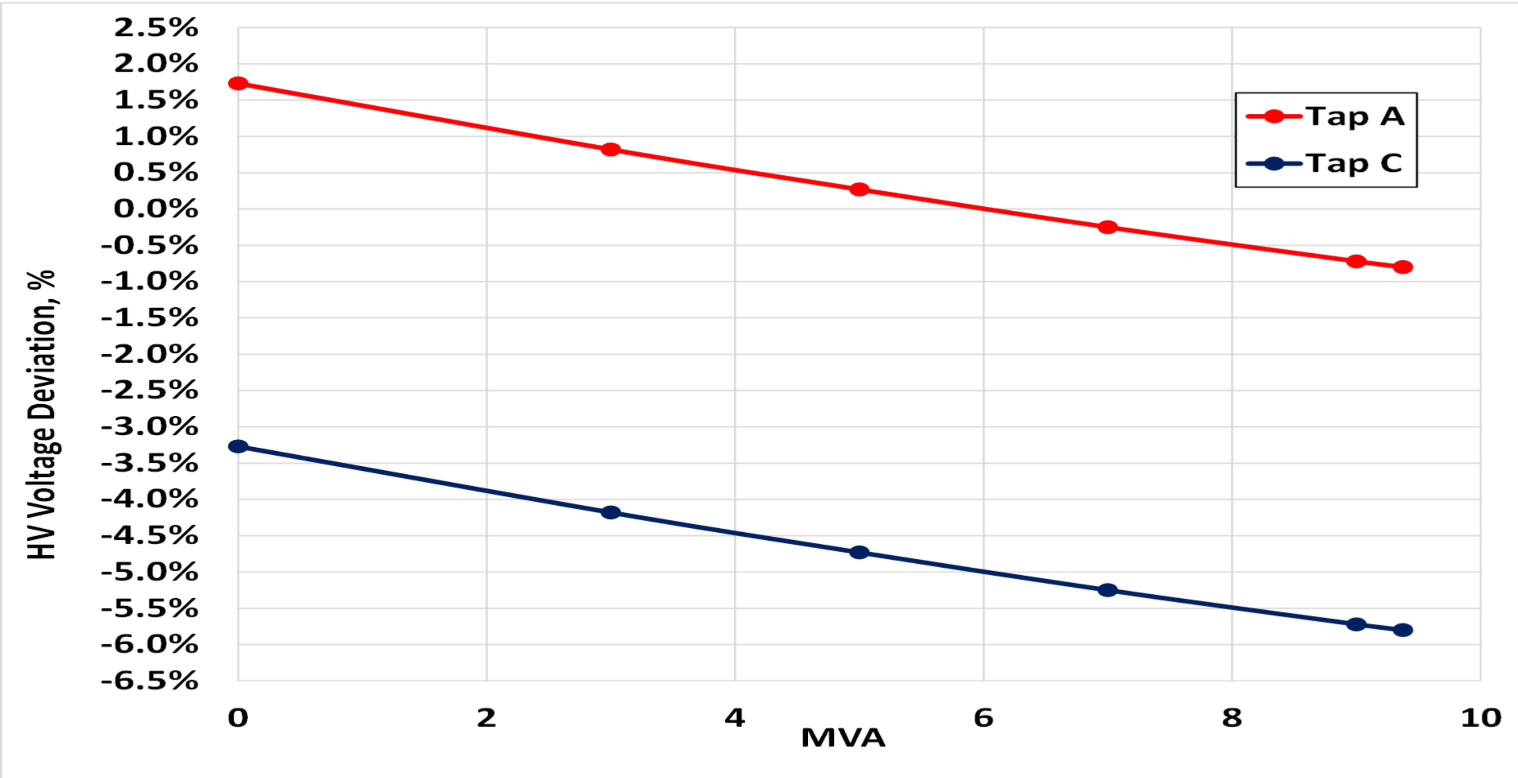
- Input Voltage = 12.47 kV, @ Rated DETC Tap Position “C”
- System Voltage: 69 kV



Voltage deviation: -2.8 to -5.8%

<u>Study Case 2</u>: 9.375 MVA, 67 (+3 x 2.69 % / -1 x 2.69 %) / 13.09 kV, cont'd

- ❑ **Input Voltage = 12.47 kV, @ Rated DETC Tap Position "C"**
- ❑ **System Voltage: 69 kV**



Voltage Deviation: Tap C: -2.8 to -5.8 %
Tap A: 1.7 to -0.8 % (much closer to System Voltage)

<u>Study Case 3</u>: 180 MVA, 138 ± 16 x 0.625 % / 34.5 / 13.8 kV

❑ A Two-way Power Flow Scenario

❑ A Step-Up Transformer, with an OLTC on the HV Winding

- Collector Transformer from Solar Farm during daytime to the Grid

❑ Also operate as a Step-Down Transformer some of the time, with LV range of ± 4 of 1.25 % taps

