Power Quality (PQ) Case Studies

Presented at

SEEM/APQI Seminar on

Power Pollution Silent Killer of Industry

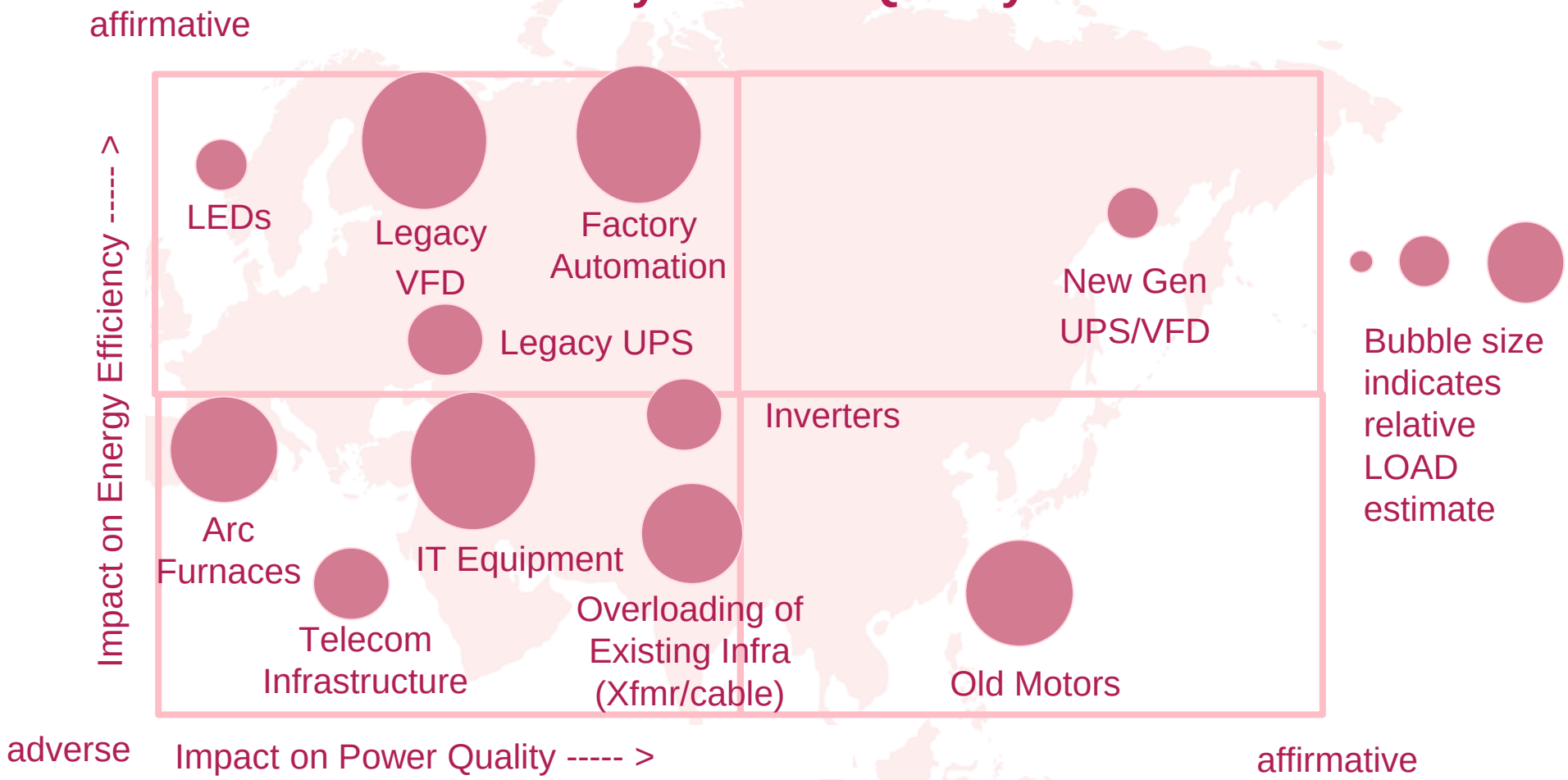
21st Feb 2018

Kerala Management Association, Kochi

ASIA POWER QUALITY INITIATIVE

Powering Tomorrow's India

Efficiency Without Quality?



