

Proactive Use of PQ Data

Beyond Post-mortem Analysis

Bill Howe, PE
Program Manager, Power Quality

**17th Annual PQSynergy™ International
Conference and Exhibition**

Chiang Rai, Thailand
24 – 26 April 2017



Approaches for PQ Data

Step 1: Identification of Goals for PQ Monitoring

(CIGRE C4.112 Guidelines for PQ Monitoring)

- **Compliance Verification**
 - Regulatory requirements
 - Conformance to standards (e.g.: IEC 61000-3-6, 7, and 13)
- **Performance analysis / benchmarking**
 - Strategic planning and asset management (IEC 61000-4-30)
 - Average PQ and overall trends
- **Site Characterization**
 - Usually customer specific, either for service quality or compliance
 - Often done with temporary monitoring
- **Troubleshooting**
 - Investigation of specific customer or grid PQ issues
 - Often conducted with temporary monitoring
- **Advanced Applications**
 - Aggressive use of PQ data in near- or real-time
 - Enabling outcomes beyond mere measurement and investigation
 - Active PQ management

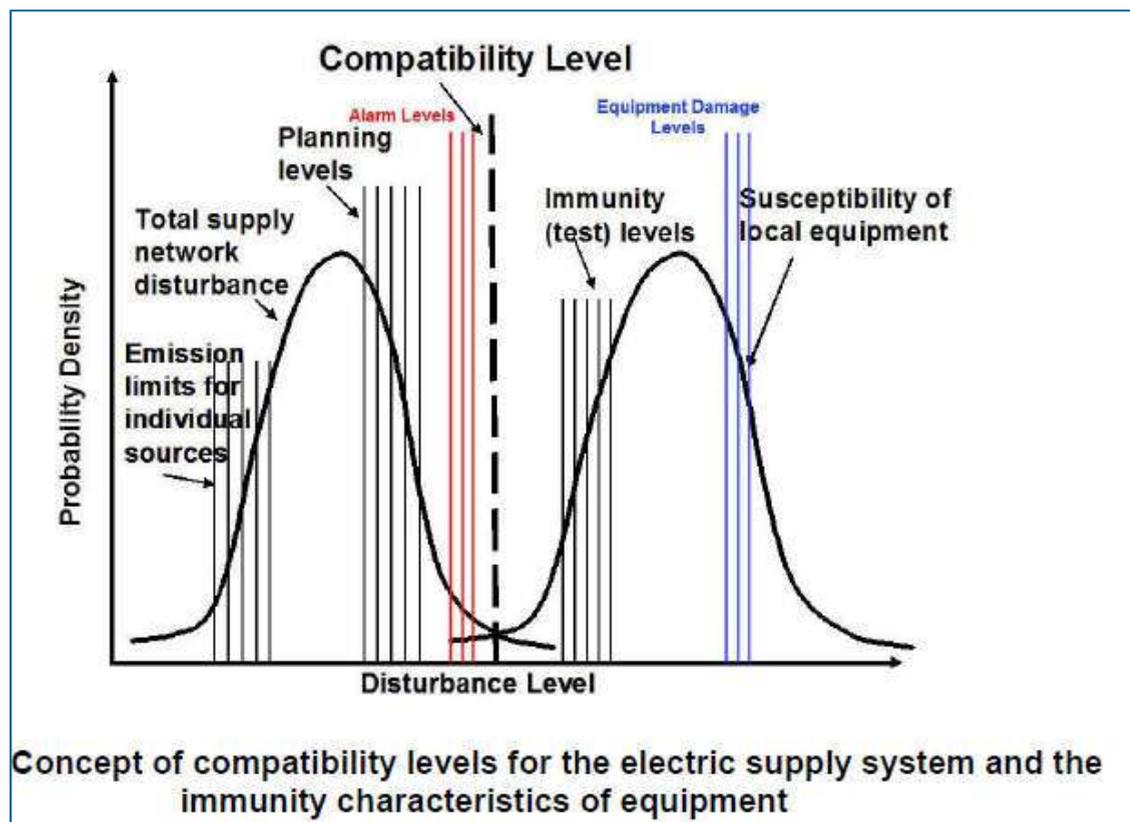
Approaches for PQ Data

Step 2: Implementation of monitoring

- PQ Monitoring Type
 - Portable
 - Characterization
 - Troubleshooting
 - Fixed, but transitory
 - Compliance and verification
 - Benchmarking
 - Permanent
 - Advanced applications plus other outcomes
- PQ Monitoring Locations
 - Customer PCC
 - Substations
 - Subset / Sample
 - All buses
 - Proximity to important grid assets

