

First Meeting of WG PC57.133

“Guide for Evaluating Transformer Performance under Reverse Power Flow”

IEEE PES Transformers Committee

3:15-4:30 PM CDT | October 29, 2024

Grand Ballroom AB (Floor 4)

Hyatt Regency St. Louis at the Arch | St. Louis, MO

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

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 - [IEEE Code of Conduct](#)
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NOVEMBER 2019

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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
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<https://standards.ieee.org/about/policies/bylaws/sect6-7.html#7>
 - Clause 6.1 of the IEEE SA Standards Board Operations Manual
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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

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- Advise the WG attendees that:
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 - 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 shall 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 should 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

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.

Our WGs Goal

Develop the PC57.133, “Guide for Evaluating Transformer Performance under Reverse Power Flow”

PAR expiration date = December 31st, 2028

We have just over 4 years

Draft schedule

Developed from “[Calendar Plan for... Draft Standard...](#)”

- Year 0 – 2024
 - Fall meeting – TODAY! – work on draft
- Year 1 – 2025
 - Spring and fall meetings – work on draft
- Year 2 – 2026
 - Spring and fall meetings – work on draft

Draft schedule

- Year 3 – 2027
 - Spring meeting – finish major changes
 - ~June – submit to MEC; initiate the Invitation to create ballot pool (30 Day)
 - Fall meeting – resolve MEC comments/any other changes; 2/3 majority vote go to ballot; establish CRG; SC meeting ask for approval to go to ballot
 - ~Nov – initiate sponsor ballot (30 days)
- Year 4 – 2028
 - Jan – CRG begins resolving comments
 - Spring meeting – resolve comments
 - Jun – run 10 day recirculation ballot
 - July – CRG reviews any recirc ballot comments
 - July – Run recirc ballot 2 if needed (10 day)
 - Aug – Request extension if approval is in doubt
 - Early Oct – Submit to RevCom
 - Fall meeting – no WG business
 - Late Dec – RevCom meeting review, standard approved
 - Dec 31 – PAR expires

Establish membership

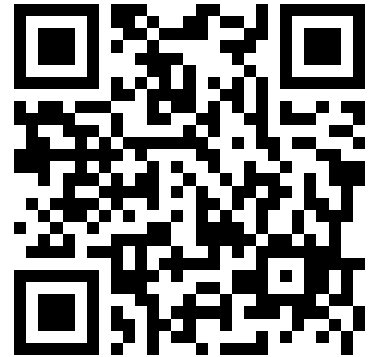
- 1st meeting of WG, establishing membership today



<https://forms.gle/cfxLT9SJkWcKjGyWA>

Agenda

- Approval of agenda
- Pull up PDF



Attendance/membership

Speakers



1. Ryan Hogg – “Reverse Power and base C57 standards”
2. Ed teNyenhuis – “Effect of Reverse Power Flow on Transformers”
3. Dan Mulkey – “Fundamental differences between power and distribution transformers”

Reverse Power and Base C57 Standards

Ryan Hogg (WG Chair)
Bureau of Reclamation

Base standards – Service Conditions

C57.12.00-2021 (liquid)

4. Service Conditions

4.1 Usual Service Conditions

4.1.8 Step-down operation

Unless otherwise specified, transformers shall be designed for step-down operation.

4.1.8.1 Generator step-up transformers

Transformers identified as generator step-up transformers shall be designed for step-up operation.

4.1.8.2 System tie transformers

Transformers identified as system tie transformers or autotransformers shall be designed for step-down operation, or step-up operation, or both, as specified by the user.

C57.12.01-2020 (dry)

4. Service conditions

4.1 Usual service conditions

4.1.8 Step-down operation

Unless otherwise specified, dry-type transformers shall be designed for step-down operation.

Base standards – Nameplates

C57.12.00-2021 (liquid)

Table 6 —Nameplate information

Nameplate C Row 21:

Step-up operation suitability^k

Footnote “k” of Table 6:

The nameplate shall state when the transformer is suitable for step-up operation.

Where, “Nameplate C shall be used on transformers rated above 500 kVA.”

C57.12.01-2020 (dry)

Table 10—Nameplate information

Fourth from last row of Table 10:

Step-up transformer suitabilityⁱ

Footnote “i” of Table 10:

If the transformer is larger than 500 kVA and is suitable for step-up operation, the nameplate shall so state.