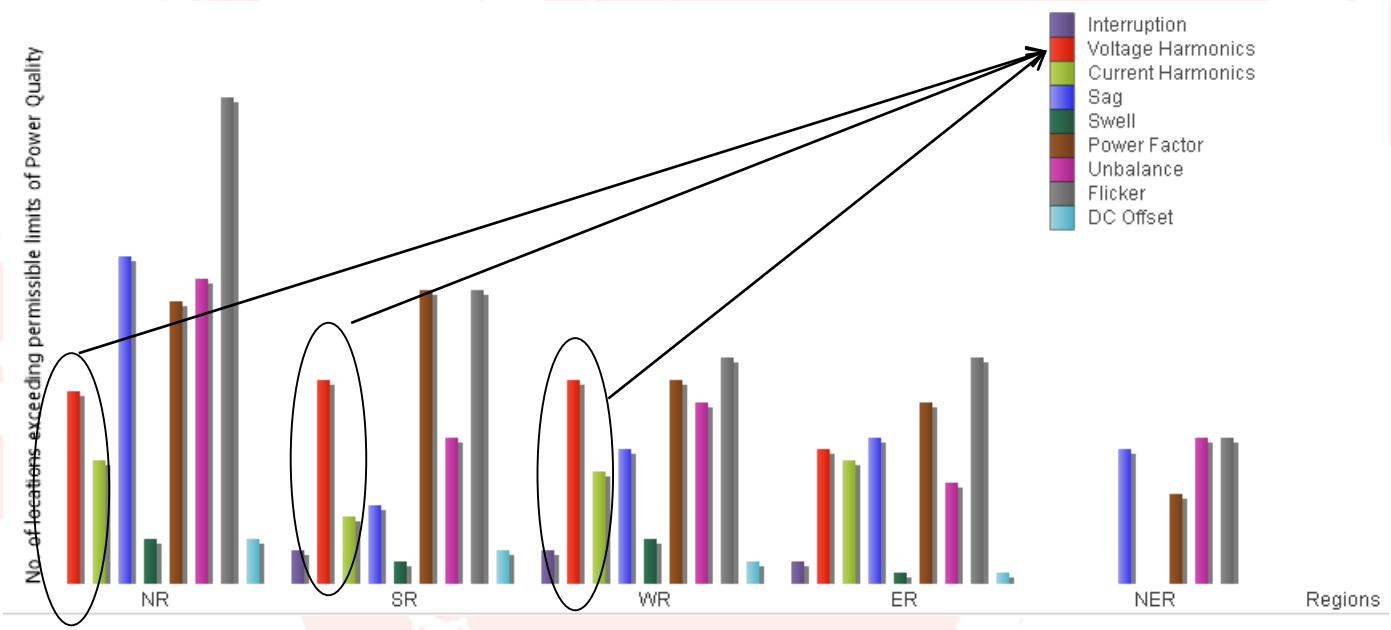
PQ –Issues→Causes→Impacts

ASIA POWER QUALITY INITIATIVE

End User Problems	Possible Causes	Impacts
Data Loss Server Reboot Noise in A/V equipment Tripping Malfunction / Failure Electrical Fire Reliability / Safety Check Lower P.U Energy	Bad PQ Sub optimal Design Improper Grounding Overheating Incorrect Power Conditioning Poor Maintenance	Productivity Loss Reduced Eqpmt Life Compromised safety Reputation Loss Wasted Energy High Maintenance

Cost Impact across all Industrial/Commercial Sector in India –
1.2 Lakh Cr to 3 Lakh Cr

India's PQ – Nearing Cliff?



Region-wise Power Quality Parameters observed across the country
(Source: Swachh Power by Power Grid Corporation of India Ltd. | Year 2014)

India's PQ – Nearing Cliff?

33% of the total States observed to have a Critical Power Quality Severity Index (>=0.5)

State wise Power Quality Severity Level
(Source: Swachh Power by Power Grid Corporation of India Ltd. | Year 2014)

Expect Further PQ Deterioration

- 2017: Digital india Push & White Good Penetration
- 2018: Over Half-Million AC Drives will be added in the industry, annually
- 2019: By 2019, 770 million LED bulbs and 35 million LED streetlights to be deployed
- 2019: Solar Installed base expected to go up by 10x; Wind by 2-3x in 2020
- 2020: Massive growth EV and charging infrastructure
- 2020: Cities with Metros to double (7 to 14) by 2020, 19 More Cities in Plan

Harmonics to increase by ~ 50-60% by 2020, from the current levels with adverse effect on other PQ indices too.

The PQ Challenge

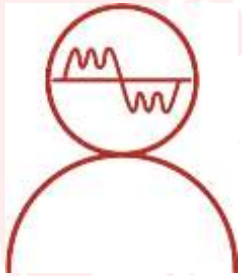
- ALARMING *lack of awareness in compliance assurance at the user end*
- ABSENCE *of correlation between PQ and downtime/failures/malfunctions/losses*
- STRIKING *lack of investments in attempts to measure, assess, learn, analyse and improve electrical power quality issues among stakeholders*

PQ for End Users

Always **feel at risk** of non-compliance

Try to solve Harmonics problems like its a **Dark Art**

Fall prey to overzealous marketing, OEM nexus etc.