Classic approaches using PQ data

- Post-mortem analysis of grid events
- Threshold-based alarming when limits are exceeded
- Benchmarking based on past performance
- Investigating customer complaints
- **We can -- and must -- do better!**

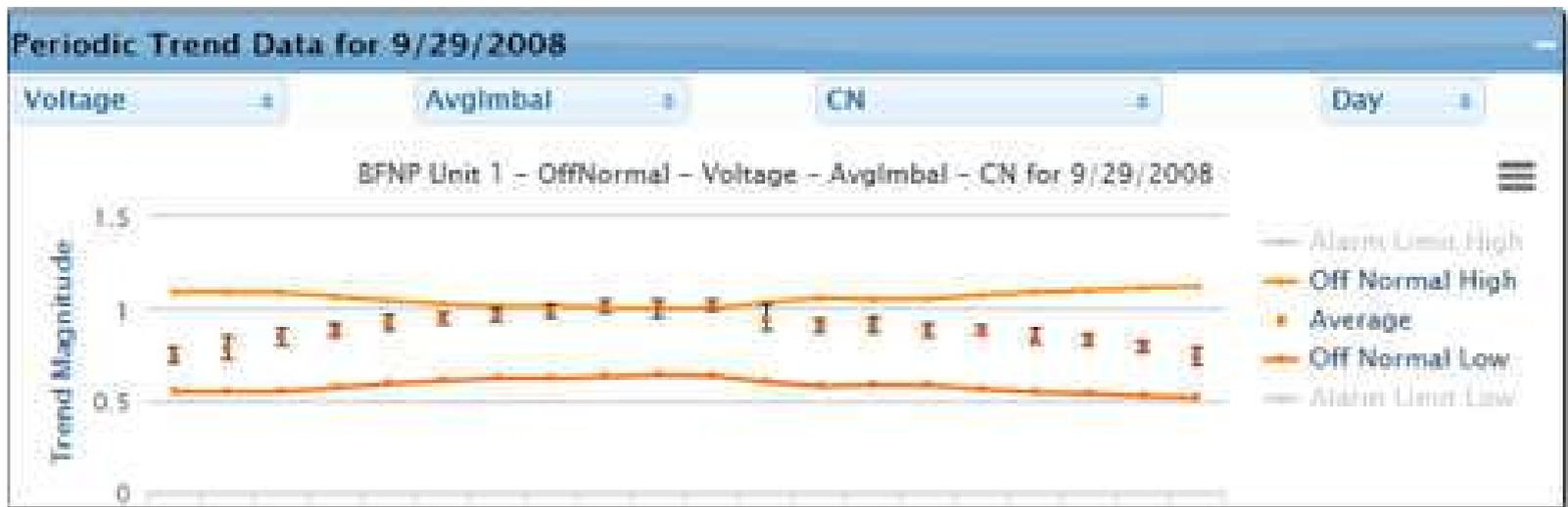


