Power Quality & Reliability Issues of Industrial & Commercial Customers

Energy Storage Solutions Meet (E$$MEET), Bengaluru
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Jayant Sinha
CEO, Ensource Consulting
Technical Consultant, APQI

Asia Power Quality Initiative

- A ***neutral collaborative platform*** shared by National Support Network (**NSN**) partners to promote **education and awareness** and facilitate policy changes
- **Objectives**:
  - help industries in Asia **address Power Quality issues** as a means to enhance their competitiveness in terms of better output quality, reduced production costs, less production line interruption and reduce losses
  - **Build up capacity** of industry / service sector in identifying and addressing PQ issues as a means to enhance quality delivery
  - Facilitate policy changes and market transformation towards '**Safe and Quality Power for All**'.

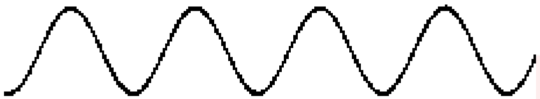
ASIA POWER QUALITY INITIATIVE

UNDERSTANDING POWER QUALITY

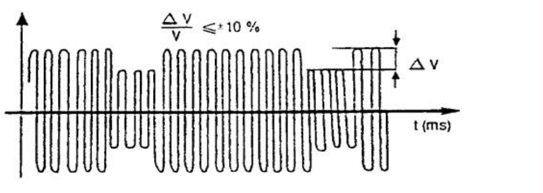
International Copper Association India
Copper Alliance

ENSOURCE
PROMISING CLEAN & SUSTAINABLE ENERGY SOLUTIONS
AN ISO 9001 AND ISO 14001 ORGANIZATION

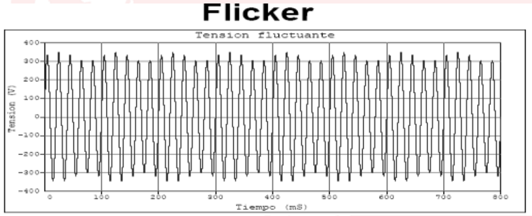
Power Quality Measurements



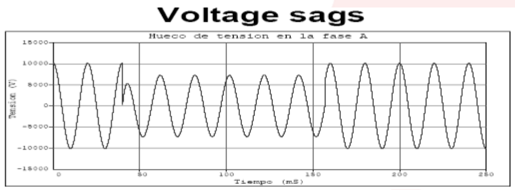
Frequency



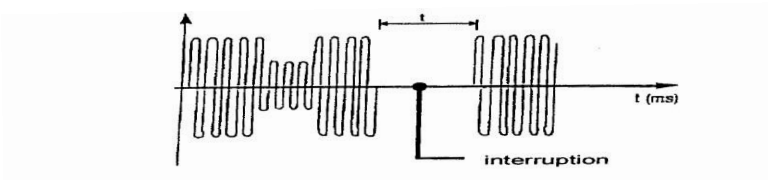
Voltage Variations



Voltage Flicker



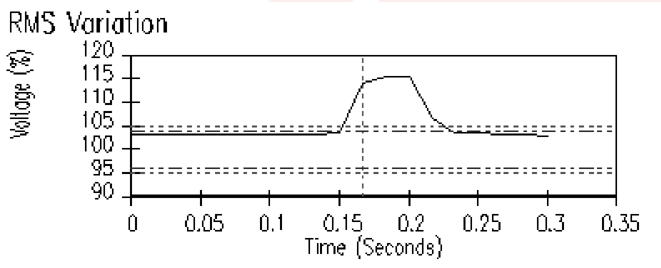
Voltage sags



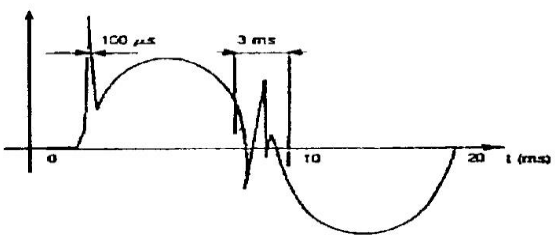
Interruptions

…Power Quality Measurements

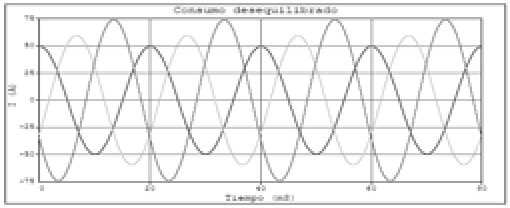
Harmonics



Overvoltage



Transients



Phase Imbalance

Impact of Harmonics

- PQ issues related to the use of non-linear loads, especially power electronics
- Distortion of voltage and current may cause power interruption or conductor heating
- Current effects:
  - Erroneous tripping of circuit breakers
  - Overheating of neutrals in 4-wire circuits
  - Overheating of DTs due to eddy current loss
  - Failure of capacitors
- Voltage effects:
  - Increased losses in induction motors
  - Over stressing of PFC capacitors

