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Power Quality Standards

Power Quality Standards and References

How to use PQ Standards in Investigations

Merlin



Types of IEEE References

Standard – intended to be mandatory by any group that adopts it. In the US, maybe adopted by state regulatory agencies, or federal requirements. May not have much explanatory material except in an informative index.

IEEE 519-2022, *IEEE Standard for Harmonic Control in Electric Power Systems*

Recommended Practice – specifications that may have limits or performance characteristics, but not necessarily mandatory. Could be adopted by a utility as an internal standard or design goal. More likely to have background material or qualitative guidance.

IEEE 1159-2019, *IEEE Recommended Practice for Monitoring Electric Power Quality*

Application Guide – Intent is to be informative with a large amount of background material, case studies, and examples.

IEEE 1250-2018, *IEEE Guide for Identifying and Improving Voltage Quality in Power Systems*

Technical Report – more narrow in scope, focusing on a specific issue. May not have recommendations or solutions. Often used as reference material for a standard, recommended practice, or application guide.

IEEE TR102, *MV Smart Grid Sensor and Sensor Systems: Measurement Accuracy and Uncertainty Considerations*



IEEE 1250: *Guide for Identifying and Improving Voltage Quality in Power Systems*

Gateway document to other standards

- Describes momentary voltage disturbances, distortions, and causes in AC power distribution systems
- Effects on sensitive equipment
- Describes types of sensitive loads, ride-through capability
- Tolerance of computers to voltage magnitude, duration variations – CBEMA/ITIC curves
- Solutions to problems caused by voltage disturbances

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IEEE Guide for Identifying and Improving Voltage Quality in Power Systems

IEEE Power and Energy Society

Sponsored by the
Transmission and Distribution Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1250™-2018
(Revision of IEEE Std 1250-2011)



IEEE 1250: *Guide for Identifying and Improving Voltage Quality in Power Systems*

Key concepts:

- Overview of generation, transmission, and distribution systems
- Concept of power quality = compatibility between utility supply and equipment needs
- Overview of disturbance and steady state PQ issues
- Survey data showing typical PQ metrics in the field (sags, harmonics, imbalance, etc.)
- Discussion of various PQ standards, e.g. comparison of IEEE and IEC standards
- Summary of other PQ standards (flicker, harmonics, etc.) giving an overview and background
- Effects of PQ issues on equipment
- Mitigation methods, for utilities and end users
- Economic aspects of power quality
- PQ Glossary
- Reference table of other PQ standards

Anyone who needs an overview of PQ should read this



IEEE 1159 *Recommended Practice for Monitoring Electric Power Quality*

IEEE STANDARDS ASSOCIATION



- Provides guidelines for power quality monitoring
- Standard definitions for short term and long term power quality disturbances, distortions
- Provides common language for identifying and describing power quality events
- Types of PQ monitors and data sources
- Pitfalls and cautions with PQ monitoring and data analysis

IEEE Recommended Practice for Monitoring Electric Power Quality

IEEE Power and Energy Society

Developed by the
Transmission and Distribution Committee

Anyone working a PQ investigation should read this (after reading IEEE 1250)

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1159™-2019
(Revision of IEEE Std 1159-2009)



IEEE 1453

Limits for voltage fluctuations relating to light flicker

- Definitions, measurement techniques, and limits
- Translating flicker metrics to other lamp types
- Using planning levels
- Flicker estimation
- Impact of interharmonics on non-incandescent bulbs
- Example: arc furnace waveform shape issues, and mitigation strategies
- Flicker transfer coefficient and allocation
- Rapid Voltage Change (RVCs)

Very technical, may not be needed for everyday flicker issues



IEEE Standard for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems

IEEE Power and Energy Society

Developed by the
Transmission and Distribution Committee

IEEE Std 1453™-2022
(Revision of IEEE Std 1453-2015)



STANDARDS



Distortion: IEEE 519:2022

- Standard for measuring and applying limits to voltage and current harmonics
- Applies at utility level – not an equipment spec
- Limits for utilities (voltage) and end-users (current)
- 519 is a load standard – meant for customers with less than 10% on-site generation – use 1547 or 2800 if the system is mostly generation

No background info in the 2022 edition



IEEE Standard for Harmonic Control in
Electric Power Systems

IEEE Power and Energy Society

Developed by the
Transmission and Distribution Committee

IEEE Std 519™-2022
(Revision of IEEE Std 519-2014)



STANDARDS



IEEE 519:1992

Save the 1992 edition! Removed in 2014:

- Harmonic Generation
- System Response Characteristics
- Effects of Harmonics
- Reactive Power Compensation and Harmonic Control
- Analysis Methods

IEEE 519:1992 Recommend Practice: 101 pages

IEEE 519:2022 Standard: 31 pages

1992 edition contained large amount of background discussion, examples – still great info, but don't use the 1992 limits or measurement techniques

2022 edition is tightly focused on just the limits and statistical analysis

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Stray Voltage: IEEE 1695:2024

IEEE Guide for Understanding, Diagnosing, and Mitigating Stray and Contact Voltage

Stray Voltage: A voltage resulting from the normal delivery or use of electricity that may be present between two conductive surfaces that can be simultaneously contacted by members of the general public or animals. Stray voltage is not related to electrical faults.

Farms, pools, elevated neutral-earth voltage near substations

Contact Voltage: A voltage resulting from electrical faults that may be present between two conductive surfaces that can be simultaneously contacted by members of the general public or animals. Contact voltage can exist at levels that may be hazardous.

Insulation breakdown, ungrounded energized metal

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IEEE Guide for Understanding,
Diagnosing, and Mitigating
Stray and Contact Voltage

IEEE Power and Energy Society

Developed by the
Transmission and Distribution

IEEE Std 1695™-2024

IEEE



STANDARDS



IEEE 1668-2017

Key document for utility customers

IEEE STANDARDS ASSOCIATION



- Methods to test sag immunity for equipment
- Sag classifications
- Recommended sag immunity levels
- Test procedures
- References SEMI F47

**IEEE Recommended Practice for
Voltage Sag and Short Interruption Ride-
Through Testing for End-Use Electrical
Equipment Rated Less than 1000 V**

IEEE Industry Applications Society

Sponsored by the
Power Systems Engineering Committee

New draft under development

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1668™-2017
(Revision of IEEE Std 1668-2014)



IEEE 1668-2017

Utility perspective

Contains primer on voltage sags:

- voltage sag basics – definitions, etc.
- utility faults and sags
- voltage sag and current relationship
- expected frequency of voltage sags
- non-fault causes of sags

Explains why utilities can not practically eliminate all sags, so there must be an acceptable level, where customer equipment is tolerant

IEEE STANDARDS ASSOCIATION



IEEE Recommended Practice for Voltage Sag and Short Interruption Ride- Through Testing for End-Use Electrical Equipment Rated Less than 1000 V

IEEE Industry Applications Society

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IEEE Std 1668™-2017
(Revision of IEEE Std 1668-2014)



IEEE 1564

Voltage sag definitions and classifications

IEEE STANDARDS ASSOCIATION



IEEE Guide for Voltage Sag Indices

IEEE Power and Energy Society

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Transmission and Distribution Committee

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New York, NY 10016-5997
USA

IEEE Std 1564™-2014



- Quantifying sags – metrics like SARFI, MAIFI, SARFI-10
- Aggregation of sag data
- Recommended metrics and tabulation
- Other sag metrics – energy, etc.
- Example computations