Choose Pseudo Solutions to restore compliance

energyberg

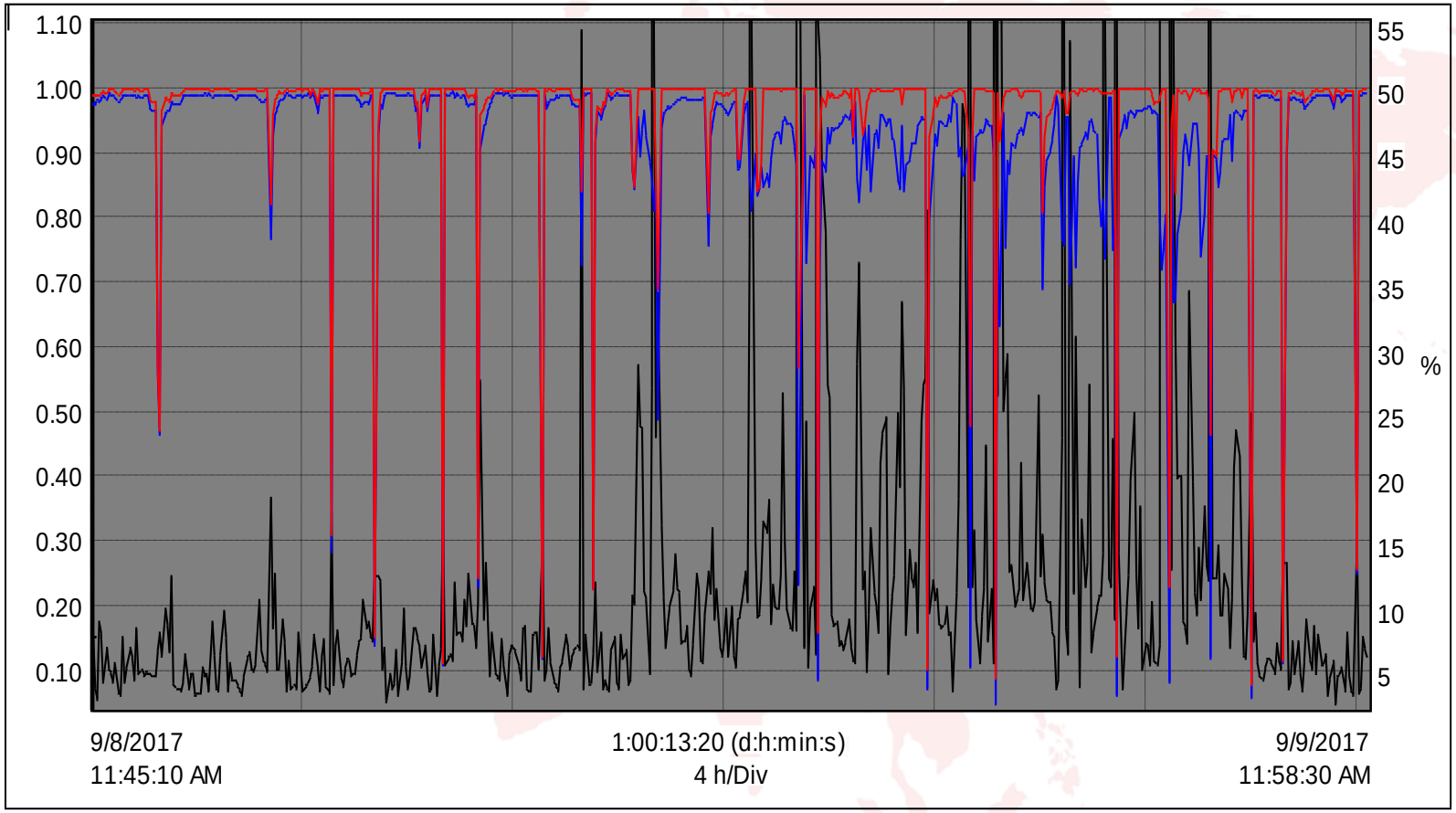
Most 'state-of-the-art' energy and power network infrastructure do NOT deliver their real worth.

What we see

What's the root cause?

Case Study
Measuring Power Factor
&
High Harmonics

Harmonics and Power Factor



DPF
TPF
% THDi

Average DPF – 0.962 **Average TPF – 0.919** **%THDi – 15.5%**

Case Study
Asia Power Quality Initiative (APQI)
LED Lights and Demand

Market for LED Lights !!!

- Increase penetration of LED lights.
  - UJALA scheme
  - EESL promoting LED lights through DISCOMS, Bulk consumers
  - Under UJALA, 25.5 crore LED Lights, 30.6 lakh LED tube lights distributed (sold)
- Awareness increasing among consumers for use of LED lights.
- Claimed Annual saving – 3340 Crore kWh