IEEE 519-2014

- IEEE 519-2014 defines the standard for THD limits

$$THD = \left(\frac{\sqrt{(V_2{}^2 + V_3{}^2 + V_4{}^2 + \cdots + V_n{}^2)}}{V_1}\right) * 100$$

$$THD_i = \sqrt{\sum_{h=2}^{H}\left(\frac{I_h}{I_1}\right)^2} = \frac{\sqrt{I_2^2 + I_3^2 + \ldots + I_{40}^2}}{I_1} * 100$$

THD Limits IEEE 519-2014

Table 1—Voltage distortion limits

Bus voltage V at PCC	Individual harmonic (%)	Total harmonic distortion THD (%)
$V \leq 1.0$ kV	5.0	8.0
1 kV $< V \leq$ 69 kV	3.0	5.0
69 kV $< V \leq$ 161 kV	1.5	2.5
161 kV $< V$	1.0	1.5[a]

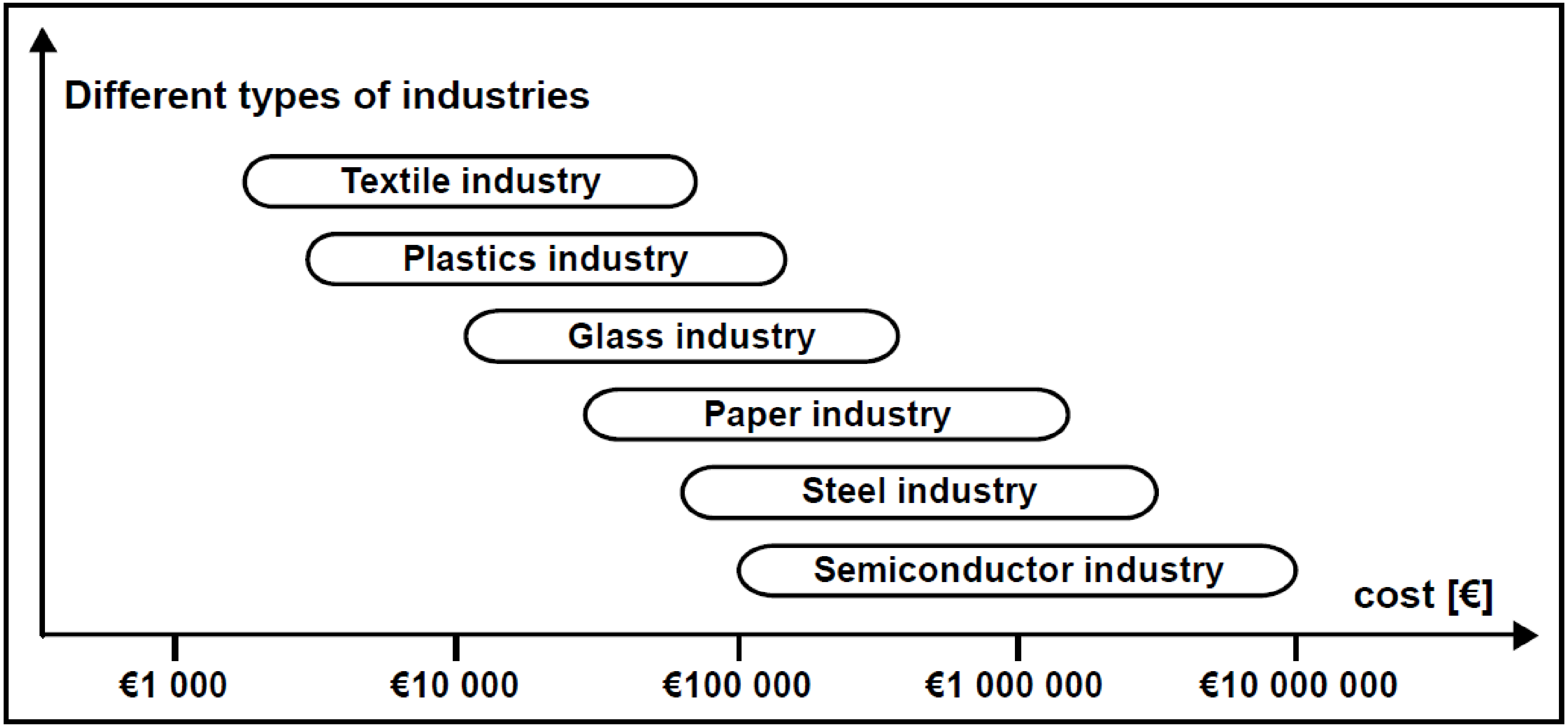
Table 2—Current distortion limits for systems rated 120 V through 69 kV