Source: IEEE 1250

Proactive Use of PQ Data

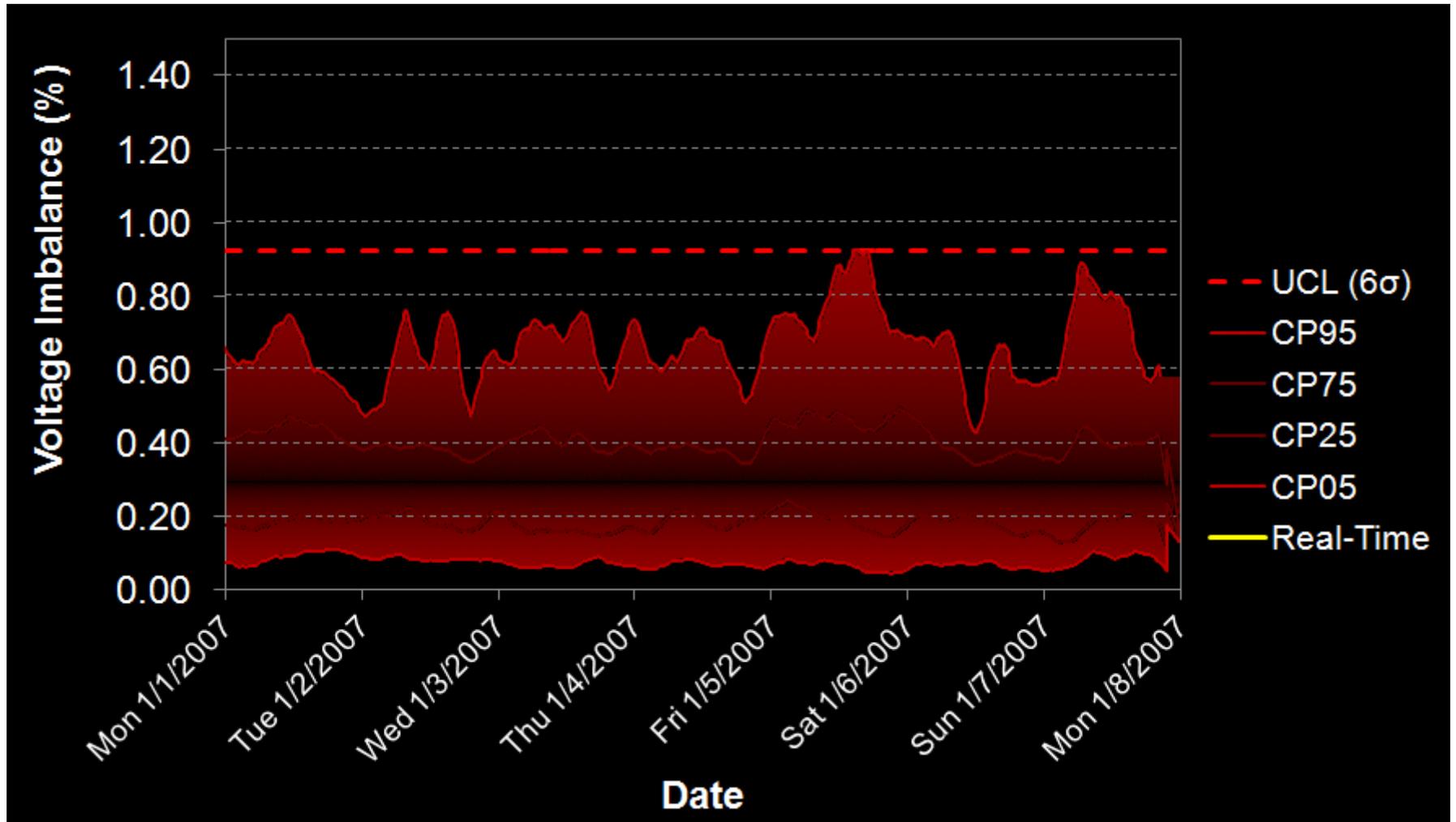
Continuous tracking of PQ Performance

- Monitoring of PQ parameters on a continuous basis rather than only after-the-fact
- Statistical Process Control (SPC) techniques can be adapted from other industries