ASIA POWER QUALITY INITIATIVE

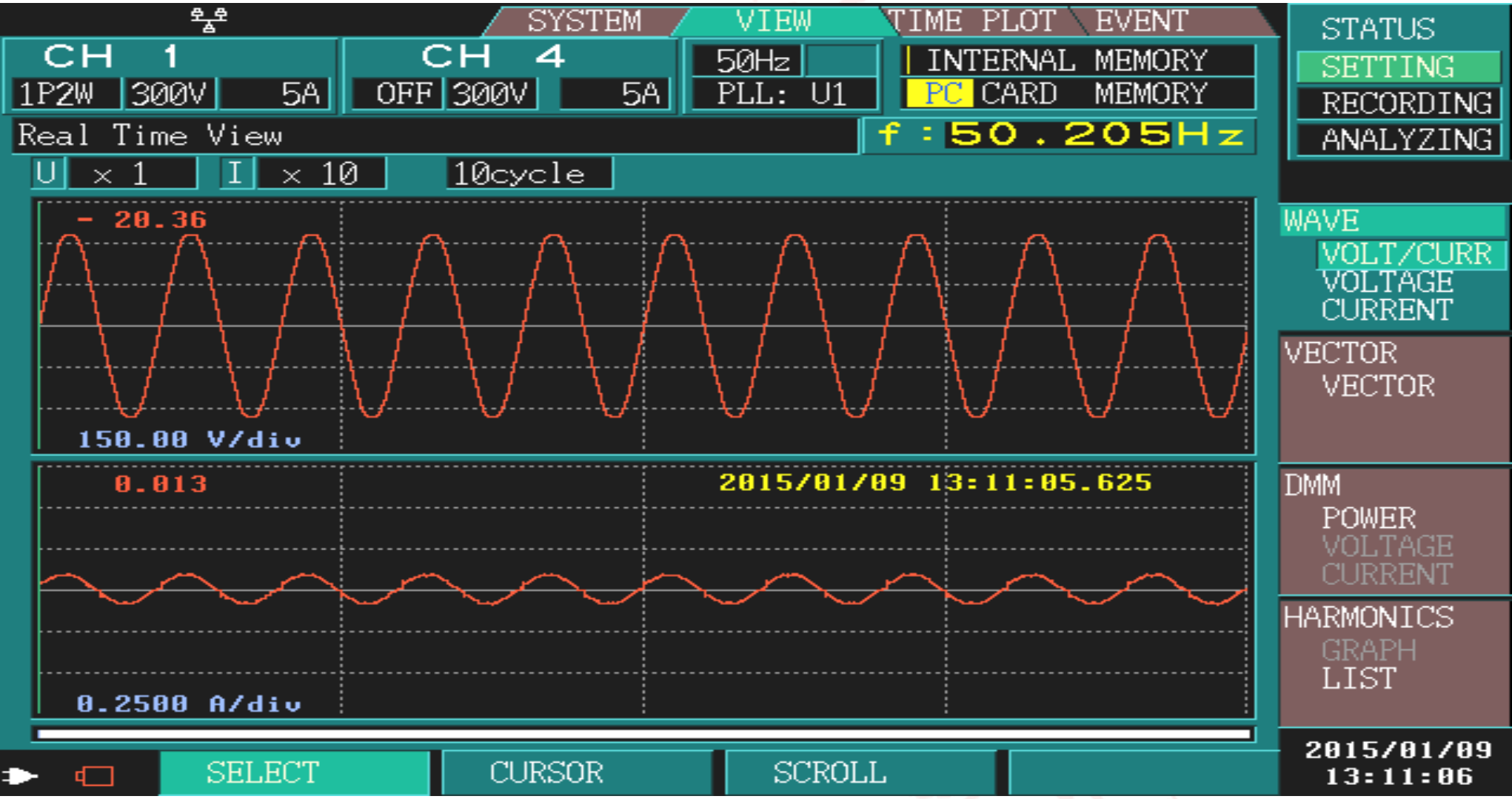
LED Market Survey – NEILSON

Published in Business Standard – 31st Oct 2017

- LED Market – INR 10,000 crore
  - 3/4th Non compliant with government consumer safety standard
  - 48% - No address of manufacturer
  - 31% - No manufacturers name
- BIS asked manufacturer to register. Less than 10% of total manufacturer registered with BIS

LED (15W) LAMP

HIGH WATTAGE LOW THD



LED (15W) LAMP

HIGH WATTAGE LOW THD: 5.89%

SYSTEM | VIEW | TIME PLOT | EVENT

CH 1: 1P2W | 300V | 5A
CH 4: OFF | 300V | 5A
50Hz
PLL: U1
INTERNAL MEMORY
PC CARD MEMORY

Real Time View
f : 50.207Hz

CH1 | I | VALUE | iHarmON

1:	100.00	0.18	2:	0.10	0.13	THD	5.89	0.91
3:	1.83	0.10	19:	0.83	0.14	35:	0.82	0.15
4:	0.06	0.11	20:	0.10	0.11	36:	0.05	0.09
5:	1.81	0.18	21:	0.65	0.15	37:	1.04	0.12
6:	0.05	0.13	22:	0.09	0.10	38:	0.12	0.09
7:	2.05	0.14	23:	1.29	0.11	39:	0.87	0.15
8:	0.09	0.12	24:	0.10	0.10	40:	0.08	0.17
9:	2.60	0.13	25:	0.71	0.12	41:	0.84	0.14
10:	0.15	0.12	26:	0.13	0.12	42:	0.08	0.12
11:	0.49	0.13	27:	0.92	0.10	43:	1.07	0.12
12:	0.07	0.14	28:	0.09	0.11	44:	0.14	0.15
13:	0.88	0.16	29:	1.07	0.17	45:	0.80	0.16
14:	0.11	0.09	30:	0.08	0.15	46:	0.10	0.09
15:	1.11	0.10	31:	0.73	0.12	47:	0.99	0.13
16:	0.11	0.11	32:	0.08	0.15	48:	0.12	0.12
17:	1.00	0.10	33:	0.96	0.17	49:	0.97	0.11
18:	0.10	0.08	34:	0.10	0.08	50:	0.17	0.10