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics)[a, b]						
I_{SC}/I_L	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h \leq 50$	TDD
< 20[c]	4.0	2.0	1.5	0.6	0.3	5.0
20 < 50	7.0	3.5	2.5	1.0	0.5	8.0
50 < 100	10.0	4.5	4.0	1.5	0.7	12.0
100 < 1000	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

Other PQ issues

- Transients are voltage disturbances of very short duration (up to few ms) but of high magnitude (up to several thousand volts) with a very fast rise time.
  - Causes are lightning strikes or fast switching of reactive loads
  - Can cause damage to the equipment
  - Can cause data disruption in communication networks
- Voltage swells may cause damage, if voltage rise is high
- Phase imbalance may cause overheating of lines and transformers, technical losses and reduced asset life.
- Flicker is a visual irritation and may cause equipment stress

Economic impact of Voltage disturbances



Source: www.leonardo-energy.org

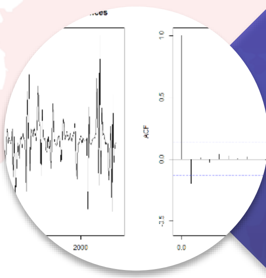
Balancing Power Quality & Energy Efficiency

Technology	Applications	Energy Efficiency View	Power Quality View
LED Lights	Industrial and Commercial Buildings, Street Lights	25%-80% less energy than traditional fluorescent or incandescent	Low PF, induces high THD and Inrush Currents
VFDs	Elevators, Motors, Process Automation, HVAC etc.	Reduce energy consumption by as much as 60%	With the inductances, the typical THD is around 30%. Without inductance, it can be 70 to 120%.
SMPS in PCs and Other devices	PCs, LED Screens, Control Systems, BMS in commercial buildings etc.	Higher power conversion efficiency from AC to DC	Large third-harmonic currents (up to 87% of the fundamental) are present in all kinds of computers
Power Storage Batteries	Electric Vehicles charging stations, UPS	Pure EVs use about four times less energy than a new internal combustion engine car	EV Chargers are highly nonlinear, have poor PF and high harmonics
Inverters to convert DC to AC	Solar PV Panels	Eco-friendly energy with much lower operational costs	Harmonic and RF noise because of the high-speed switching.
Wind Power Plant	Wind Energy	Environment friendly energy with much lower operational costs	Flickers, potential risks of large current surges in the grid

In driving energy efficiency goals, the issues of power quality cannot be overlooked. It is important to strike a balance between the two.

Mitigating PQ problem

Measure



Analyse

Improve

Actions to improve PQ…

- **DC link reactor (DC choke):** VFD, being a non-linear load, is also a source of harmonics. DC Choke reduces the impact of harmonics from VFDs
- **Passive Filters:** Reduces current harmonics in R-L Loads. In addition, they provide Reactive power compensation, and help improve PF.
- **Capacitor Banks**: Improves PF by reducing the phase difference between voltage and current.
- **Zero Sequence Filters or Triplen Filter:** ZSF reduces rms value of line current by reducing zero sequence harmonic current generated by single phase non-linear loads in three phase systems.

…Actions to improve PQ

- **Active Front End (AFE):** This is a controllable rectifier that provides bidirectional power exchange between AC and DC power
- **Active Harmonic Filters:** This provides not only harmonic filtering but also damping, isolation, reactive-power control for PF correction, voltage regulation, load balancing and voltage-flicker control
- **Phase shifting Transformers:** Given the inductive nature of the power system, it is important to ensure the flow of power between load and source with a phase lag between the terminals. This is achieved by Phase shifting transformers
- **Noise**: This is superimposition of high frequency signal on the power supply waveform. Causes are electromagnetic interference, EM radiations from welding machines, arc furnaces etc.