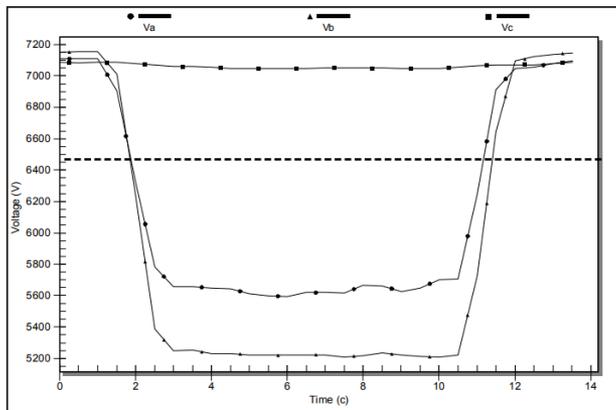


Figure 4—Voltage sag example: Three-phase voltage rms samples with sag threshold

ANSI C84.1

American National Standard for Electric Power Systems and Equipment— Voltage Ratings (60 Hertz)

Nominal voltage levels and ranges for point of connection (utility), and point of utilization (equipment)

Voltage unbalance

Developed from the Edison Electric Institute in the 1940s, then adopted by NEMA. Approved by ANSI in 1954. Last updated in 2020 to include discussion of distributed generation

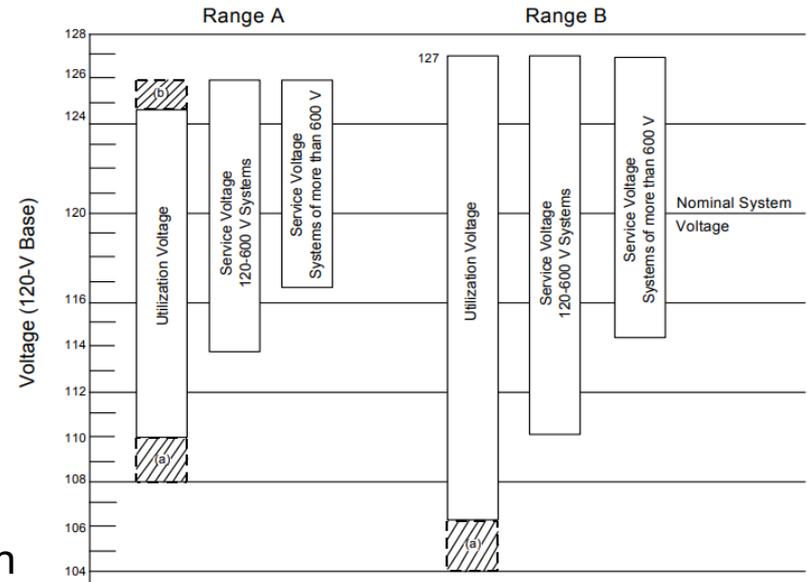


Figure 1. Voltage Ranges, ANSI C84.1

Range A: +/- 5%- design target, should be met most of the time, typically 95%

Range B: +6%, -13% - short term excursions only



IEEE 1409 – PQ Solutions

- Guide for methods to improve PQ
- Solutions for utilities and end users

- Overview of PQ issues and possible mitigation
 - Survey of typical feeder characteristics
 - Utility vs. customer solutions
- Voltage sags
- Harmonic filters and compensators
- Reactive power correction
- Case studies
- Economics of various solutions

Types of solutions: SVC, STATCOMs, DVRs, stored energy backup devices, surge arrestors, CVTs, line reactors, harmonic filters, etc.

IEEE Guide for Application of Power Electronics for Power Quality Improvement on Distribution Systems Rated 1 kV Through 38 kV

IEEE Power & Energy Society

Sponsored by the
Transmission and Distribution Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1409™-2012

27 April 2012



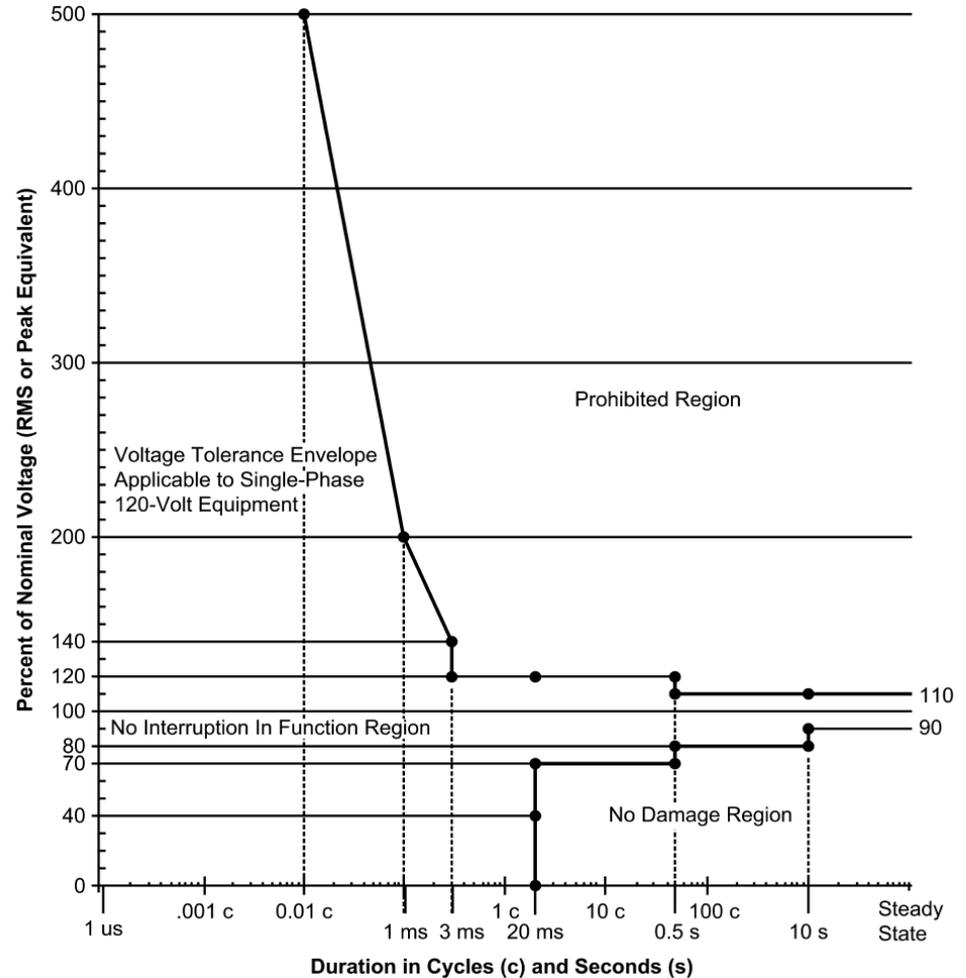
ITIC “Application Note”

ITIC Curve

- Replaces CBEMA curve
- Applies to common 120V computer equipment
- Withstand capability – ride-through of loads to voltage variations
- Percent voltage vs duration of disturbance