STATUS
SETTING
RECORDING
ANALYZING

WAVE
VOLT/CURR
VOLTAGE
CURRENT

VECTOR
VECTOR

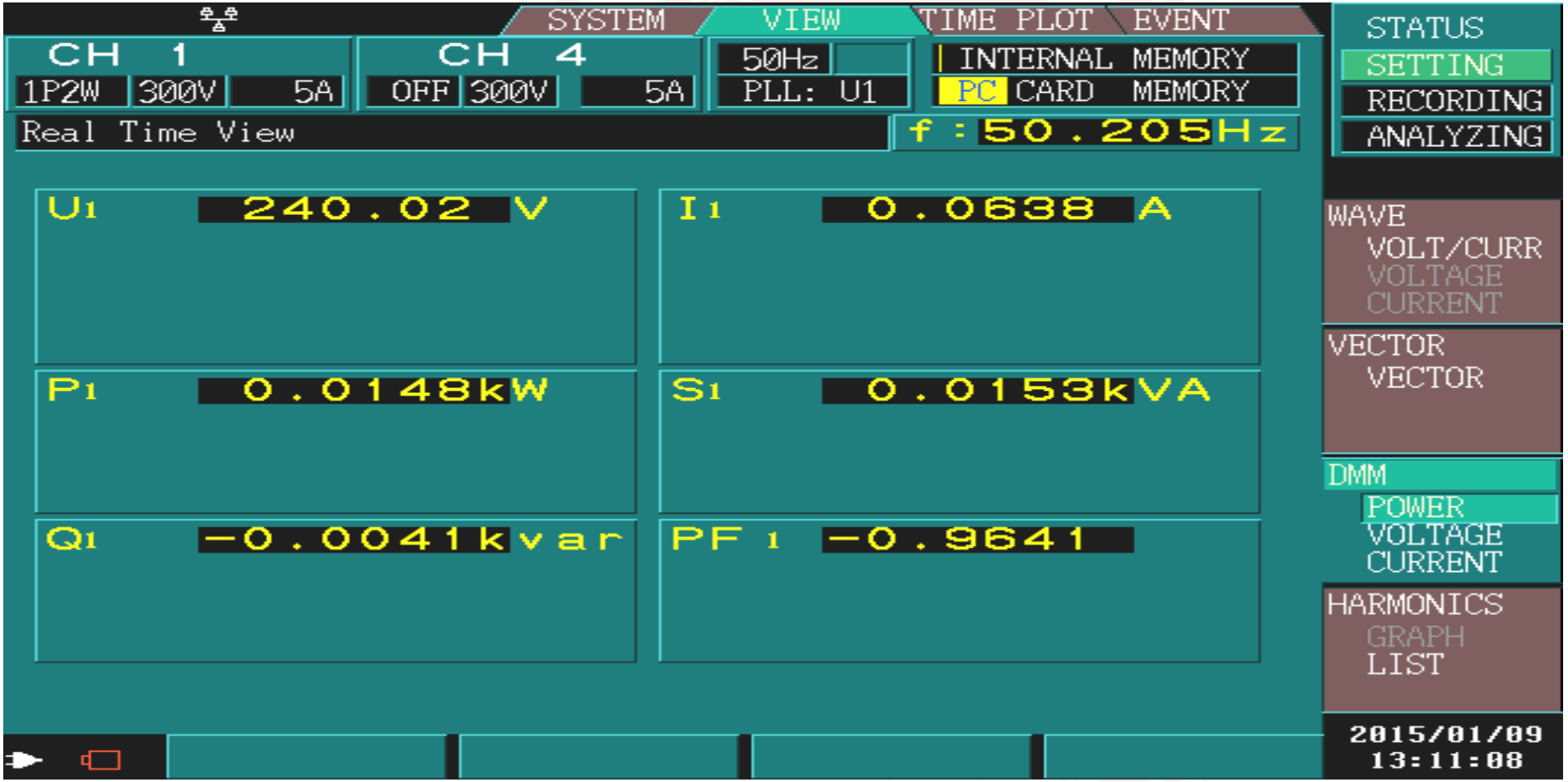
DMM
POWER
VOLTAGE
CURRENT

HARMONICS
GRAPH
LIST

2015/01/09
13:11:04

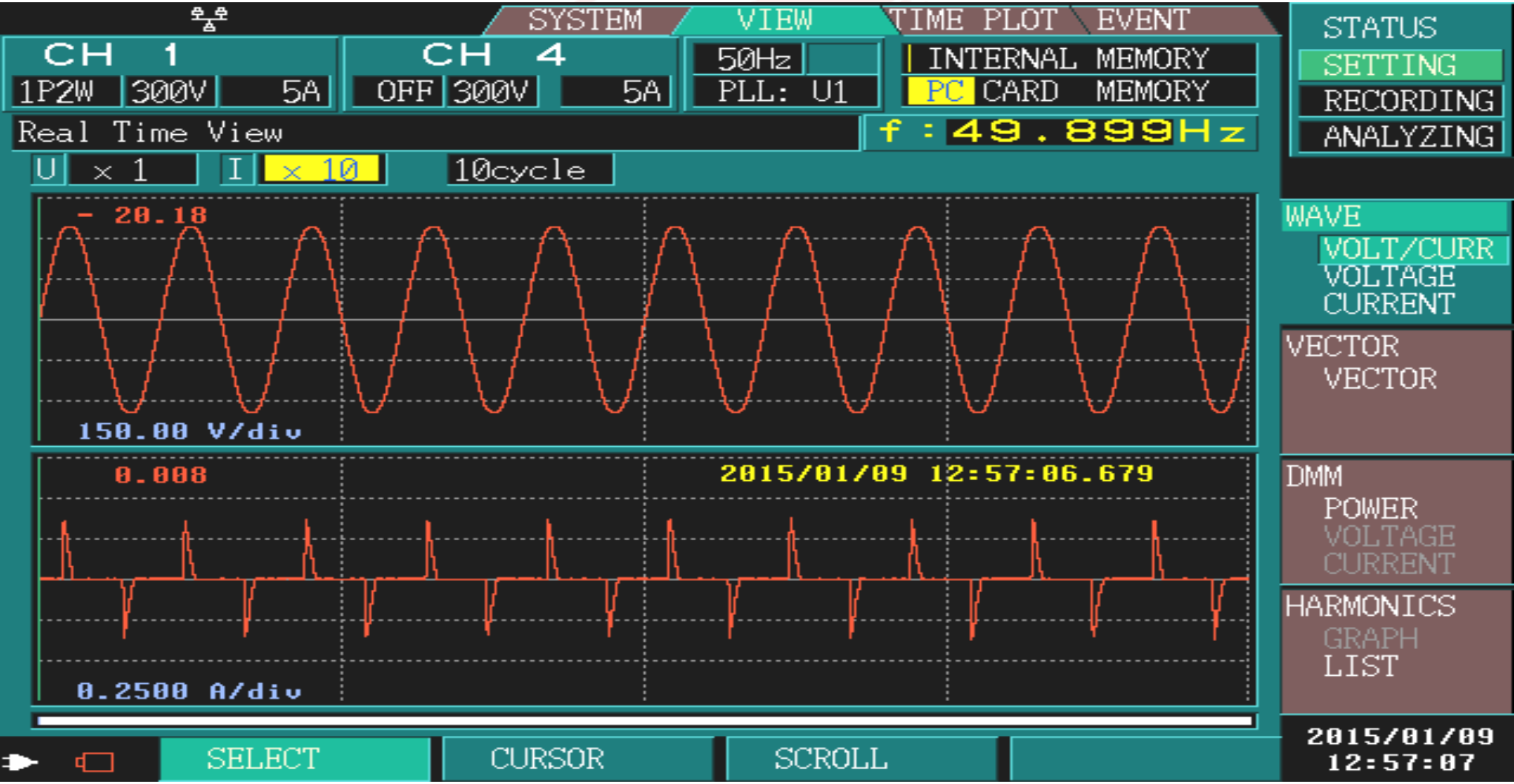
LED (15W) LAMP

Power factor – 0.96



LED (10W) LAMP

MEDIUM HIGH WATTAGE HIGH THD



LED (10W) LAMP

MEDIUM HIGH WATTAGE HIGH THD: 166%

SYSTEM | VIEW | TIME PLOT | EVENT

CH 1: 1P2W 300V 5A
CH 4: OFF 300V 5A
50Hz PLL: U1
INTERNAL MEMORY
PC CARD MEMORY

Real Time View
f : 49.889Hz

CH1 | I | VALUE | iHarmON

1:	100.00	0.19	2:	1.13	0.22	THD	166.04	2.80
3:	93.25	0.30	19:	21.65	0.38	35:	7.71	0.40
4:	1.22	0.23	20:	2.32	0.54	36:	1.65	0.28
5:	81.08	0.40	21:	18.22	0.38	37:	7.24	0.28
6:	1.64	0.33	22:	2.26	0.53	38:	1.61	0.28