Statistical Process Control for PQ

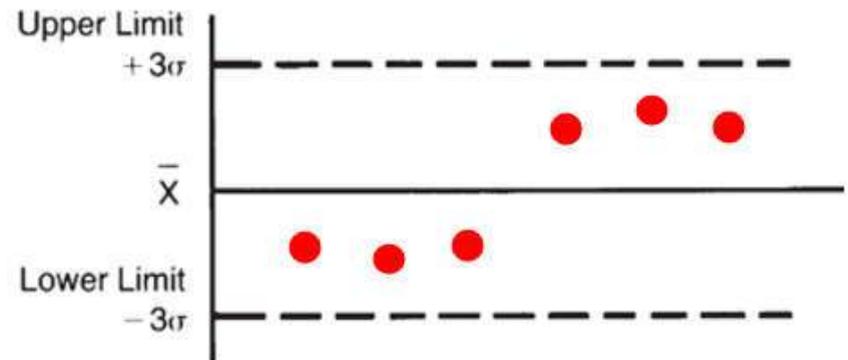
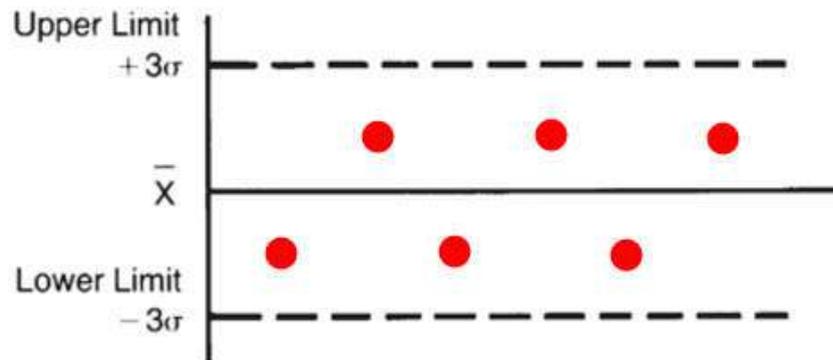
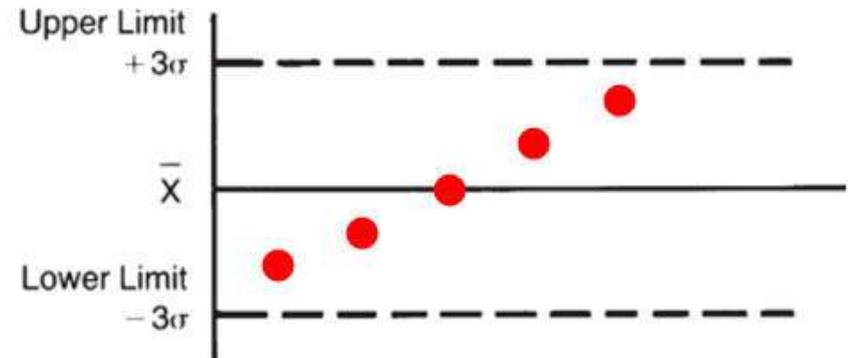
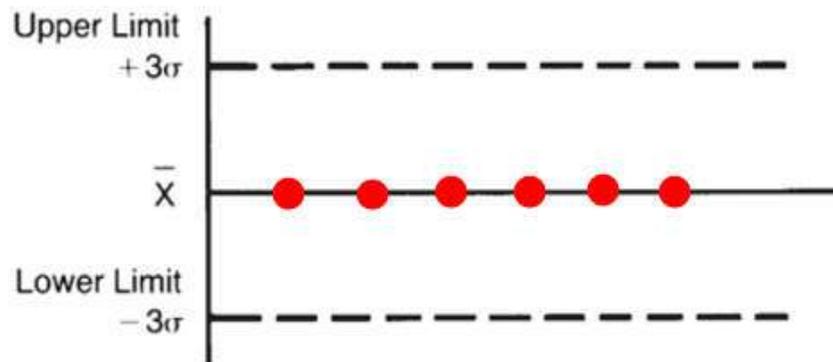
Example



Statistical Process Control for PQ

Detecting problems/issues before they become problems

- In addition to continuous tracking of PQ, SPC techniques allow detection of a very wide range of issues
- Other benefits include data validation