Not a utility spec, intended for electronic equipment manufacturers

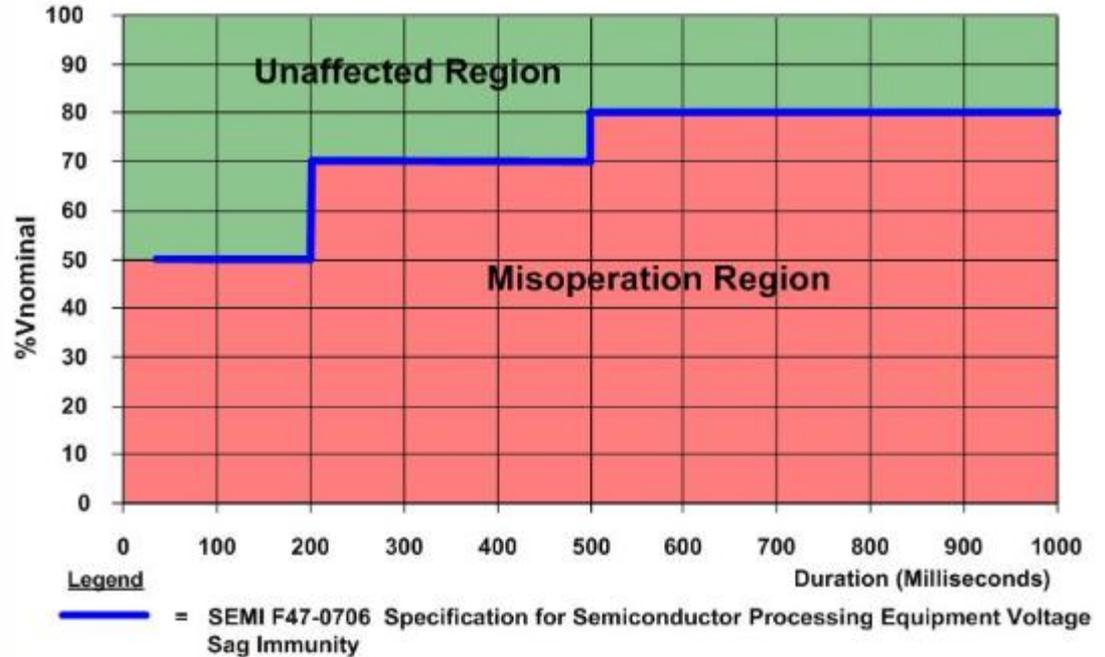
Guideline for minimum ruggedness and ride-through



SEMI F47-0706

- Originated from EPRI R&D in the late 1990s
- Sag immunity tests/requirements for semiconductor manufacturing equipment
- Designed to prevent extremely costly downtime from utility sags

Contains sag withstand requirements, and test procedures for equipment



Not a utility spec, but equipment designed to SEMI F47 should be compatible with most utility sag patterns

Often used for other industrial equipment, such as VFDs



IEEE 1547-2018

Requirements for DER inverters connected to distribution

- Performance Requirements
- VAR/Power/Voltage Control
- **Power Quality**
- Islanding
- Secondary grids/spot networks
- Test & verification requirements

IEEE STANDARDS ASSOCIATION



IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

IEEE Standards Coordinating Committee 21

Sponsored by the IEEE Standards Coordinating Committee 21 on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1547™-2018
(Revision of IEEE Std 1547-2003)



IEEE 1547.2 Application Guide

This guide provides technical background and application details to support understanding of IEEE Std 1547-2018.

Guides to 1547 (DR requirements), and 1547.1 (DR test requirements)

Background discussion on DRs and the effect on power quality

“Tips, techniques, and rules of thumb”

Discussion of different types of DRs

System impact studies

IEEE SA
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**IEEE Application Guide for
IEEE Std 1547™-2018, IEEE Standard
for Interconnection and Interoperability
of Distributed Energy Resources with
Associated Electric Power Systems
Interfaces**

IEEE SA Board of Governors
and the
IEEE Power and Energy Society

Developed by the
Distributed Generation, Energy Storage, and Interoperability Standards Committee
and
Transmission and Distribution Committee
Energy Development and Power Generation Committee

IEEE Std 1547.2™-2023
(Revision of IEEE Std 1547.2-2008)

 **IEEE**



IEEE 2800

Requirements for transmission-connected IBRs

- Interconnect requirements
- Reactive power control requirements
- Frequency requirements
- Response to sags, frequency deviations
- Power quality limits (voltage fluctuations, harmonics, overvoltage)
- Protection requirements
- Test and Verification requirements
- Several informative annexes – voltage stability, system strength, protection settings, modeling, etc.

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IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems

IEEE Power and Energy Society

Developed by the
Energy Development & Power Generation Committee, Electric Machinery
Committee, and Power System Relaying & Control Committee

IEEE Std 2800™-2022



STANDARDS



NRECA Guide to 1547

GUIDE TO THE IEEE 1547-2018 STANDARD AND ITS IMPACTS ON COOPERATIVES

March 2019

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<https://www.cooperative.com/programs-services/bts/Documents/Reports/NRECA-Guide-to-IEEE-1547-2018-March-2019.pdf>



519, 1547, 2800

Standard	519-2022	1547-2018	2800-2022
Scope	DG < 10% of average load	Distribution DG	Transmission IBRs
Voltage Harmonics	Yes	No	No
Current Harmonics	Harmonic subgroups, based on short circuit current and max demand load current	Yes, includes interharmonics and TRD	Yes, includes interharmonics and TRD
Flicker	No	Yes	Yes
Rapid Voltage Change	No	Yes	Yes
RMS Overvoltage	No	Yes	Yes
Instantaneous Overvoltage	No	Yes	Yes



Power Quality Standards

Power Quality Standards and References

How to use PQ Standards

Merlin



Power Quality is about Compatibility

Engineering standards give utilities and equipment manufacturers guidelines so the compatibility burden is reasonably divided

Excessive burden on utilities to provide extremely high quality power regardless of customer loads



Excessive burden on customers to purchase rugged equipment or power conditioning devices



Standards are the electrical “contract” between the utility and customer



“Clean Bill of Health”

Use the standards to show customers that delivered voltage is within spec

These standards cover virtually all voltage quality variations:

- Voltage Sags, Swells – IEEE 1668, SEMI-F47, ITIC/CBEMA
- Voltage Regulation – ANSI C84.1
- Flicker – IEEE 1453
- Imbalance – ANSI C84.1, IEEE 2844
- Harmonics, Notching – IEEE 519
- Transients, HF noise – IEEE 1159



“Clean Bill of Health”

If you are in compliance with all voltage quality standards, the customer's equipment is too sensitive, and needs filtering, UPS, conditioning, etc.

- Voltage Sags, Swells – customer's equipment not meeting CBEMA/SEMI-F47 guidelines, or customer causing own sags – need soft starters/VFD, line reactors
- Voltage Regulation – customer's C84.1 utilization voltage too low -> wiring problem in facility
- Flicker – cheap LED bulbs, not as good as incandescent
- Harmonics, HF noise – overly sensitive AFCI/GFCI, or customer causing own distortion with nonlinear loads
- Transients – equipment not meeting minimum surge suppression standards, threshold settings too tight
- Imbalance – motor/VFD protection settings too tight



Enforcement Tool

If a customer is disrupting voltage quality for other customers – the standards (through the tariff agreement) are a mechanism to force customer action

- Customer introducing voltage distortion – must meet 519 harmonic current limits
- Customer causing sags or flicker for others – must limit sags to 1668 levels, limit flicker contribution per IEEE 1453
- Distributed Generation site producing flicker, harmonics, etc. – must comply with IEEE 1547

A standards violation is a concrete, objective reason to threaten to disconnect the customer unless action is taken.



Enforcement Tool

IEEE 519, 1547, 1453 – explicit customer contribution focus for PQ issues

These standards are focused on limiting one customer's ability to disrupt voltage quality for other customers

Not concerned with customers causing their own problems.