- Charging batteries from the grid during nighttime

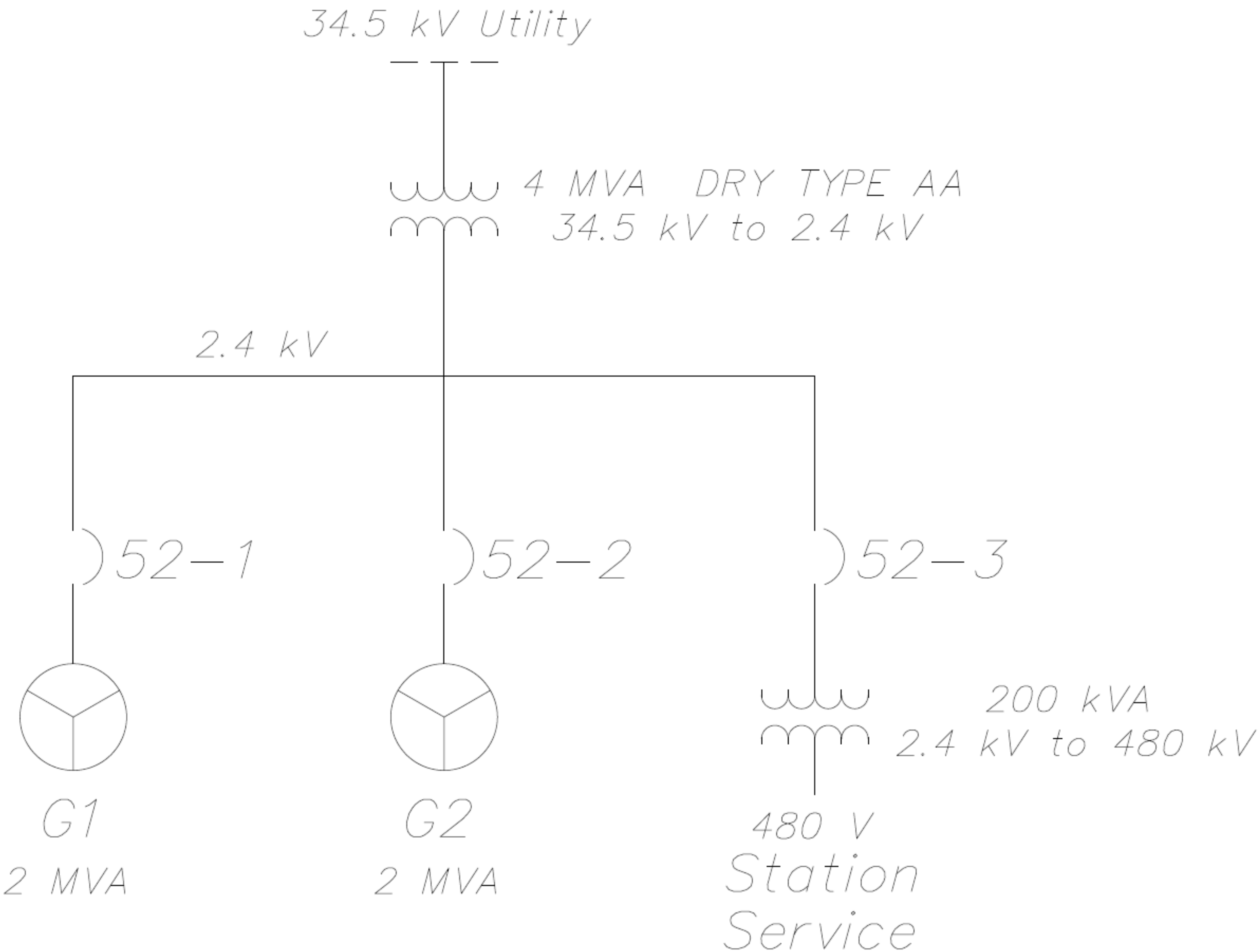
❑ This required:

- Providing a PT on the LV winding to monitor Voltage at LV Terminals of Transformer
- Rewiring and programing the OLTC to control the Voltage at LV Terminals of Transformer
- Providing OLTC Table for the Step-Down operation

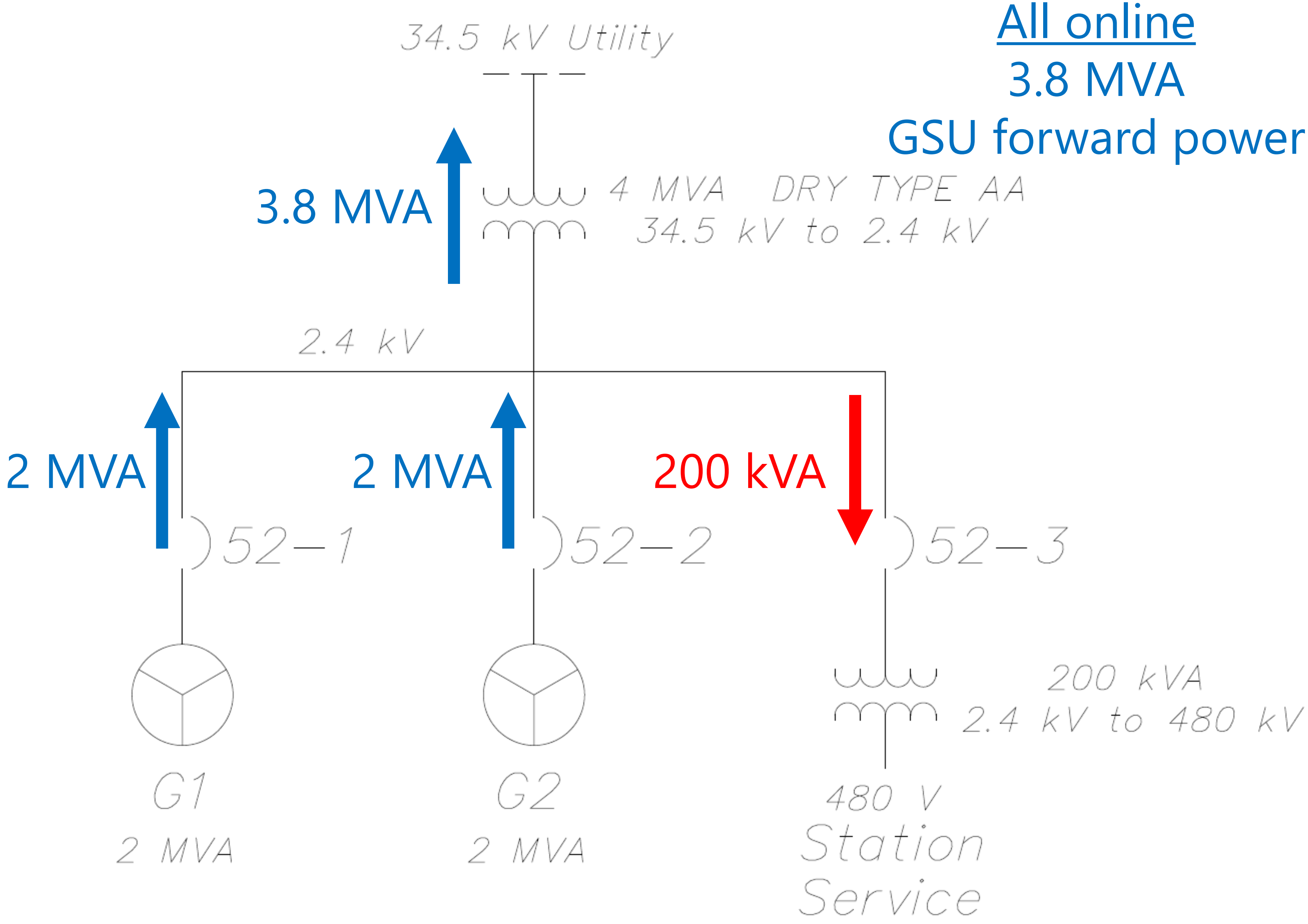
Questions?