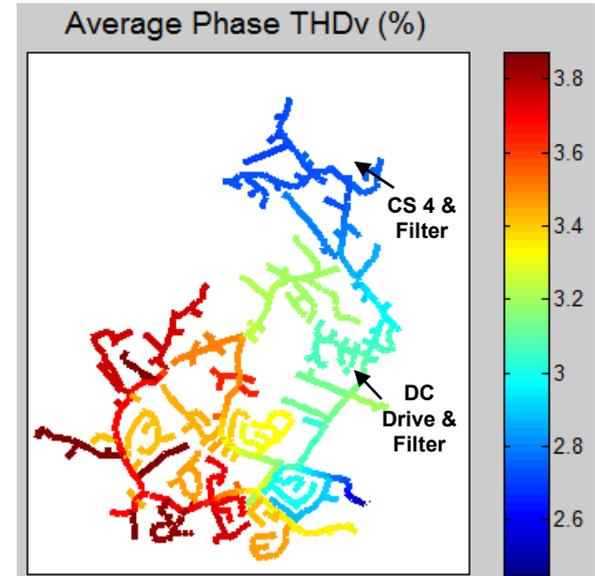


Proactive Use of PQ Data

Scenario Analysis of PQ *future* impact of grid configurations and loads

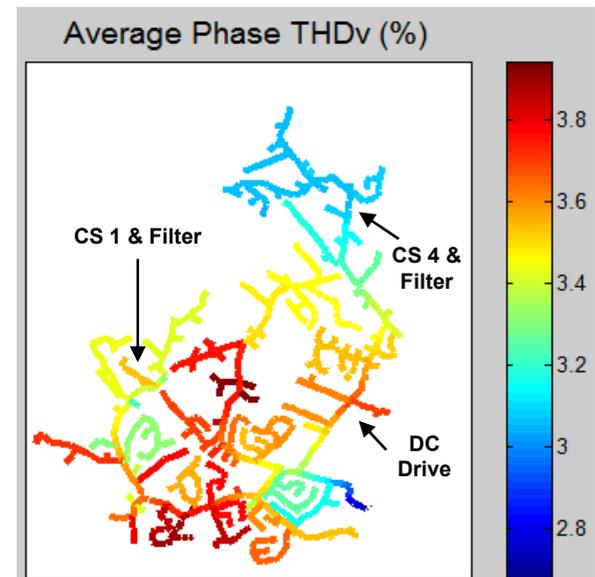
3) Edit Capacitor Bank Attributes

	Capacitor Name	Bus	Status	Kvar	Filter	Tuning	Connection
1	Capacitor.mdv201_hn_2_116_ab...	28285	<input type="checkbox"/>	600	<input type="checkbox"/>	0 wye	▼
2	Capacitor.mdv201_hn_2_818_ab...	63707	<input checked="" type="checkbox"/>	300	<input type="checkbox"/>	0 wye	▼
3	Capacitor.mdv201_hn_2_345_ab...	8081	<input checked="" type="checkbox"/>	450	<input type="checkbox"/>	0 wye	▼
4	Capacitor.mdv201_da_8_153_ab...	74433	<input checked="" type="checkbox"/>	600	<input checked="" type="checkbox"/>	4.7000 wye	▼
5	Capacitor.63711	63711	<input checked="" type="checkbox"/>	600	<input checked="" type="checkbox"/>	4.7000 wye	▼



3) Edit Capacitor Bank Attributes

	Capacitor Name	Bus	Status	Kvar	Filter	Tuning	Connection
1	Capacitor.mdv201_hn_2_116_ab...	28285	<input checked="" type="checkbox"/>	600	<input checked="" type="checkbox"/>	4.7000 wye	▼
2	Capacitor.mdv201_hn_2_818_ab...	63707	<input checked="" type="checkbox"/>	300	<input type="checkbox"/>	0 wye	▼
3	Capacitor.mdv201_hn_2_345_ab...	8081	<input checked="" type="checkbox"/>	450	<input type="checkbox"/>	0 wye	▼
4	Capacitor.mdv201_da_8_153_ab...	74433	<input checked="" type="checkbox"/>	600	<input checked="" type="checkbox"/>	4.7000 wye	▼
5	Capacitor.63711	63711	<input type="checkbox"/>	600	<input checked="" type="checkbox"/>	4.7000 wye	▼



Scenario Analysis of PQ *future* impact of grid configurations and loads

Comparing configurations

- Type (positive/Zero)
- Cap configuration
 - ✓ User selected
 - ✓ All possible combinations
- Screening capability to identify potential problem configurations