PQ issues in Renewable Energy Systems

- **Intermittency or unpredictability of RE generators:** The solar or wind generators are affected due to meteorological conditions, speed drives, invertors, etc.
- **Variable or Nonlinear loads:** The power quality affects due to abrupt changes in load such as start / stop of large motor loads, arc furnaces, lightning, switching devices, traction drives etc.
- **Grid Faults:** These are the problems related to grid infrastructure due to ageing of grid network, problems with transmission lines, insulators etc.

Classification of costs related to PQ problems

- **Direct costs**: These costs include damage to equipments in continuous process industry, loss of production, loss of raw material, idle cost of machinery, restart costs, loss of equipment efficiency and life
- **Indirect costs:** Difficult to evaluate as these relate to delay or cancellation of orders, loss of reputation, regulatory penalties and costs associated to fix PQ problems

Managing PQ in Smart Grid/ Microgrid

- Microgrid is powered from renewable sources connected to loads operating in either islanded or grid-connected mode.
- Microgrid systems aim to integrate multiple sources of energy operating in unison to improve reliability and power quality
- Smart grid is an intelligent infrastructure which uses smart metering, two-way communications, sensors and automation for enhanced power efficiency, reliability and quality
- Smart grids are fault-tolerant, self-healing network which balances generation with demand, while ensuring power quality by reducing voltage sags, swells, spikes and harmonics in the network
- With modern technology, it is possible to address PQ issues despite volatile renewable energy connections, disparate T&D systems and varying loads.

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CASE STUDY

Enhancing Productivity & Energy Efficiency through Power Quality improvement in Steel Wire Rope Mill

Cu International Copper Association India
Copper Alliance

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Problem Statement

- High failure rate of Motors
- High failure rate of Control electronics
- Nuisance tripping of Circuit Breakers
- Failure of SWG
- Specific Energy Consumption was 173 kWh/Ton

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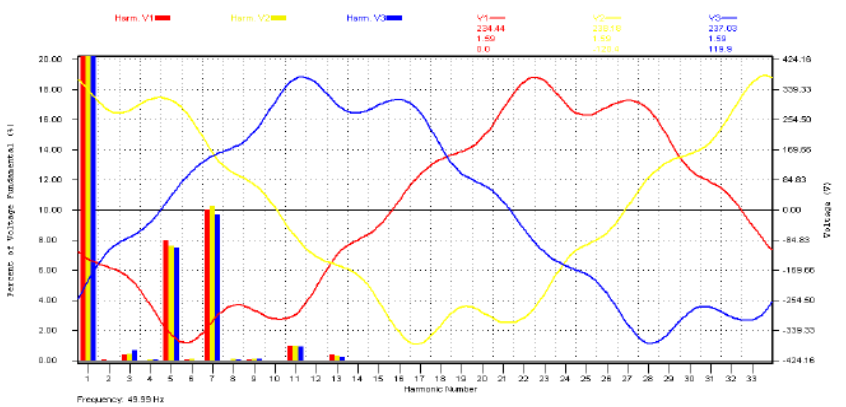
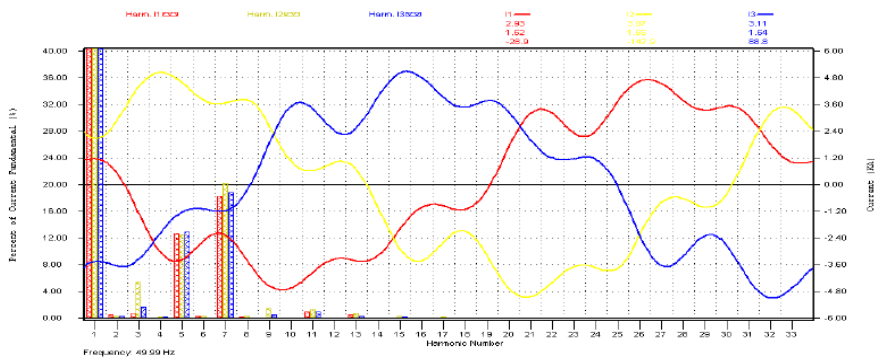
Harmonic Measurement & Analysis
Before correction