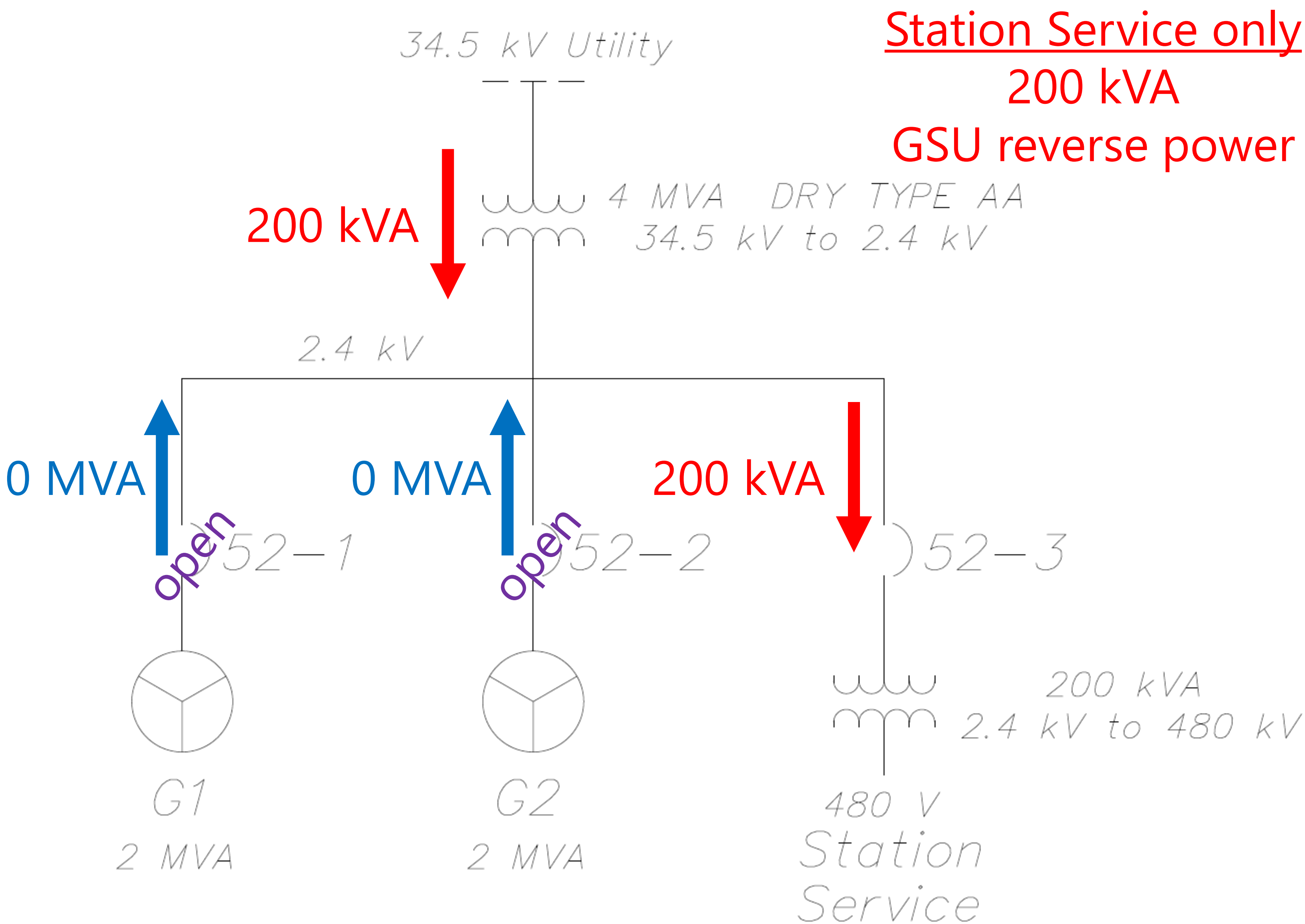
Dry Type GSU and Station Service Power

Ryan Hogg
Bureau of Reclamation


34.5 kV Utility
4 MVA DRY TYPE AA
34.5 kV to 2.4 kV
2.4 kV
52-1
52-2
52-3
200 kVA
2.4 kV to 480 kV
G1
2 MVA
G2
2 MVA
480 V
Station
Service

<u>All online</u>
3.8 MVA
GSU forward power




Station Service only
200 kVA
GSU reverse power
34.5 kV Utility
200 kVA
4 MVA DRY TYPE AA
34.5 kV to 2.4 kV
2.4 kV
0 MVA
0 MVA
200 kVA
open
52-1
open
52-2
52-3
200 kVA
2.4 kV to 480 kV
G1
2 MVA
G2
2 MVA
480 V
Station
Service

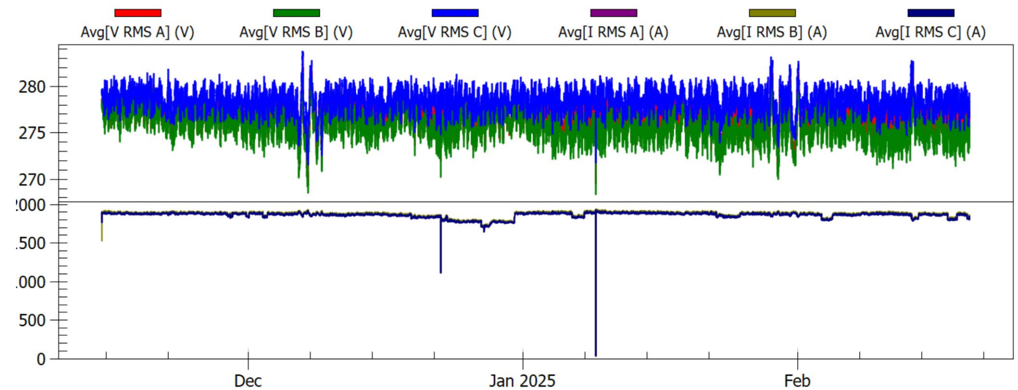
Questions?