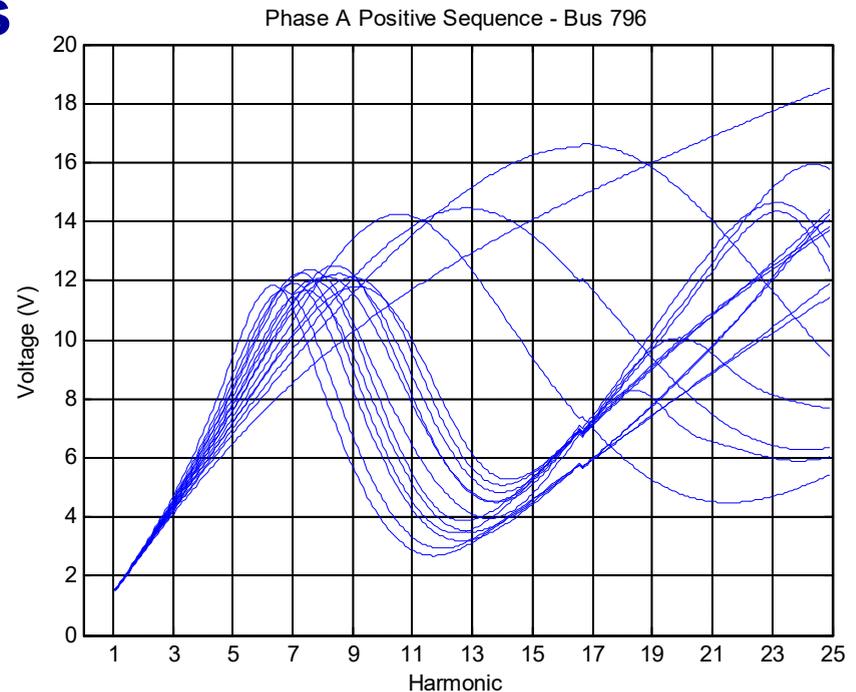


Figure 20: Worst harmonic magnification cap status

	H3	H5	H7	H9	H11	H13	H15
Capacitor.mdv201_hn_2_116_abc28285-1	1	1	1	0	0	0	0
Capacitor.mdv201_hn_2_818_abc63707-1	1	1	1	1	1	1	1
Capacitor.mdv201_hn_2_345_abc8081-1	1	1	1	1	1	0	0
Capacitor.mdv201_da_8_153_abc74433-1	1	1	0	0	0	0	0

2030 Load Mix Harmonic Analysis

- Below is the estimate of proportion of loads belonging to category of non-linear loads based on EIA outlook
- Assumptions for the load mix

Non-linear Load Projections

Load category	2010	2030 Projection	2030 Projection
		Excluding electronic Lighting and Drives	Including electronic Lighting and Drives
Commercial	40%	48%	60%
Residential	44 %	50%	60%

Combined Impact of Various Harmonic Sources

- The combined impact is not linear as individual harmonics are added vectorally

Voltage Harmonics at Substation

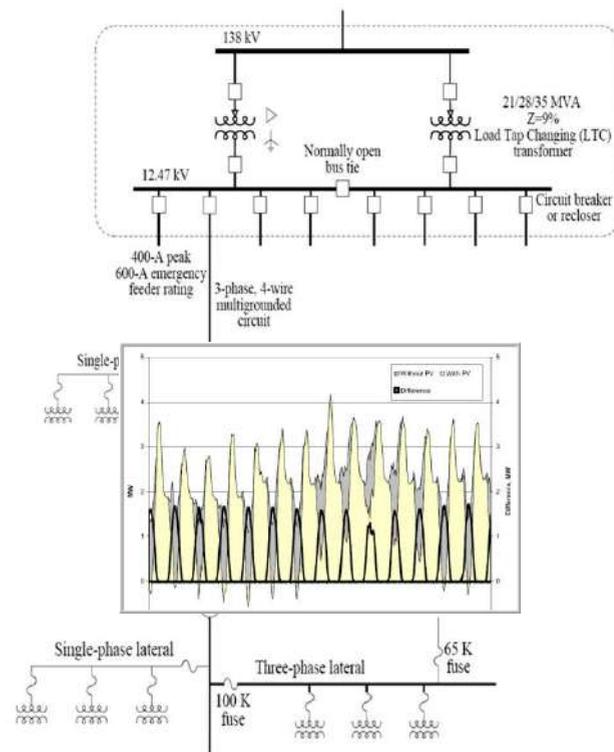
Harmonic	Base Case	Added CFL Alone	Added PEV Alone	Added Entert. Load Alone	Added ECM HVAC Alone	Added All the Loads
H3 (%)	1.9	2.2	1.8	2.1	2.3	2.8
H5 (%)	2.7	2.2	2.4	2.8	2.0	2.0
H7 (%)	2.1	4.9	1.9	2.7	3.2	4.5
THD (%)	4.2	6.0	3.9	4.7	4.7	5.9