Utilities are expected to size transformers, conductors, etc. for thermal reasons, not for voltage quality mitigation in the presence of customer standards violations

Open issue – local overvoltage due to on-site solar, wind generation

Example – residential customer PV pushing voltage > 252 Vrms – larger transformer would mitigate this – who pays??



Justification Tool

If you are out of compliance the standards are a mechanism to justify utility spending

- Transformer or service change
- Regulator adjustment or new regulator/cap bank
- Detuning capacitor resonance
- Zero-crossing switching devices
- Rebalancing feeders
- Separating customers
- Reconductoring
- Outside consultant use



Special Case: IEEE 519

Limiting distortion is a “shared responsibility” – utility and end users

- Utility – keep system impedance low to minimize voltage distortion with “acceptable” harmonic currents
- Users – keep load harmonics “acceptable” to allow a utility to operate with reasonable impedances

Transformer, service drop, etc. sized for thermal loading, not lowering distortion.

Watch out for resonances – increases utility impedance

Related: overvoltage on secondary due to PV



High Voltage on the Secondary

1. inverter output raises secondary voltage
2. inverter trips off due to high voltage
3. upset customer who is prevented from generating

Common problem with smaller PV systems, even residential

Opposite of voltage sag – high impedance separating inverter from primary creates voltage drop, *increasing* voltage on secondary

- Change transformer tap to lower steady-state voltage
- Upsize transformer
- Increase service drop conductor size
- Ensure conductors to inverter are sized appropriately – may need to be larger than NEC minimums

Secondary current pushing voltage higher, not lower

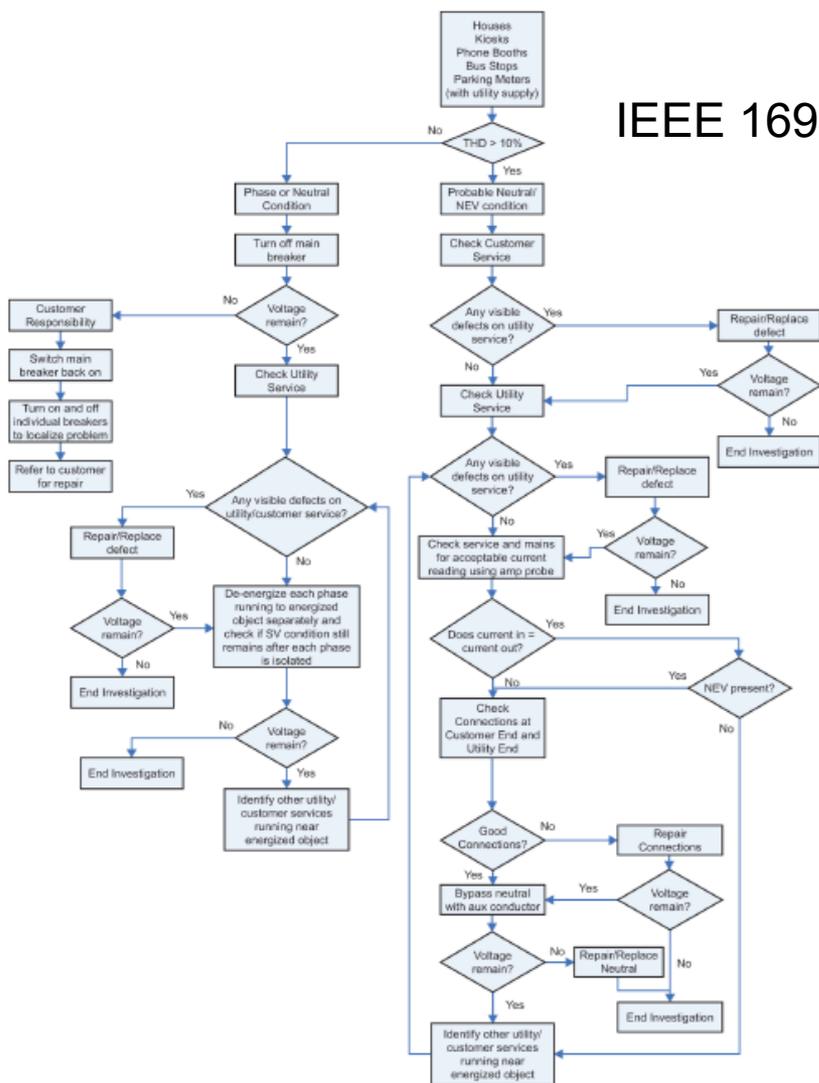
Transformers typically sized for thermal loading, not voltage

Rely on service vs. utilization voltage language in ANSI C84.1



“How To” Tools

IEEE 1695 – Stray Voltage Investigations



IEEE 1159 – PQ Investigations

Table 5—Suggested threshold settings for 120 V loads

Conducted phase voltage thresholds		
Sag	108 V rms	Minus 10% of nominal supply voltage.
Swell	132 V rms	Plus 10% of nominal supply voltage.
Transient	200 V peak	Approximately twice the nominal phase-neutral voltage.
Noise	1.5 V	Approximately 1% of the nominal phase-neutral voltage.
Harmonics	5% THD	Voltage distortion level at which loads can be affected.
Frequency	± 0.1 Hz	—
Phase imbalance	2%	Voltage imbalance greater than 2% can affect equipment. (Three-phase induction motors should be derated when operated with imbalanced voltages; see IEEE Std 141-1993 [B24].)
Conducted phase to neutral voltage thresholds		
Swell	3.0 V rms	Typical level of interest for neutral and/or ground problems.
Impulsive transient	20 V peak	Ten to twenty percent of phase-neutral voltage.
Noise	1.5 V rms	Typical equipment susceptibility level.

Figure 32—Troubleshooting flow chart for objects that are directly fed by the electric system (customer and/or utility)



Power Quality Standards

Power Quality Standards and References

How to use PQ Standards in Investigations

Merlin



Using AI for Power Quality

Use algorithmic code for basic measurements and compliance determination – **don't use AI or LLMs for math!**

Feed raw PQ data, computed measurements, compliance results to AI
Ground all AI with detailed PQ knowledge and **standards** – no hallucinations!

Deterministic-first: math/compliance by code; AI handles **triage, narrative, correlation**, never raw calculations.

“Eyes on” – Merlin™ looks at **everything**

- Every waveform capture
- Every stripchart graph
- Every PQ type analyzed
- Every compliance report generated and reviewed

Merlin™ provides
baseline PQ analysis
narrative around the data
correlation among PQ data types
trend/pattern detection
powerful report writing ability



Merlin™ Goals

- **Cut review time** with automatic analysis of all waveforms, stripcharts, and metrics.
- **Turn deterministic analytics into clear narratives**, translating RMS trends, sag metrics, flicker indices, and compliance checks into engineer-ready explanations.
- **Highlight what matters**, ranking events by severity, cause, risk, and customer impact to shorten triage and guide priorities.
- **Provide human-verifiable reasoning**, grounding every conclusion in standards-based computations and citations to IEEE/ANSI/SEMI clauses.
- **Expose subtle PQ issues** that are easy to miss in large datasets.
- **Provide expert, standards-based PQ review** — every IEEE standard, PMI white paper, and 30 years of heuristics applied to every PQ recording
- **Create polished reports** for customers and internal teams with tunable tone and style



AI as an Interpreter, Not A Replacement

A familiar lesson from medical imaging

- When AI-based image interpretation entered radiology, many feared it would replace radiologists
- Instead, scan volumes increased and **demand for radiologists grew**
- AI now performs **first-pass screening and prioritization**
- Human experts focus on **judgment, context, and communication**

The same model applies to power quality

- Merlin™ reviews *every* waveform and stripchart—something humans don't have time to do
- Engineers remain the authority for **causality, decisions, and actions**
- AI reduces time spent hunting for issues, not the need for human judgement



What Goes into Merlin?