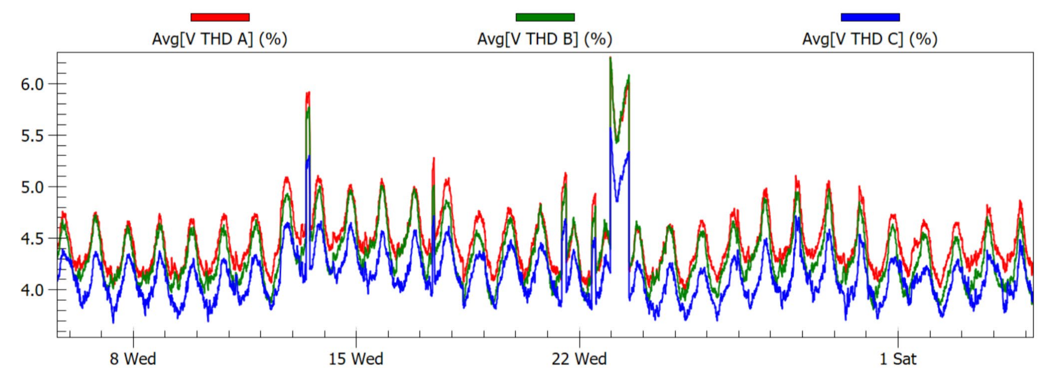
Distributed generation

Vinay Patel
Con Edison of New York

System Overview

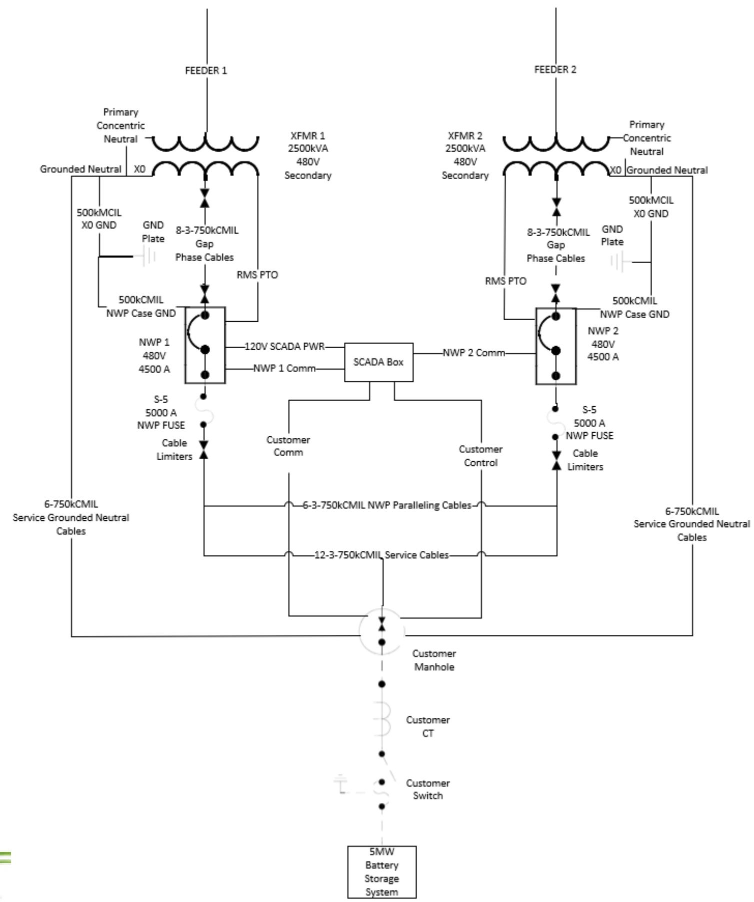
- Installed Capacity:
  - Battery storage: 96 MW
  - Solar/PV: 500 MW
  - SCADA location: 70
- Initial Installation and Verification
  - PQ instrumentation
  - Measured total harmonic distortion
  - Load flow analysis





Battery Storage System

• Standard Layout



• Design & Equipment

- **Installation capacity:** 5 MW
- **Transformer primary:** 4,13,27,33 kV
- **Transformer secondary:** 480/277 GRDY

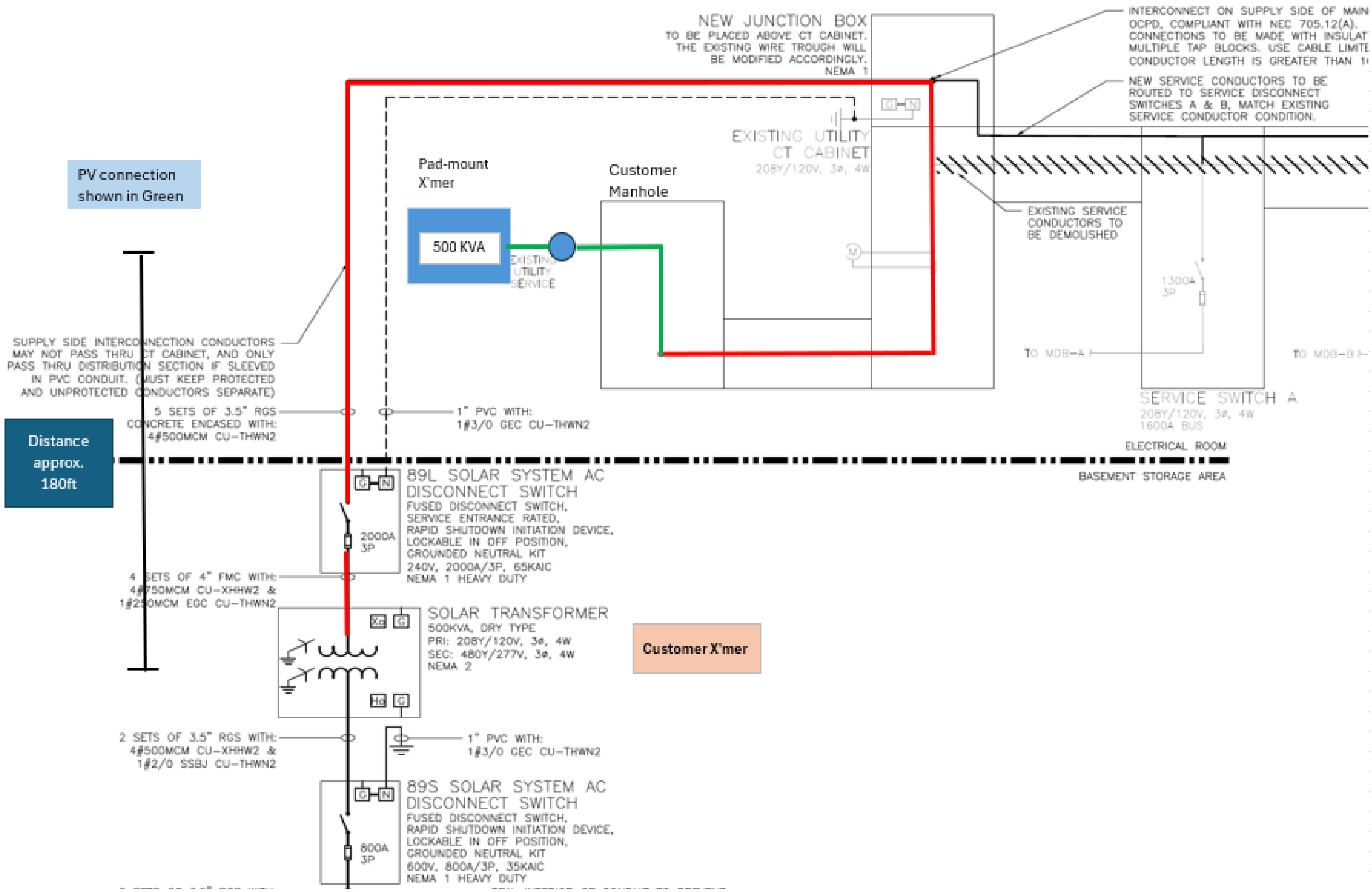
❖ **Equipment and Design:**

- Transformer type (network & pad-mount)
- Network protector
- Relay
- SCADA box
- Bus/Cables