Predicted increase in THD: ~40%

Proactive Use of PQ Data

Incipient Failure Detection

- PQ Monitors are an important sensor
 - Strategically located
 - Higher resolution data
- PQ monitoring, however, is NOT just a sensor
 - A dedicated team committed to design, O&M, and application of the data
- Many grid-connected devices can be monitored using PQ data
 - Transformers
 - Capacitors
 - Load Tap Changers
 - Reclosers
 - Etc.



Incipient Failure Detection using PQ Data

Capacitor Switch Assessment

- CSA Extended Analytics Service for PQ Dashboard (Software)
 - **Gap:**
 - Last years Capacitor Switching Assessment Module (CSA-DLL), does not have the appropriate interface for automated reporting through PQ Dashboard.
 - **Objective:**
 - Provide an automated reporting function through PQ Dashboard or other platform to report Capacitor Switching Assessment
 - **Description:**
 - 2015 delivered:
 - *Implementation of Capacitor Switching Assessment Module (CSA-DLL), a Matlab Based DLL, Product ID: 3002005960*
 - *Open Source Extended Analytics Service Template (EAS-T), Product ID: 3002005961*
 - The EAS-T will be used to develop an EAS to run the CSA-DLL utilizing PQ data through OpenXDA for reporting through the PQ Dashboard
 - **Benefits & Value:**
 - Automatic process performs near real-time analysis in time to react to CSA condition instead of post event analysis.
 - Currently being applied at TVA and other utilities

Capacitor Switching Assessment using PQ Data

Sample CSA Event & Report

The screenshot displays a web-based interface for analyzing a Capacitor Switching Assessment (CSA) event. The main window shows a list of events, with the selected event (ID: 128) details displayed in a table. A secondary window shows the waveform viewer for this event, displaying voltage waveforms for various phases (VAN, VBN, VCN) and their RMS values. A third window shows the CSA details, including event ID, start time, and various quality metrics.

Events Overview (For Date Range)

Start Time	Event Type	Line Name	Line KV	Phase	Distance
2008-01-21 06:54:14.369000	Swell	PQM0019 Stub Line 1 L0019	0	CN	

CSA Details - Google Chrome

ppqdashboard/dev/CSAService.aspx?eventid=128

CSA Details	
ID:	81
EventID:	128
IsDataError:	Complete
IsCapSwitch:	Yes
IsCapSwitchCondL:	High
OutFrequency:	300
OutVoltagesMax:	1.26278419879746
OutVoltagesMean:	1.06224763615883
OutQConditionRPBFlag:	Balanced
OutQConditionMRPC:	1645.3402509652
OutQConditionRPCA:	1622.99635994963
OutQConditionRPCB:	1665.30049839624
OutQConditionRPCC:	1665.30049839624
OutQConditionMPFI:	-0.90135238028588
OutQConditionPFA:	-9.82783326529414
OutQConditionPFB:	5.14168619102658
OutQConditionPFC:	1.98208993340991
OutRestrikeFlag:	No
OutRestrikeNum:	0
OutRestrikePHA:	No
OutRestrikePHB:	No
OutRestrikePHC:	No
OutVTHDFlag:	None
OutVTHDBefore:	0.258545955465039
OutVTHDAfter:	0.330027272430184
OutVTHDIncrease:	0.0714813169651447

openSEE • Waveform Viewer

Line: PQM0019 Stub Line 1 | Event Type: Swell | Event Time: 2008-01-21 06:54:14.3690000 | Start: 06:54:14.3690000 | Duration: 16.99 cycles

Legend:

- VAN
- VBN
- VCN
- VAN RMS
- VBN RMS
- VCN RMS
- VAN Amplitude
- VBN Amplitude
- VCN Amplitude
- IAN
- IBN
- ICN
- IAN RMS
- IBN RMS
- ICN RMS
- IAN Amplitude
- IBN Amplitude
- ICN Amplitude



Together...Shaping the Future of Electricity