1.1 Scope, “These transformers are generally used for step-down purposes...”

IEEE Std C57.12.23™-2018 (submersible 1 ϕ $\leq$ 250 kVA, HV $\leq$ 34.5 kV, LV $\leq$ 600 V)

IEEE Std C57.12.34™-2022 (pad 3 ϕ $\leq$ 10 MVA, HV $\leq$ 34.5 kV, LV $\leq$ 15 kV)

IEEE Std C57.12.38™-2014 (pad 1 ϕ $\leq$ 250 kVA, HV $\leq$ 34.5 kV, LV $\leq$ 480 V)

IEEE Std C57.12.40™-2024 (network 3 ϕ $\leq$ 2500 kVA, HV $\leq$ 34.5 kV, LV $\leq$ 600 V)

Assumption in the scope is that the transformers are **step-down**

Future item = review all “base” standards and understand their approach to step-up vs. down

C57.12.80-2010

3.425 step-down transformer

A transformer in which the **power transfer** is **from** a **higher** voltage source circuit **to** a **lower voltage** circuit.

Custom, Ryan summary:

Power higher to lower voltage

3.426 step-up transformer

A transformer in which the **power transfer** is **from** a **lower** voltage source circuit **to** a **higher voltage** circuit.

Custom, Ryan summary:

Power lower to higher voltage

Question – **active/real**, **reactive**, or **apparent** power?

Suggested reference:

<https://relaytraining.com/understanding-the-great-leading-vs-lagging-power-debate/>

Figure 3-20→



C57.12.80-2010

3.332 primary winding

The winding on the energy input side.

3.393 secondary winding

The winding on the energy output side.

Questions?

Effect of Reverse Power Flow on Transformers

Ed teNyenhuis
Hitachi Energy

- Ed's slides

Power & Distribution Transformer Differences

Dan Mulkey
Mulkey Engineering Inc.

From IEEE Std C57.167-2023

Guide for Monitoring Distribution Transformers

“1.2 Background into selection of monitoring for distribution transformers

The goal of the electric power system is to safely and continuously deliver electric power to the end customer. Both power and distribution transformers are critical parts of that system.

There are two alternative designs in power systems. In one, the customer is unaffected if a portion of the system is taken down or isolated. In the other, if a piece of the system is out, then the customer is out of power for the duration. In general, transmission systems and power transformers in North America are in the former category, while distribution systems and distribution transformers are in the latter.”

From IEEE Std C57.167-2023

Guide for Monitoring Distribution Transformers

“Of course, there are exceptions:

- Power transformers served by a radial transmission line—an outage affects customers.
- Network transformers serving secondary network distribution systems—customers remain in service for first-order events
- System intertie transformers on distribution main lines that can be cleared without affecting customers.
- Wind power transformers and solar power with a somewhat predictable cyclic load that allows for limited shutdowns without interruptions.

These exceptions involve a very small portion, probably $< 2\%$, of the transformers in North America. It is also important to keep in mind that even for these, the length of the outage is critical, as no necessary portion of either a transmission system or a distribution system can be left out of service indefinitely.”

From IEEE Std C57.167-2023

Guide for Monitoring Distribution Transformers

“IEEE Std C57.12.80™, Standard Terminology for Power and Distribution Transformers, defines power and distribution transformers as follows:

- *Distribution transformer*: A transformer for transferring electrical energy from a primary distribution circuit to a secondary distribution circuit or consumer's service circuit.
- *Power transformer*: A transformer that transfers electric energy in any part of the circuit between the generator and the distribution primary circuits.”

From IEEE Std C57.167-2023

Guide for Monitoring Distribution Transformers

“Other important distinctions are as follows:

a) Power transformers, in general:

1) Can be repaired, refurbished, or rebuilt, as follows:

i) Have interiors that are large enough to access components.

ii) Windings are not baked into a solid mass.

2) Custom designed for a specific location.

3) Often equipped with an on-load tap changer (OLTC).

4) Very expensive.

5) Cost of the transformer typically exceeds the cost of installation.”

From IEEE Std C57.167-2023

Guide for Monitoring Distribution Transformers

b) “Distribution transformers, in general:

1) Repairs are very limited, as follows:

i) They are compact in size with very limited access to interior components.

ii) Tanks are often welded shut.

iii) Windings are baked into a solid mass.

2) Designed for stock replenishment without any specific location or purpose in mind.

3) Rarely include any active voltage regulation and, hence, are not within the scope of this project

4) Purchase cost is relatively inexpensive.

5) Cost of installation far exceeds the cost of the transformer.”

From IEEE Std C57.167-2023

Guide for Monitoring Distribution Transformers

c) “Hence, for the typical user:

- 1) A significant problem with a distribution transformer typically results in its replacement with a new transformer, and the vast majority of those removed are then just scrapped.
- 2) A significant problem with a power transformer typically results in a clearance and a repair attempt. Replacement is the last recourse, and extensive repairs and subsequent reuse can be economic.”