Monitoring and Equipment Maintenance

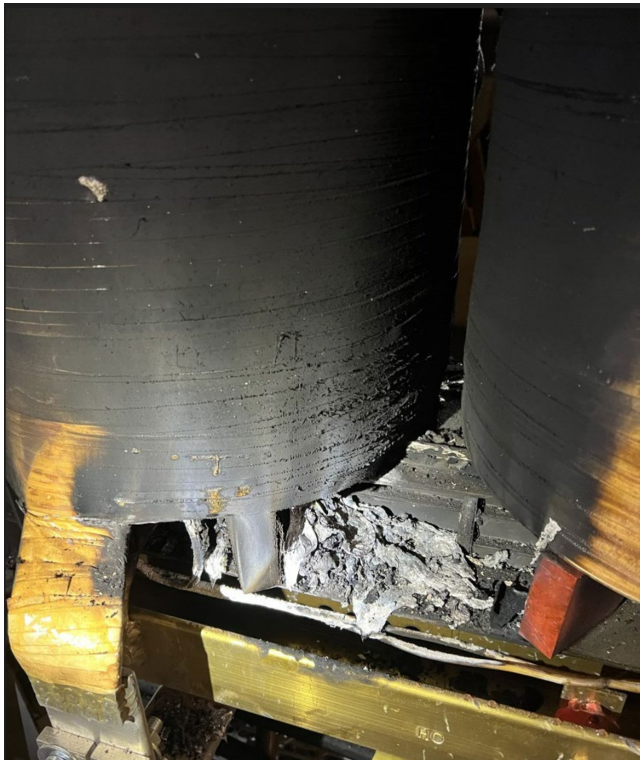
- **SCADA System :**
  - Customer voltage and power generation
  - NWP status
  - Voltage data
  - NWP control
- **Transformer Maintenance :**
  - Data driven for network transformer
  - Time based inspection for pad-mount
  - No control over customer owned equipment

Transformer Failure Incident



Customer Transformer Failure Incident

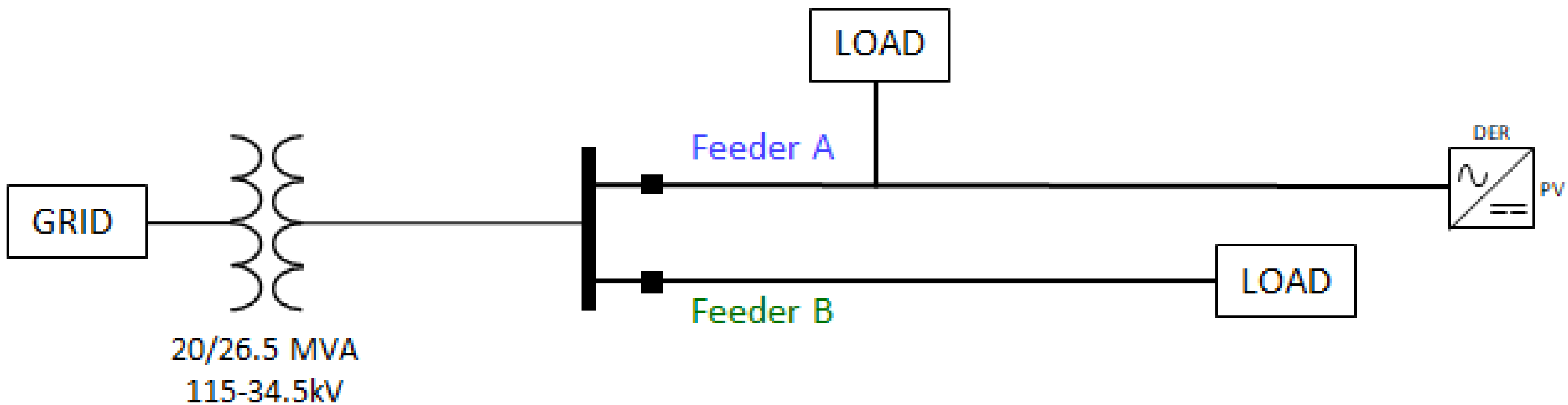
- Dry type transformer
- Rating: 500 kVA
- Primary voltage: 208/120 GRDY
- Secondary voltage: 480/277 GRDY