PMI PQ knowledge

- Over 400 technical PQ whitepapers
- Tens of thousands of PQ recordings
- Petabytes of PQ data
- Over a year of AI work, refining LLM analysis and multi-agent orchestration
- Decades of helping utilities translate PQ findings into actionable results and customer-facing explanations

IEEE/ANSI Standards Knowledge

- Key thresholds and guidance
- Background on how to apply the standards
- Apply standards to regulatory and tariff requirements

Utility-specific Overlay

- State regulatory PQ requirements
- Internal guidelines
- Site-specific rules



Merlin™ Overview

← → ↻ pqcanvass.powermonitors.com

Pump_lift_station.nsf

[Overview](#) | [Recording](#) | [Info](#)

[Back](#) | [Refresh](#) | [Start Analysis](#) Severity: 0 Low 5 Moderate 10 High

Power Quality Report

★ Severe sags/swells, chronic V2 distortion, pump-start RVCs

TOP ISSUES

- Voltage sags Severity 10
Deep fault-like sags plus pump-start dips
- Voltage swells Severity 10
Fault/regulator-driven overvoltages
- Harmonics Severity 10
Persistent 6–11% V2 voltage THD

Severe sags/swells, chronic V2 distortion, pump-start RVCs →

Compliance

- 0 Voltage Regulation
ANSI C84.1
- 7 Sag Immunity
IEEE 166B
- 5 Flicker
IEEE 1453
- 2 Imbalance
ANSI C84.1

Power Quality Sub-Reports

 Flicker	Low flicker with pump RVCs; compliance uncertain
 Harmonics	Feeder-dominated 6–11% phase-2 voltage THD
 Sags	Deep single-phase sags, pump-start RVCs, rare collapses
 Swells	Extreme three-phase swell and V2 regulator swells

Click any row to view the full report →

Waveforms



Motor-start RVCs plus utility faults causing sags/interruptions →

Stripcharts



Click to see a detailed breakdown →



Waveform Classifier

Every waveform examined by Merlin™, providing:

- Disturbance classification
- Severity ranking
- IEEE standards clause cite
- Utility vs customer attribution
- Possible root cause
- Steady state analysis (Vrms, imbalance, harmonic distortion)
- Narrative explaining the analysis

SEVERITY

7

OSCILLATORY TRANSIENT

CAPTURE

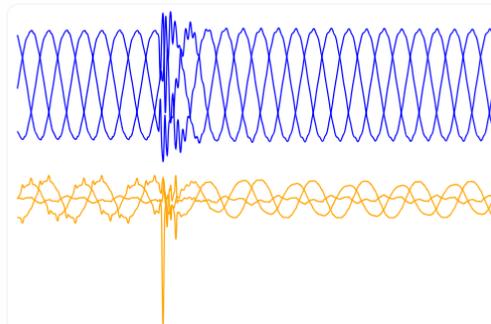
18

Low-frequency oscillatory transient; small voltage step

Damped low-frequency oscillatory transient on all phases centered near 45–55 ms. Initial spike reaches about 1.46 pu (~994 V peak) followed by several cycles of decay; total disturbance ≈10–12 ms (IEEE 1159 §4.4.1–4.4.1.3). Sliding RMS shows a narrow overshoot and a step to ~1.06 pu; duration above 1.1 pu is <0.5 cycle, so no swell per IEEE definition (IEEE 1159 §4.4.2.3). Waveform shape and the slight positive voltage step with concurrent switching currents are consistent with upstream capacitor-bank energization or feeder switching.

DEBUG REASONING

- RMS visual check: no ≥0.5-cycle swell/sag
- Interruption check: Vmin far >0.1 pu
- Peak ≈993 V ≈1.46 pu; severity 7
- Clear damped ringing 45–55 ms
- Bad-sample ruled out: multi-sample ring



CAPTURE DETAILS

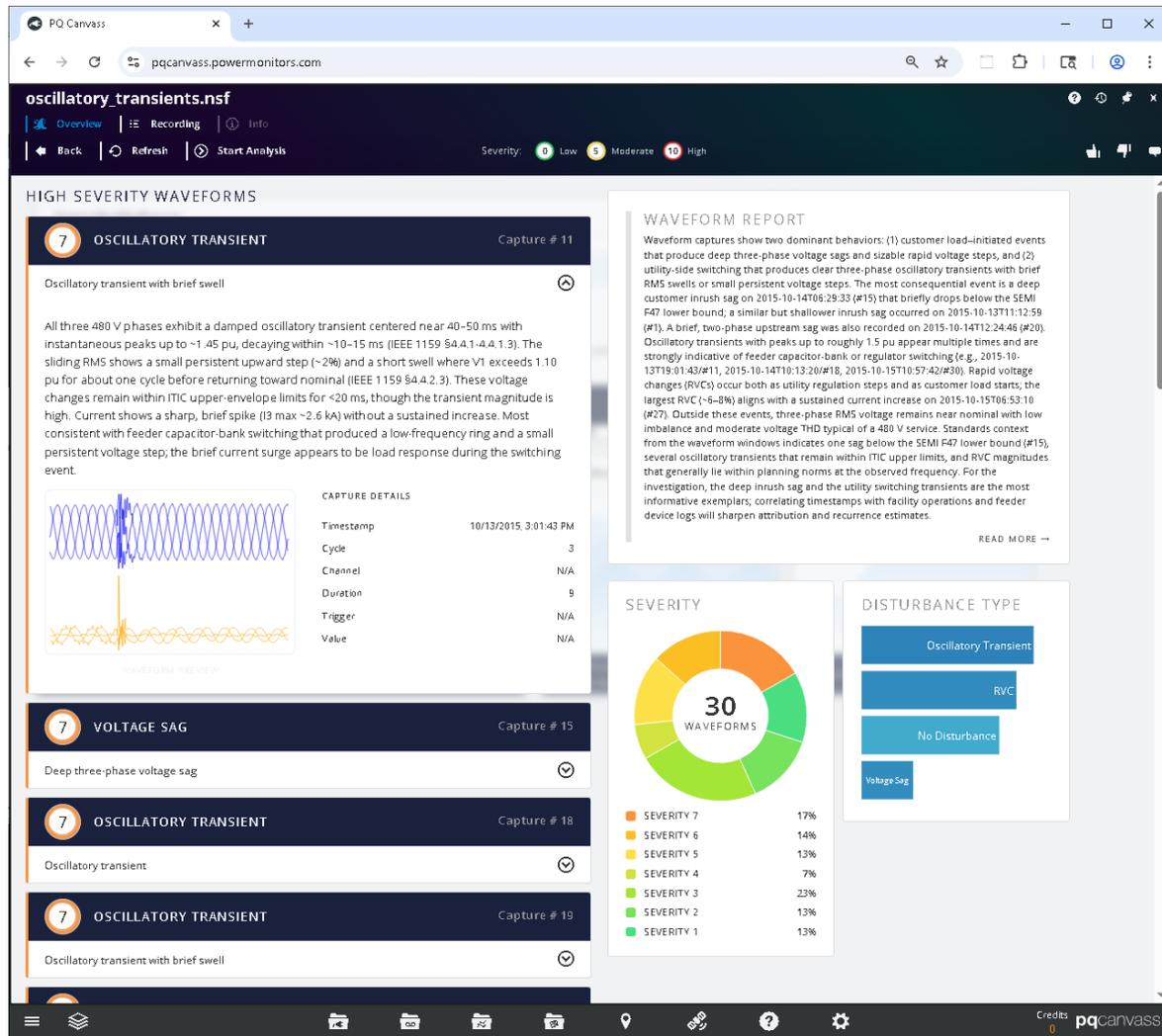
Timestamp	10/14/2015, 6:13:20 AM	Cycle	51
Channel	N/A	Duration	9
Trigger	N/A	Value	N/A