High harmonic content – V_{THD} and I_{THD}



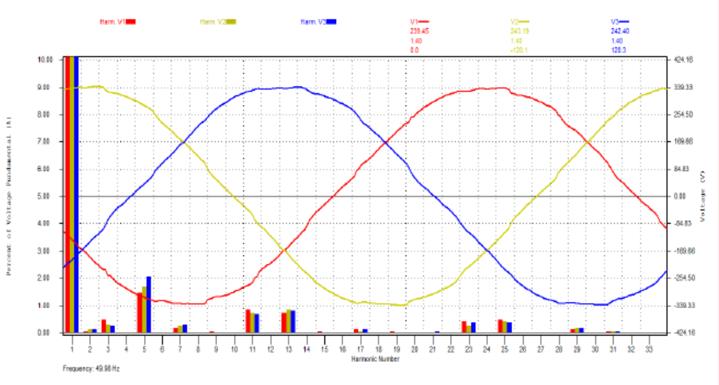
V_{THD} - Transformer A : 12%
Transformer B : 15%



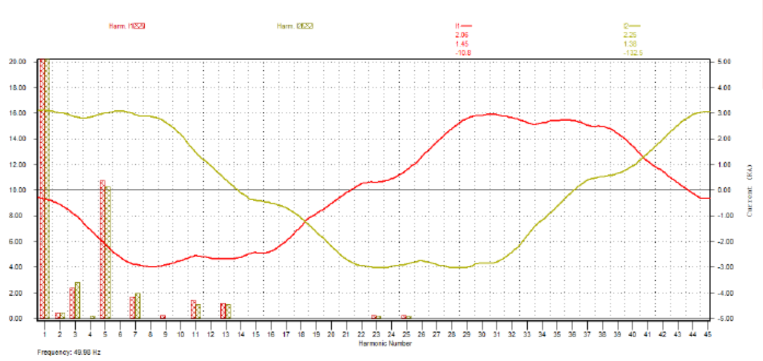
I_{THD} - Transformer A : 21%
Transformer B : 60%

Harmonic Measurement & Analysis

After installation of Passive Filter



V_{THD} - Transformer A : 2.1%
Transformer B : 1.2%



I_{THD} - Transformer A : 11.2%
Transformer B : 7.2%

SUMMARY OF BREAKDOWN ANALYSIS

Equipment	No. of failure in 1 year before PQ correction	No. of failure in 1 year after installing harmonic filter	% Reduction in failure rate
Motors	43	8	81.40
Drives	52	8	84.62
PLCs	22	8	63.64

- Average monthly cost saving : INR 240,000 → [Cost savings]
- Average increase in run time: 98 hours per month → [Productivity increase]
- Specific Energy Consumption (KWh/ ton) reduced: 11.6% → [Energy savings]
- Payback Period on PQ correction investment → [7 months]

Common Solar PV configurations

- Grid connected Solar PV system without battery storage
- Grid connected Net Metering system with battery storage
  - Solar PV system is disconnected from Grid in the event of Grid failure or captive use through battery
- Off-grid standalone Solar PV system, with battery-supplied power to a community microgrid
- Off grid dedicated standalone Solar PV system used for independent houses, street lights, pump sets, etc.

Power Quality & Safety Recommendations Rooftop Solar PV systems…

- Grid-interactive/ Grid-tied inverter should have surge protection at DC inputs and AC outputs.
- The efficiency of the inverter should be more than 97%.
- Have smart inverters to provide an alert on any change in output power quality.
- Have Inverter which shuts down automatically during power blackout or fault with Solar PV system
- The Inverter should have an in built or separate filter for harmonic and reactive power compensation
- The inverter should have provision for harmonics monitoring and recording
- Inverter should comply with CEA (Standard for connectivity of Distributed Generation) 2013 and CEA (Technical standard for Grid connectivity) 2007 regulations

Power Quality & Safety Recommendations …Rooftop Solar PV systems

- Monitor the effect of change in loading pattern of Solar PV system for any additional harmonic filter requirements based on the load
- Provide for power supply to the Grid be disconnected at the time of grid failure
- Make AC isolation arrangement at grid connected point to isolate Grid supply by a mechanical switch as per CEA Regulations
- Isolator installed at the grid connected point of rooftop Solar PV system should be accessible to isolate the system during maintenance or tripping of Grid
- For large Solar PV systems, a centralized monitoring system helps in monitoring the status of installation at consumer premises

Thank you!

Jayant Sinha
CEO, Ensource Consulting
Technical Consultant, APQI
E: jayant.sinha@ensource.in
M: +91 9920684271

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