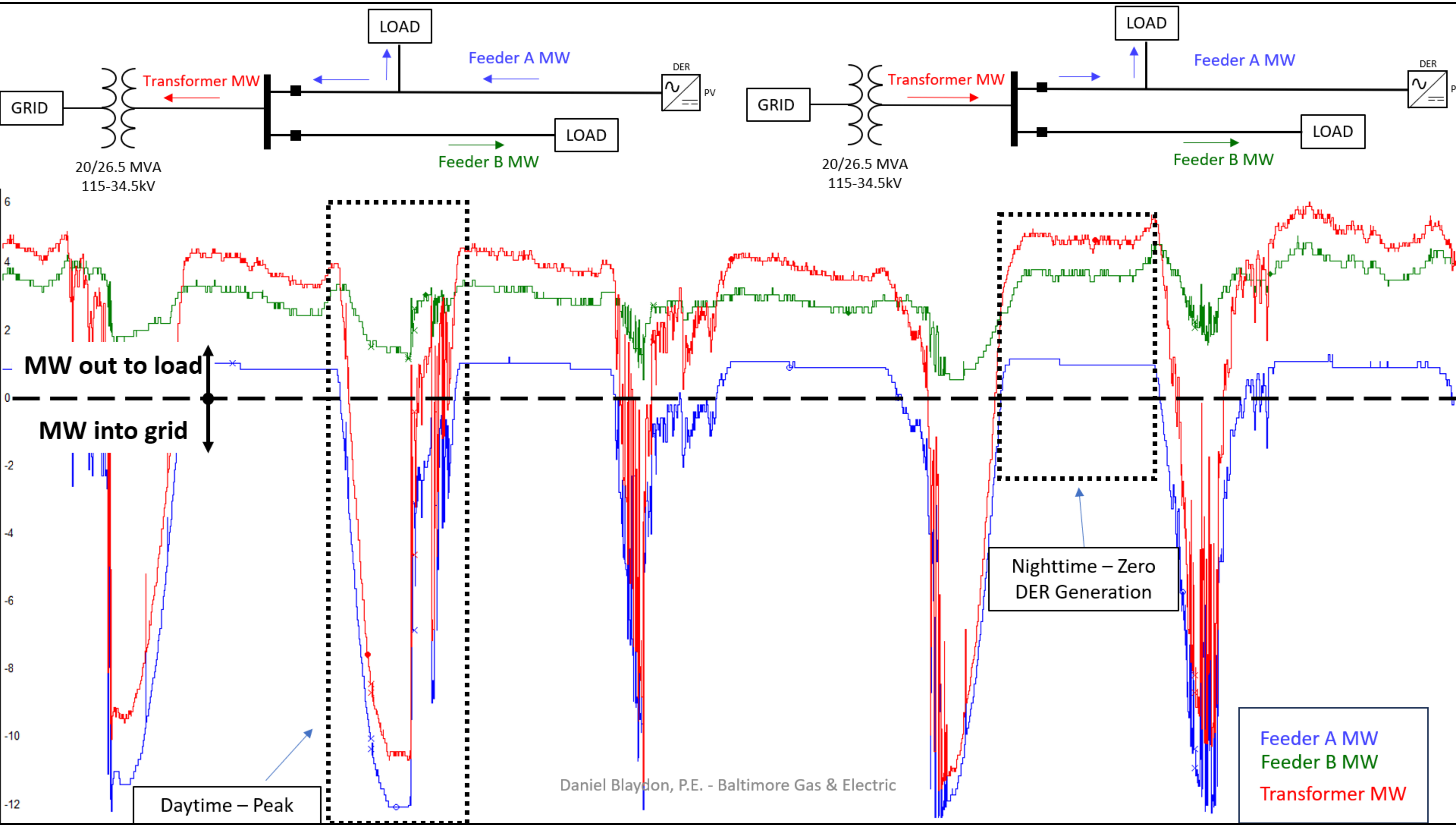


Questions?