7:	65.84	0.54	23:	14.74	0.36	39:	7.07	0.30
8:	2.24	0.40	24:	2.35	0.60	40:	1.45	0.26
9:	50.10	0.49	25:	12.39	0.41	41:	6.64	0.25
10:	2.90	0.45	26:	2.30	0.57	42:	1.40	0.32
11:	37.02	0.47	27:	11.40	0.44	43:	5.88	0.29
12:	3.01	0.41	28:	2.20	0.53	44:	1.43	0.20
13:	29.00	0.38	29:	10.86	0.46	45:	5.00	0.40
14:	3.02	0.38	30:	1.93	0.51	46:	1.37	0.27
15:	25.82	0.36	31:	9.89	0.48	47:	4.24	0.40
16:	2.77	0.37	32:	1.86	0.42	48:	1.33	0.35
17:	24.09	0.36	33:	8.71	0.38	49:	3.99	0.43
18:	2.50	0.39	34:	1.78	0.34	50:	1.22	0.44

STATUS
SETTING
RECORDING
ANALYZING

WAVE
VOLT/CURR
VOLTAGE
CURRENT

VECTOR
VECTOR

DMM
POWER
VOLTAGE
CURRENT

HARMONICS
GRAPH
LIST

2015/01/09
12:57:33

LED (10W) LAMP

Power factor – 0.5

ASIA POWER QUALITY INITIATIVE

What happens to Demand !