Waveform Dashboard

Waveform Report Sections

- Executive Summary
- High Severity Captures
- Compliance Summary
- Attribution (Utility/Customer)
- Summary of All Captures
- Patterns and Likely Origins
- Closely Spaced Events
- Junk Waveforms
- Steady State Trends
- Investigative Guidance
- Waveform Exam Next Steps
- Followup Recording Advice



Narrative and compliance report around entire waveform dataset in recording



Waveform Report

Analysis over entire waveform set

- Disturbance summary
- Severity ranking
- Patterns among multiple captures
- Overall steady-state trends

The screenshot displays the 'oscillatory_transients.nsf' report in the PQ Canvas interface. The left sidebar lists report sections: Disclaimer, Executive Summary, High Severity Captures, Compliance Summary, Attribution, Summary Of All Captures, Patterns And Likely Origins, Closely Spaced Multi Trigger Events, Junk Waveforms, Steady State Trends, Investigation Guidance, Waveform Exam Next Steps, and Followup Recording Advice. The main content area is divided into three sections: Compliance Summary, Attribution, and Summary of All Captures. The Compliance Summary section states that based on the captured waveform windows, one sag on 2015-10-14T06:29:33 (#15) briefly falls below the SEMI F47 absolute lower bound, and a sag on 2015-10-13T11:12:59 (#1) is above the SEMI F47 bound for its duration but dips below the ITIC lower envelope. The short two-phase sag on 2015-10-14T12:24:46 (#20) remains within both ITIC and SEMI F47 envelopes. The Attribution section identifies two attribution families: customer-origin disturbances including a deep inrush sag on 2015-10-14T06:29:33 (#15) and an earlier inrush sag on 2015-10-13T11:12:59 (#1), and utility-side behavior indicated by multiple three-phase oscillatory transients with a small persistent Vrms step and little net current change. The Summary of All Captures section notes that thirty captures were reviewed, with dominant classes being oscillatory transients (10) and RVCs (9). Capture timestamps are distributed across the session, with activity clusters around 2015-10-13T14:42 and 2015-10-15T09:25.

Narrative and compliance report around entire waveform dataset in recording



PQ Topic In-Depth Reports

Deep-dives on specific PQ Topics: sags, swells, flicker, harmonics

The screenshot displays a web-based Power Quality Report for 'Pump_lift_station.nsf'. The interface includes a navigation bar with 'Overview', 'Recording', and 'Info' tabs, and a severity indicator showing 0 Low, 5 Moderate, and 10 High. The main report area is divided into several sections:

- Power Quality Report:** A summary box highlights 'Severe sags/swells, chronic V2 distortion, pump-start RVCs'. Below this, 'TOP ISSUES' are listed: Voltage sags (Severity 10), Voltage swells (Severity 10), and Harmonics (Severity 10).
- Compliance:** A sidebar on the right shows compliance scores for Voltage Regulation (0), Sag Immunity (7), Flicker (5), and Imbalance (2).
- Power Quality Sub-Reports:** A section highlighted with an orange border, containing a table of sub-reports:

Topic	Description
Flicker	Low flicker with pump RVCs; compliance uncertain
Harmonics	Feeder-dominated 6-11% phase-2 voltage THD
Sags	Deep single-phase sags, pump-start RVCs, rare collapses
Swells	Extreme three-phase swell and V2 regulator swells

Below the sub-reports table are three visualization sections: 'Waveforms' (Motor-start RVCs plus utility faults causing sags/interruptions), 'Stripcharts' (Click to see a detailed breakdown), and a footer with '© Power Monitors, Inc. 2026' and 'MREC, 2/12/2026'.



Example - Voltage Sag Report

Voltage Sag Report Sections

- Executive Summary
- High Severity Sags
- Compliance Summary
- Attribution (Utility/Customer)
- Summary of All Sag Evidence
- Patterns and Likely Origins
- Closely Spaced Events
- Junk Inputs
- Sag Exam Next Steps
- Investigative Guidance
- Followup Recording Advice

← → ↻ pqcavass.powermonitors.com

Pump_lift_station.nsf

Overview | Recording | Info

Back | Refresh | Start Analysis

Severity: 0 Low 5 Moderate 10 High

Report Sections

- Disclaimer
- Executive Summary
- High Severity Sags
- Compliance Summary
- Attribution
- Summary Of All Sag Evidence
- Patterns And Likely Origins
- Closely Spaced Multi Trigger Events
- Junk Inputs
- Investigation Guidance
- Sag Exam Next Steps
- Data Quality And Confidence
- Followup Recording Advice

Voltage Sag Report

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Disclaimer

This report was created using generative AI. Accordingly, it may contain errors or inaccuracies and should not be relied upon as a substitute for professional advice. This is not intended to be used as the sole basis for any decision making and is provided on an "as is" basis, without warranties of any kind, whether express or implied. For any questions, seek professional advice from a qualified expert.

Executive Summary

In this week-long 240 V three-phase lift-station recording, voltage is normally well regulated but there are a few very deep sags and brief collapses, together with frequent pump-start rapid voltage changes that produce only shallow dips. Across roughly 6.8 days, six instantaneous sags were captured in high-speed waveforms, including a single-phase depression on one phase to about 0.23 pu for 9 ms and a sequence near 2024-08-05T07:52:44-07:52:46 where that phase remained around 0.17-0.31 pu for roughly 0.13 s and was followed by momentary interruptions; these are fault-like events that almost certainly caused load dropout. Earlier, a cluster around 2024-08-04T11:43:56-11:44:21 shows a mix of pump-driven sags on the heavily loaded phases and deeper upstream-driven three-phase sags to roughly 0.45-0.53 pu lasting 75-133 ms, while 10-second RMS trends reveal another deep but less extreme sag around 2024-08-02T16:08 and two near-zero collapses over the week. Most pump starts draw 250-370 A and cause only 2-6% voltage steps and minima of 0.96-0.99 pu, so flicker risk is moderate; the high-severity impact is dominated by infrequent upstream faults, possible single-phasing conditions, and the anomalously deep pump-associated sag. Data coverage is asymmetric: the RMS disturbance list covers only the first few hours of the record and shows no true sags, while high-speed waveforms and the sag-compliance evaluation are back-loaded over 2024-08-04-2024-08-05; 10-second RMS stripcharts provide continuous context and confirm that the deep events are rare but real.

High Severity Sags

The most severe activity is the outage-like sequence around 2024-08-05T07:52:44-07:52:46. Waveforms show one phase (V1) collapsing to roughly 0.17-0.31 pu for at least 0.13 s while the other phases are near nominal or slightly elevated, followed by brief single- and three-phase interruptions; the sag-compliance engine reports a minimum retained voltage of about 0.234 pu for 9 ms during this sequence. Load current does not increase appreciably before the depression, and all three phase currents decay as the voltage collapses, so this cluster is best interpreted as an upstream single-line event and subsequent clearing, with high likelihood of contactor and control dropout on affected loads. 10-second RMS stripcharts around 2024-08-05T07:53 show all three phase voltages and currents near zero for at least one interval, confirming that the event progressed into a full service collapse rather than a measurement artifact.