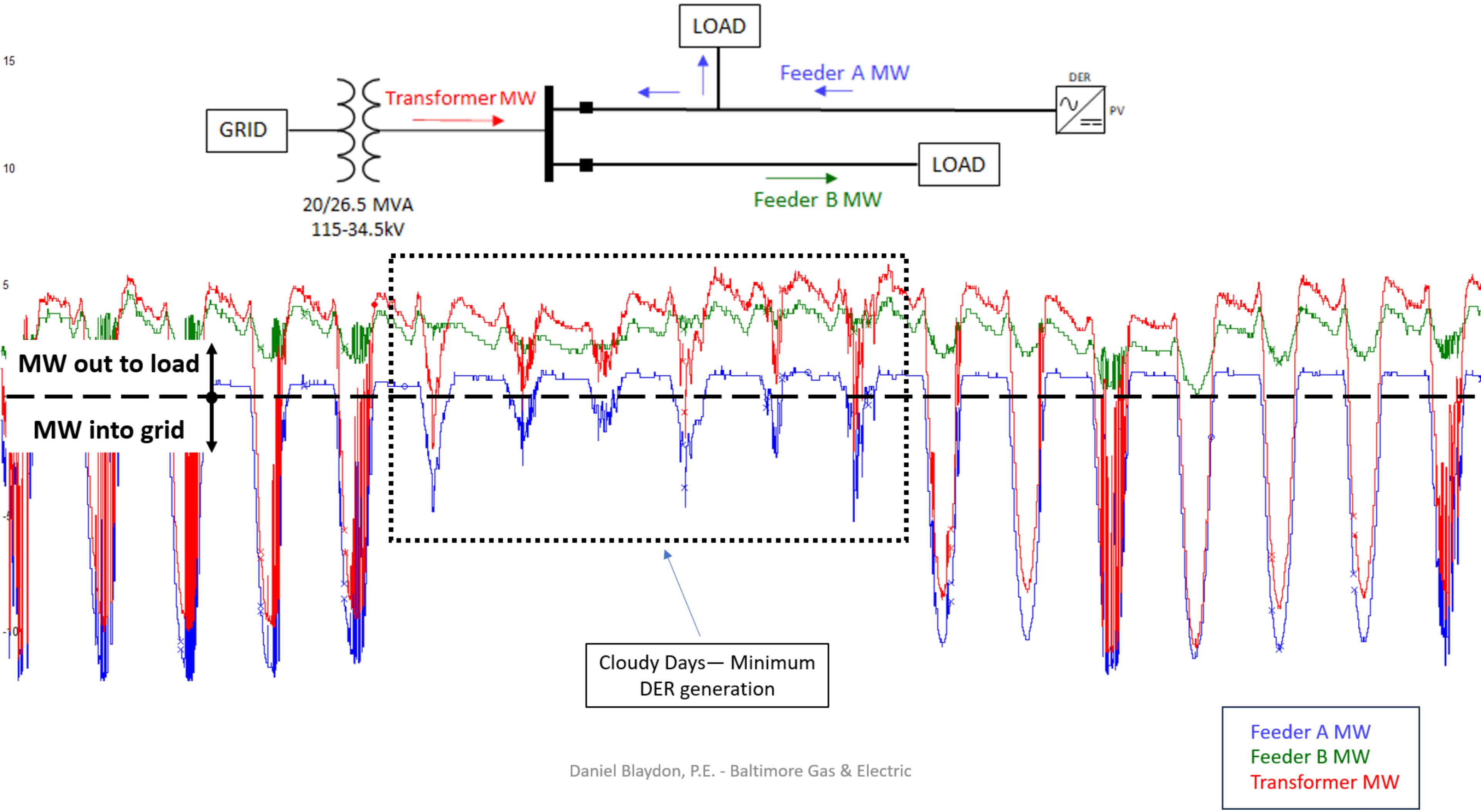
Solar DER

Dan Blaydon
Baltimore Gas & Electric


LOAD
Feeder A
DER
PV
GRID
LOAD
Feeder B
20/26.5 MVA
115-34.5kV



Daniel Blaydon, P.E. - Baltimore Gas & Electric



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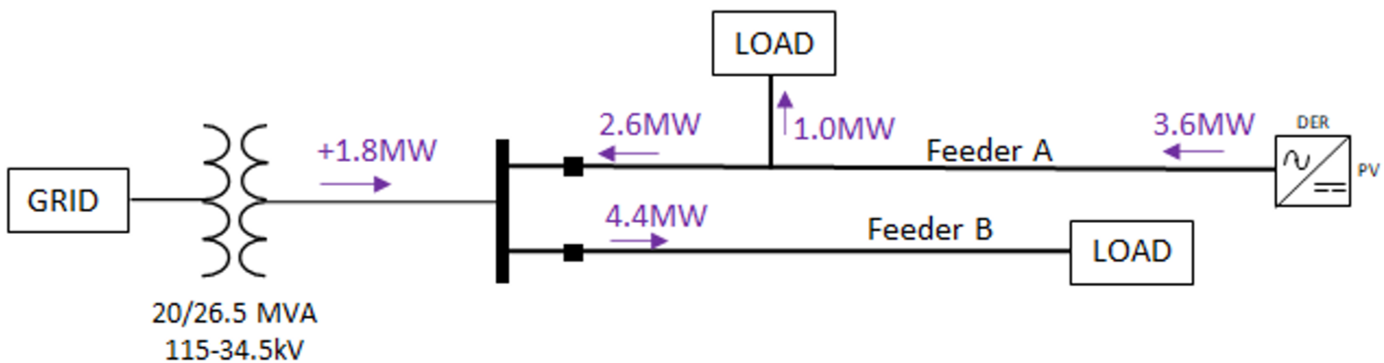
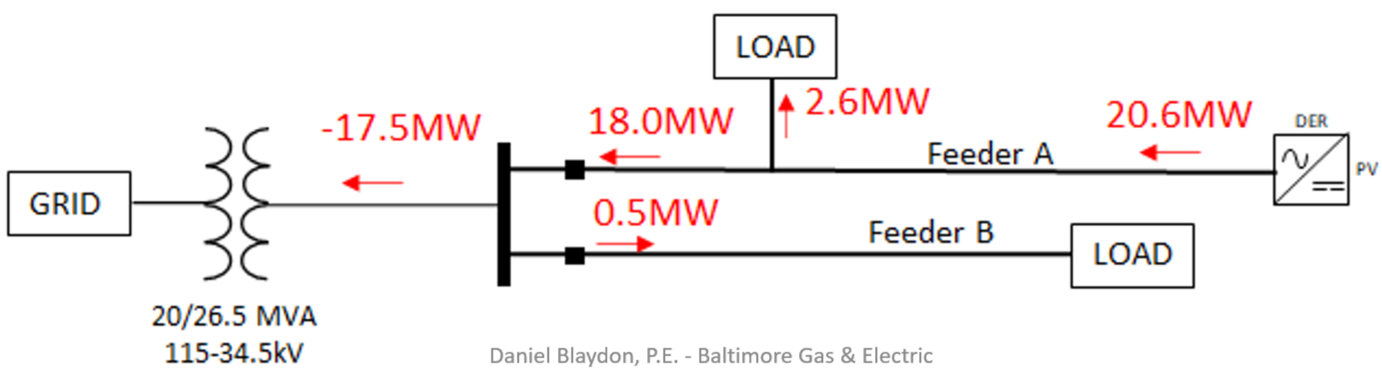
Solar DER generating during cloudy day



Solar DER generating during sunny day

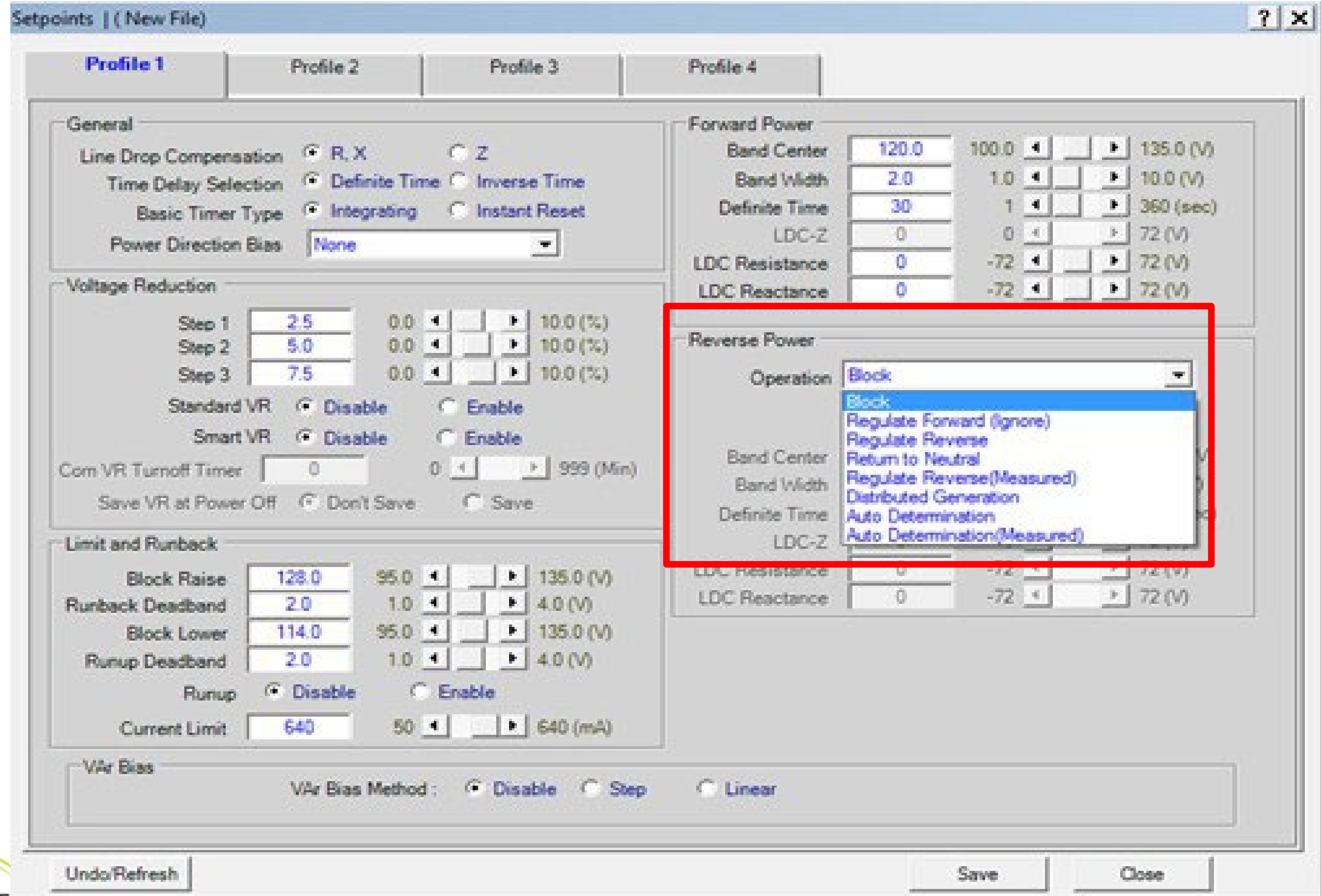


Questions?