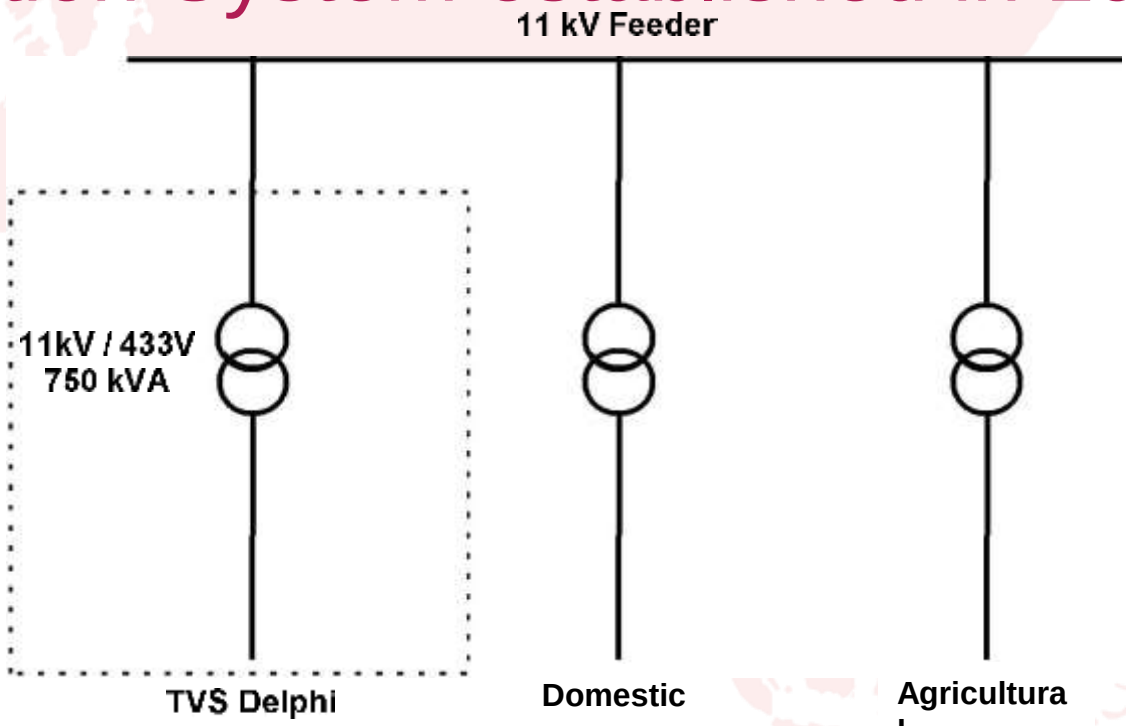
- Take such 10 W lamps with 0.5 lag PF and THD 166%, you need to make provision of 0.0215 kVA per lamp
  - 10 Crore LED bulbs need 100000000 X 0.0215 = 2150000 kVA = 2150 MVA
- If you had such lamps with 0.96 lag PF, means 0.0111 kVA per lamp
  - 1110 MVA need from supply grid

So right standard and call for right specification to ensure EE are real and not just HOPE

Case Study
Total Power Quality Management – TVS Delphi

Total Power Quality Management – TVS Delphi

- TVS Delphi – Manufacturer of Diesel Fuel Injection System established in 1990



Problem Faced – External issues

- Frequent interruptions due to un scheduled loads by agricultural sector and various natural issues
- Un balanced voltage
- Voltage variation – 8 kV to 12 kV
- Change in phase sequence after restoration of lines
- Surges and transient due to failure of lightning arrestor

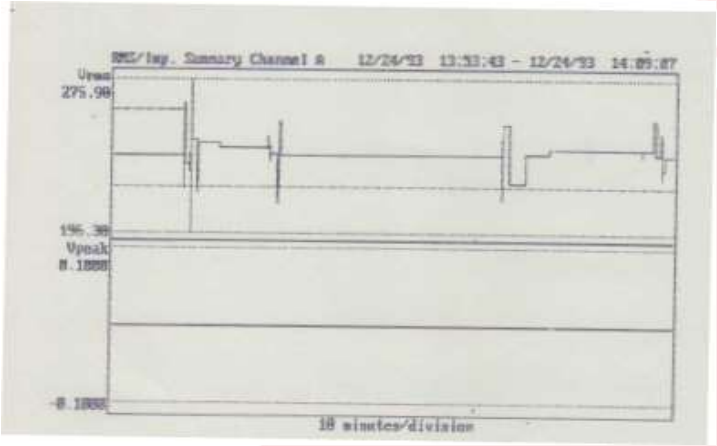
Problem Faced – Internal issues

- Frequent Tripping of Sensitive Equipments
- Failure of Power Supply in the CNC Equipments
- Burning of neutral at R&D
- Software corruption of CNC programs