A second high-severity cluster occurs around 2024-08-04T11:43:56-11:44:21. Initial captures show sags on the pump phases (V2 and V3) into the 0.5-0.65 pu range with Irms on those phases rising above 100 A, followed by a deeper three-phase sag where all phases sit near 0.45-0.47 pu for roughly 75-133 ms. Portions of this sequence are classified as multi-phase Type II and Type III sags in the compliance analysis, with worst retained voltages in the 0.53-0.64 pu range for 19-58 ms, while the waveform classifier sees cycle-by-cycle minima closer to 0.45-0.47 pu for several cycles. These sags are deep enough and long enough to cross below the ITIC lower curve and approach or fall below the SEMI F47 0.50 pu bound in parts of the waveforms, so three-phase motors and sensitive control loads would be at significant risk of tripping.



Compliance In-Depth Reports

Deep-dives on ANSI C84.1 voltage regulation and imbalance, IEEE 1668 Voltage Sags, IEEE 1453 Flicker, IEEE 519 Harmonics

The screenshot displays a web interface for a power quality monitoring system. The browser address bar shows 'pqcanvass.powermonitors.com'. The page title is 'Pump_lift_station.nsf'. Navigation options include 'Overview', 'Recording', and 'Info'. A 'Severity' indicator shows 0 Low, 5 Moderate, and 10 High. The main report is titled 'Power Quality Report' and features a summary: '★ Severe sags/swells, chronic V2 distortion, pump-start RVCs'. Below this, 'TOP ISSUES' are listed: Voltage sags (Severity 10), Voltage swells (Severity 10), and Harmonics (Severity 10). A 'Compliance' section is highlighted with an orange border, showing scores for Voltage Regulation (0), Sag Immunity (7), Flicker (5), and Imbalance (2). The 'Power Quality Sub-Reports' section lists Flicker, Harmonics, Sags, and Swells with brief descriptions. 'Waveforms' and 'Stripcharts' sections provide visual data representations.

Power Quality Report

★ Severe sags/swells, chronic V2 distortion, pump-start RVCs

TOP ISSUES

- Voltage sags Severity 10
Deep fault-like sags plus pump-start dips
- Voltage swells Severity 10
Fault/regulator-driven overvoltages
- Harmonics Severity 10
Persistent 6–11% V2 voltage THD

Compliance

- 🔊 Voltage Regulation (0)
ANSI C84.1
- ⚡ Sag Immunity (7)
IEEE 1668
- ☀ Flicker (5)
IEEE 1453
- 📊 Imbalance (2)
ANSI C84.1

Power Quality Sub-Reports

- ☀ Flicker: Low flicker with pump RVCs; compliance uncertain
- 📊 Harmonics: Feeder-dominated 6–11% phase-2 voltage THD
- ⚡ Sags: Deep single-phase sags, pump-start RVCs, rare collapses
- ⬆ Swells: Extreme three-phase swell and V2 regulator swells

Waveforms

Motor-start RVCs plus utility faults causing sags/interruptions

Stripcharts

Click to see a detailed breakdown



In Beta: Chat with Merlin

Interactive chat session, with PQ recording in Merlin's memory

Ask question about the data

Give it background and context (transformer size, customer complaint, etc.)

Brainstorm solutions

The screenshot displays a web browser window with the URL `pqcanvass.powermonitors.com`. A chat window titled "Town well intermittent power loss" is open, showing a conversation with an AI assistant named Merlin. The chat content includes:

Merlin: To move the investigation forward, we'll need to record help:

- 1) Where exactly is the PQ recorder tied in relative to the ATS and generator (utility side vs load side vs at the motor MCC)?
- 2) Do you have timestamps for any of the "few-second" loss-of-power events, and do any fall between November 19 and 26?

User: From there we can decide whether:

- You need a follow-up recording on the load side of the ATS or at the pump MCC, or
- You should extend monitoring over a longer period to try to capture one of these events.

User: do any waveform captures seem important for this?

Merlin: No - not for your specific symptom.

This recording only has one waveform capture, and it's during a large three-phase inrush event late in the week. That waveform shows:

- Clean three-phase sinusoidal voltage.
- THD still low.
- Only a shallow 1-2% voltage droop from an already slightly high base (around 1.02-1.03 pu).
- No sign of an interruption, ATS transfer, or generator pickup in that window.

So the waveform is useful as a sanity check that:

- The source is very stiff, even during big motor/plant starts.
- There are no hidden fast transients or deep instantaneous sags during that captured inrush.

But for the issue you care about - "few-second loss of power, generator sometimes starting, no breakers trip" - this waveform doesn't show such an event at all. It doesn't capture a momentary loss of voltage, nor the scheduled 8:13-8:40 AM generator run as a drop at the recorder location.

If you want waveform evidence of those brief outages or ATS operations, you'd need:
The recorder placed on the load side of the ATS (or at the well MCC) need

At the bottom of the chat window, there is a text input field with the placeholder "Ask a follow-up question..." and a send button.

In the background, the dashboard shows a "Compliance" section with metrics for Voltage Regulation (ANSI C84.1), Sag Immunity (IEEE 1668), Flicker (IEEE 1453), and Imbalance (ANSI C84.1). A "Stripcharts" section displays a line graph of voltage data over time.



In Beta: Chat with Merlin

Interactive chat session, with PQ recording in Merlin's memory

Merlin chat includes:

- entire PQ recording digest in context window – ask questions about the data, patterns found, etc.

- Embedded knowledge of all IEEE/ANSI PQ thresholds, with PMI-generated guidance on application – no hallucinating

- Internal guidance on utility-specific issues relating to power quality

- Access to over 400 PMI technical PQ whitepapers to draw from



In Beta: Document Writer

Uses power of Merlin™ to shape output documents: customer letter, internal technical report, compliance filing, email summary, etc.