Auto-determination OLTC controls

Drew Welton
Intellirent

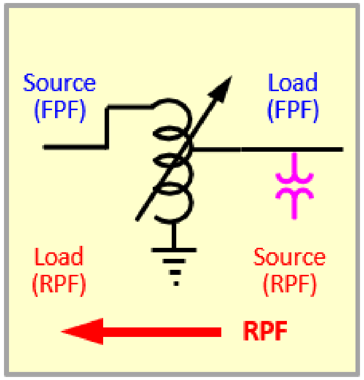
OLTC Controls for RPF



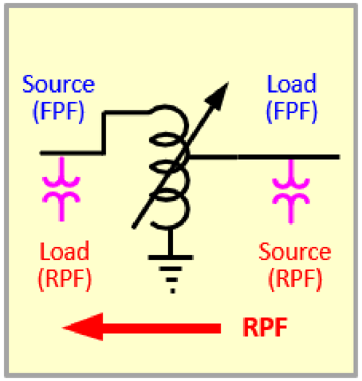
DER vs. DA

REGC/LTCC: Reverse Power, "Regulate Reverse"

- **Regulate Reverse (Calculated):**
  - Voltage Sensing: With RPF, control uses tap position knowledge and FPF side voltage
  - Regulates according to reverse power settings
    - Use where RPF source to OLTC is a stronger source
    - Regulate voltage on the RPF side of the OLTC
      - Typically used for reconfiguration



- **Regulate Reverse (Measured):**
  - Voltage Sensing: With RFP, control switches its voltage sensing input to a RPF side VT
    - RFP side VT must be available
  - Regulates according to reverse power settings
    - Use where RPF source to REG is a stronger source
    - Regulate voltage on the RPF side of the REG
      - Typically use for reconfiguration



Questions?

Review document outline

- Draft outline on next 2 slides
- Also, Thomas Dauzat proposal in 3 slides

Draft PC57.133 Outline

Introduction – "how we got here" as an industry

1. **Overview**
   1.1. Scope
   1.2. Purpose
   1.3. Word Usage
2. **Normative References**
3. **Definitions, acronyms, and abbreviations**
   3.1. Definitions
   3.2. Acronyms and abbreviations
4. **Historical context** *(this might become an informative annex)*
   4.1. Watts and VARs chart
   4.2. Typical causes of reverse power flow *(note similarity to proposed Annex B)*
5. **C57 Standards and Power Flow Direction**
   5.1. Step-down, step-up, bi-directional, same voltage both sides
   5.2. C57.12.00, C57.12.01… other standards and how they discuss power flow direction
6. **Potential effects**
   6.1. Voltage regulation (including OLTC and controls)
   6.2. Core saturation (LV taps, variable flux)
   6.3. Winding heating (common windings of autos)
   6.4. Voltage imbalance (battery back feeding, delta connections and grounding)
   6.5. Volts per turn increase (low voltage winding on step-down transformer, but providing VARs back to system)
   6.6. Asymmetrical pennant cycle tap changer (does not work in reverse)
   6.7. Inverters – Step down not designed to be inverter transformers, now operating as step-up (e.g., two grounds = harmonics; core design (shielding/grounding)
   6.8. …

7. **Transformer designs and potential effects**
    7.1. Simple two winding
    7.2. Two winding w/ LV taps
    7.3. Two winding w/ LV taps, variable flux
    7.4. Auto transformers
    7.5. Multi winding transformers
    7.6. Amorphous vs grain-oriented cores
8. **Recommended actions for operation of existing transformers**
9. **Recommended guidance for new transformers (e.g., specification type language)**

Annexes

Annex A: (informative) How to determine numerical values for Watt/VAR values for a specification

Annex B: (informative) How to assess which transformers are/may be subject to reverse power flow (system condition, therefore informative annex)

Thomas Dauzat – proposed sections:

- *Per email on February 27, 2025*
- Reverse Power Flow – Power
- Reverse Power Flow – Transmission/Substation
- Reverse Power Flow – Distribution/Feeders

Request TFs chairs and volunteers for:

Initial plan = present initial draft language at Fall 2025 meeting

Maybe 2-3 people per item below - *Right # of people per TF?*

1. Historical Context (Watts and VARs chart, typical causes reverse power)
2. C57 Standards and Power Flow Direction (step-up/down, primary/secondary winding, C57.12.00, C57.12.01, C57.12.80…)
3. Potential effects – Voltage regulation (including OLTC and controls)
4. Potential effects – Core saturation (LV taps, variable flux)
5. Potential effects – Winding heating (common windings of autos)
6. Potential effects – Voltage imbalance (battery back feeding, delta connections and grounding) – *with #9?*
7. Potential effects – Volts per turn increase (low voltage winding on step-down transformer, but providing VARs back to system)
8. Potential effects – Asymmetrical pennant cycle tap changer (does not work in reverse)
9. Potential effects – Inverters – Step down not designed to be inverter transformers, now operating as step-up (e.g., two grounds = harmonics; core design (shielding/grounding)
10. *Others? (if more potential effects identified during WG meeting)*

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Request – Volunteers to present

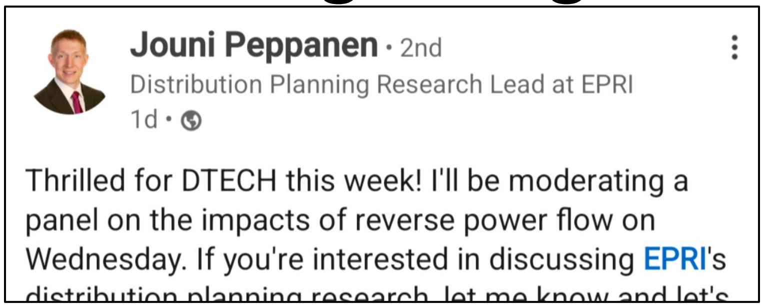
- Have presentations during our in-person meetings
- Idea:
  - How have you/your organization been approaching reverse power?
  - What impacts are you/your organization seeing?
- In the works:
  - Fall 2025 – Joe White
- Volunteers?

Old Business

None

New Business

Email from Roger Dugan today:


Jouni Peppanen • 2nd
Distribution Planning Research Lead at EPRI
1d •

Thrilled for DTECH this week! I'll be moderating a panel on the impacts of reverse power flow on Wednesday. If you're interested in discussing EPRI's distribution planning research, let me know and let's

https://www.distributech.com/2025-technical-conference-sessions/understanding-reverse-power-flow-impacts-at-national-grid-and-firstenergy

Chairperson
James Helmberger
(Omaha Public Power District)

Speakers
Wei Ren (EPRI)
Jouni Peppanen (EPRI)
Nathan Walsh (National Grid MA)
Ryan Boudreau (Hydro One)

Technical concerns:

1. Voltage regulating and feeder automation misoperation
2. Increased potential for unintentional islanding
3. Power frequency over voltages
4. Equipment loading impacts

"There is currently industry debate regarding the need to **derate substation transformers** when reverse power flow exists and research findings will be shared that address this concern." *(emphasis added)*

New Business

Any other new business?

Next Meetings

1. Possible virtual
   – If did not establish initial TFs to begin drafting text, host a virtual meeting to finalize outline and assign TFs
2. In-person Fall 2025: Bonita Springs, FL

Note: Planning on third meeting of "TF Definition of Transformer Reverse Power" week of April 6, 2025

Adjourn

Thank you everyone

See you in Bonita Springs, FL