Dan's Analogy:

A power transformer is like a store – it is designed for a specific site, is expensive and takes a long time to build, maintenance and repairs makes sense.

A distribution transformer is like goods in a store – when one leaves the shelf, another is ordered and placed in stock, there is no plan for where it is going or why, if one is damaged it is scrapped and easily replaced.

North America Electric Power System Overview

Transmission system is connected in a grid with a normally closed breaker between each section. Thus, a problem on any section typically results in the de-energization of that section but no loss of power to any customer. Typical transmission grid voltages are 750 kV, 500 kV, 345 kV, 230 kV, 138 kV, 115 kV, and 69 kV. These are the bulk power delivery systems. The higher the voltage the longer the lines are, and the greater the amount of power that is transferred.

Distribution lines are generally connected as tied-radial lines. The line starts at a substation bus operating at voltages ranging from 2.4 kV through 34.5 kV. They end at multiple normally-open switches where they tie to other radial lines. A problem on a line section results in the de-energization of part or all of the distribution line and the resulting loss of power to some or all of the associated customers.

Power transformers supply the connections between transmission grids of different voltage levels. They are also used to step-up generation voltages and to step-down transmission voltages to distribution levels. Distribution transformers make the connection between the distribution system and the customers.

Electric Power Flow Control

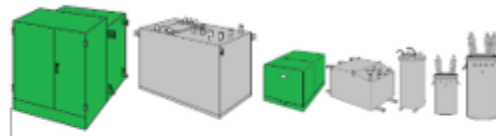
The photovoltaic effect and Faraday's and Kirchhoff's laws determine why and how electricity flows. Sunlight hitting solar cells produces electric power. A conductor cutting through magnetic lines of force, makes a current flow. Where there is a voltage difference between two points, a current will flow from the point with the higher voltage to the point with the lower voltage. Battery banks can absorb energy and later release it. Individual customers somewhat control how much power they draw from the system by the loads they turn on or off. Hydro, nuclear, and fossil fuel generators can control how much power they put into the system. Wind and solar generators only produce when conditions are right. Dispatchers manage the bulk transmission system by modifying the controllable generation levels to match forecast loading levels, trying to maintain voltages and current levels within prescribed limits. Battery banks, while controllable, only supply a tiny part of the overall power. While the distribution system has automatic voltage control, its power flow direction is largely uncontrolled.

The net effect is that most of the power flow is highly variable, and except for generator step-up (GSU) transformers, a transformer that is stepping down now may be stepping up in the next minute.

Recommendation

With the possible exception of GSUs, all transformers covered by the IEEE Transformers Committee should be designed for both step-up and step-down power flow.

MULKEY ENGINEERING INC.



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MULKEYENGINEERING@YAHOO.COM

Definition of Reverse Power

- Status of C57.12.80 addendum PAR Study Group – Reverse Power Flow definition
- Plan to hold an interim meeting to develop a draft “Reverse Power Flow” definition
- Before interim meeting – please send proposed definitions to chair, considerations:
 - Watts, VARs
 - Step-up, step-down, same voltage on both sides
 - >2 windings
 - Primary or secondary winding

Working Outline

1. Historical context

1. Watts and VARs chart
2. Typical causes of reverse power flow
3. How to assess which transformers are/may be subject to reverse power flow
(*possible informative annex; system condition not a transformer issue*)

2. Step-down vs step-up vs bi-directional vs same voltage both sides

1. C57.12.00, C57.12.01... others standards and how they discuss power flow direction

3. Potential effects

1. Voltage regulation
2. Core saturation (LV taps, variable flux)
3. Winding heating (common windings of autos)
4. ...
5. Include different transformer designs and potential concerns:
 1. Simple two winding
 2. Two winding w/ LV taps
 3. Two winding w/ LV taps, variable flux
 4. Auto transformers
 5. Multi winding transformers...

4. Recommended actions for operation of existing transformers

5. Recommended guidance for new transformers (e.g., specification type language)

Old Business

None

New Business

Any?

Next Meeting

Discuss – likely interim meetings for:

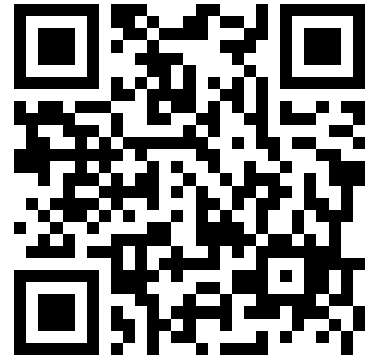
1. Definition of reverse power
2. Discuss “working outline”

Then in person (Denver, CO)

Adjourn

Thank you everyone

See you in Denver



Attendance/membership