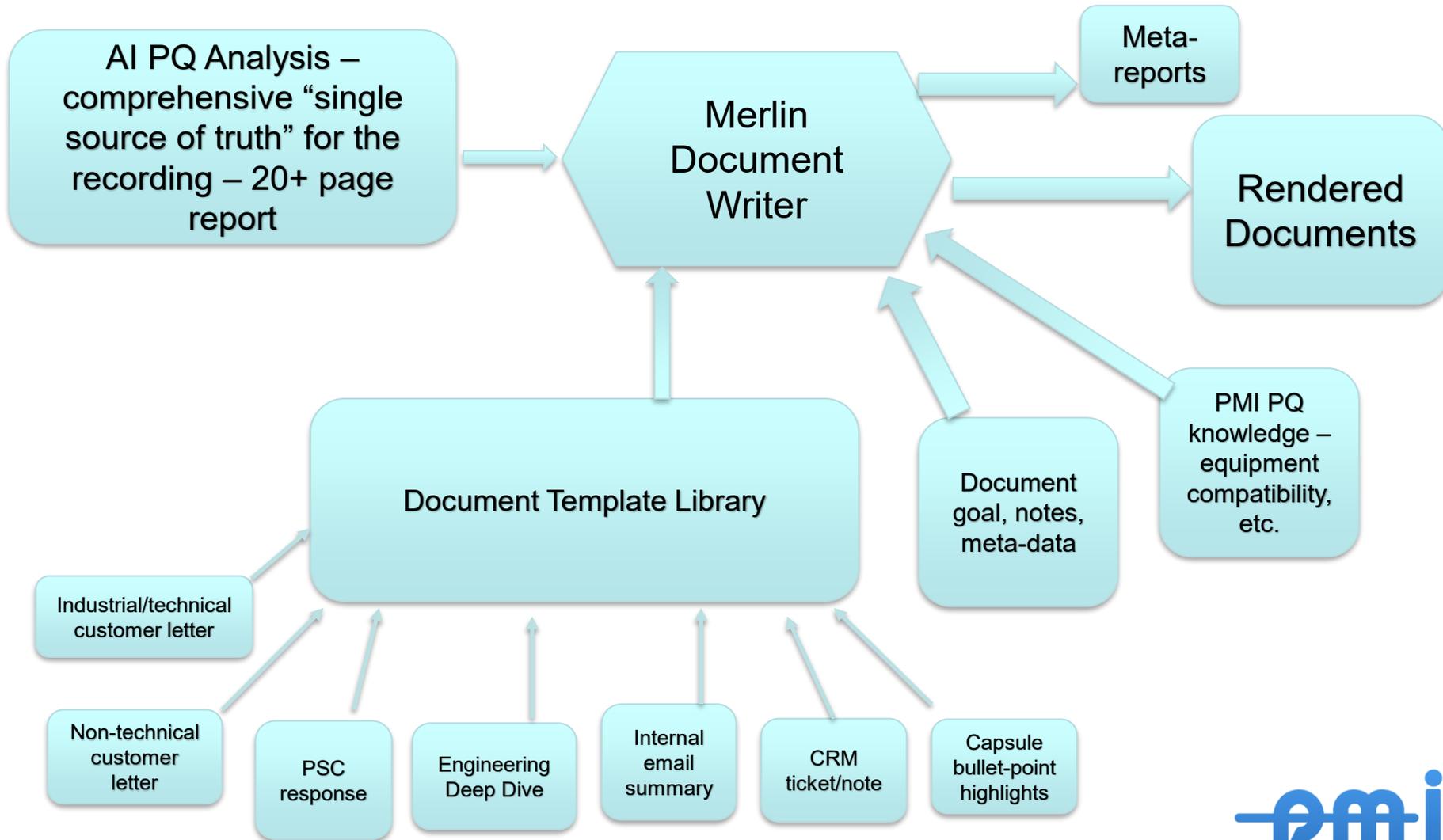
- Output is composed by Merlin full PQ recording analysis in memory, along with any meta-data (transformer info, customer symptoms, equipment specs, etc.)
- Composition may be “tuned” as needed – no facts changed, just the framing and narrative
- All claims backed by representative graphs zooms, event logs, etc. from the PQ recording and IEEE standards citations
- Formats: Letter, memo, short email, formal report, technical or non-technical customer-facing vs internal, etc.

Adjustment tuners:

- **Voice Bias**: Directional narrative preferences (tone, perspective, framing)
- **Style Tuners**: Volume/intensity knobs for report structure (verbosity, citations)
- **Attention Weights**: Relative emphasis across PQ categories (e.g. sags vs transients)



Merlin™ Report Writer



Template Examples

CRM / Ticket Note

Purpose: Fast, internal triage note for ops/ticketing.

Tone & Rigor: Neutral–technical, concise, low verbosity.

Highlights:

- Very short (<150 words) internal note.
- Focus on **PQ issues**, **root cause**, and **attribution**.
- Lightly technical, mild causal language.
- Strong emphasis on **next-step clarity** for ops crews.
- Very low numeric density; no images; no exposition.
- High utility + customer action emphasis for actionable follow-through.
- High complaint-integration — meant for ticket closure.

Regulatory Filing (PSC)

Purpose: Formal complaint response to a Public Service Commission.

Tone & Rigor: Maximal rigor, formal/regulatory tone.

Highlights:

- 1–2 page structured PSC-grade report with section headers.
 - Heavy numeric detail + high citation density.
- Balanced attribution, no overclaiming (causality_bluntness=0)

Residential Customer Letter (English)

Purpose: Customer-friendly letter explaining PQ findings & attribution.

Tone & Rigor: Soft, friendly-formal, low rigor.

Highlights:

- Gently but clearly communicates **customer-side cause** of flicker.
- High background explanation for layperson readability.
- Strong customer-action emphasis (what they can do).
- Moderate images; light numeric detail.
- Very high complaint integration; designed to reduce callbacks.

Engineering Deep Dive

Purpose: Full internal engineering analysis.

Tone & Rigor: High-rigor SME mode; clause-aware; verbose.

Highlights:

- Multi-page, detailed technical report with all sections.
 - Heavy citations, heavy numeric detail, extensive images.
 - High event-listing detail and long narrative explanations.
 - Balanced attribution; moderate prescriptiveness.
 - Intended for PQ engineers, not customers.
- Surfaces compliance margins, mechanisms, and root causes

Senior Management / Executive Summary

Purpose: Leadership-level summary of PQ findings and business impact.

Tone & Rigor: Polished, concise, mildly formal.

Highlights:

- <350-word high-level memo with section headers.
- Dense numeric content but short narrative.
- Balanced attribution; highlights customer impact & utility risk.
- Moderate prescriptiveness — focuses on next decisions.
- Mentions business consequences, KPIs, potential risks.
- Only 1 image; minimal event detail.

Spanish-Language Customer Letter

Purpose: Same as residential letter but in Spanish (mandatory).

Tone & Rigor: Customer-friendly; explanatory; utility-leaning.

Highlights:

- Entire output **must be in Spanish**.
- Explains flicker as customer-caused.
- High background exposition; soft tone despite strong attribution.
- Same structure as English version but culturally adapted.
- Suitable for residential customers with limited technical background.

Industrial Plant Engineer Letter

Purpose: Technical letter to facility/plant engineering staff.

Tone & Rigor: Medium-high technical detail; professional.

Highlights:

- 1–2 page engineering-grade letter with section headers.
- High numeric detail; moderate-heavy images.
- Balanced technical tone (neither customer nor utility biased).
- Focus on equipment impacts, compatibility, and operations.
- Strong prescriptive action items for both sides.
- Includes IEEE references where relevant.
- Strong prescriptiveness but within regulatory guardrails.
- High emphasis on standards compliance + measurement limitations.
- Includes many images and detailed event listings.
- Designed for auditors, legal review, and formal dockets.



Template Examples - Internal

Templates can also generate internal-use documents and notes ...

“Give me some talking points for a customer call about this PQ recording. Anticipate what they may ask about and give me some possible responses.”

“Suggest questions to ask and equipment to inspect for an upcoming on-site visit based on the PQ data”

“Analyze the PQ data specifically for combability with this attached VFD spec sheet”

“Attached are notes from a customer call about this PQ data. Give me a 1 page report on next-steps for our engineering team based on these notes and the recording.”



Trying Merlin

Free demo: See Merlin on pre-analyzed files by signing up for the demo:

<https://pqcanvass.powermonitors.com/demo/>

If you have a PQ Canvass account and would like to try on your own files:

contact your sales rep (sales@powermonitors.com) and ask for some trial credits

If you're ready to start using Merlin, simply purchase Merlin credits in PQ Canvass, or with a purchase order



Thank you for attending!



1-800-296-4120 support@powermonitors.com
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24/7 Technical Support