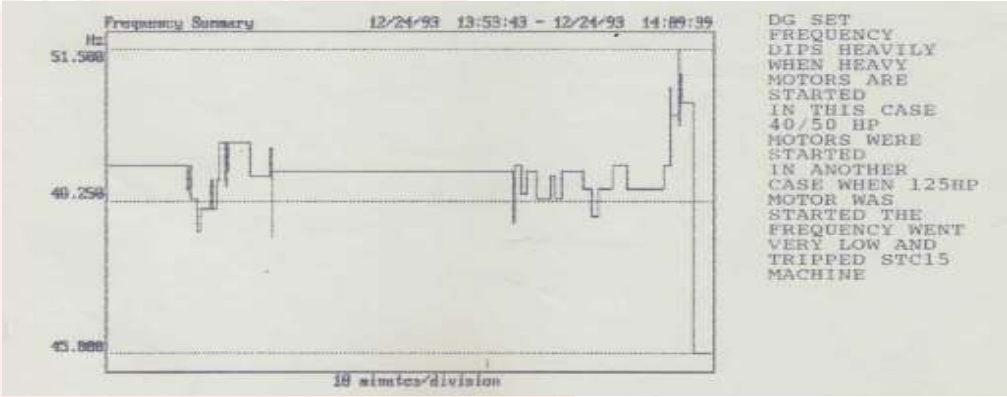
Impact on business

- Customer dispatch was seriously affected.
- Purchase of costly tools resulting in increased M/C tools.
- Too Many Electronics Failures resulting in increased down time.
- Increase in Scrap & Rejection cost

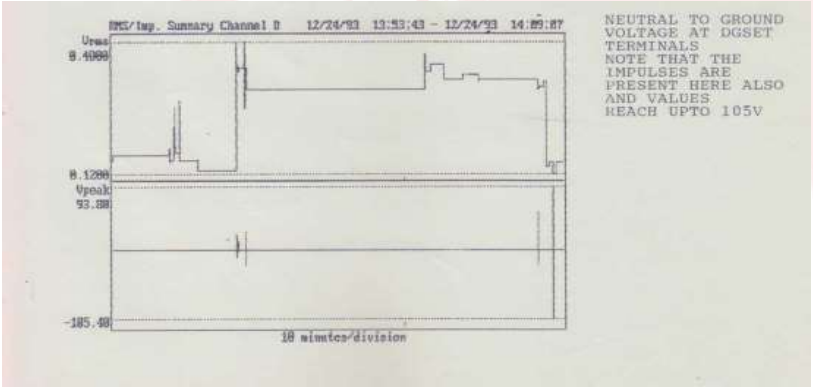
Various power quality issues



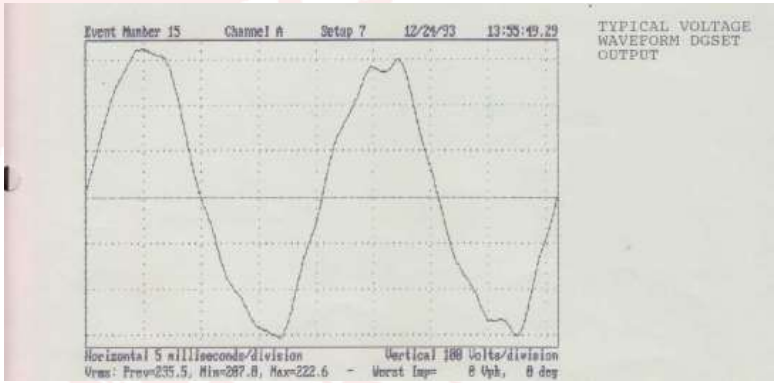
Voltage profile



Frequency profile



Neutral to Ground Voltage



Voltage Waveform

Various PQ issues and adopted mitigation techniques

Sr. No	Power Quality issue	Solution adopted
1.	Non reliability of power	DG sets
2	Noise	Isolation Transformer
		Filter
		Re-design of equipment to suit power quality
3	Voltage quality	Improved operating practice
		Higher capacity of DG sets
4	Cost of electricity	Adopting low cost fuel
		Improving efficiency of system
		Better utilization of available grid power by installing AVR
5	Reliability of operation	Installed UPS system – 2690 kVA
		Bus bar trunking 40 no's each of 5m long
		Higher size of neutral conductor
		Lower size of capacitors for APFC

Expenditure on PQ Mitigation

Capex cost	**INR**
Cost of 1000 kVA DG set	130,000,000.00
Voltage stabilizers	2,500,000.00
UPS system	143,000,000.00
AVR	5,000,000.00
Captive power plant	45,000,000.00
Total	**325,500,000.00**

Expenditure on PQ Mitigation

Parameter	Before	Now	In case if mitigation measures were not adopted	
Total Consumption	1200000	2500000	2500000	kWh
DG	840000	0	1750000	kWh
Captive	0	750000		kWh
EB	360000	1750000	750000	kWh
Cost of power generation through DG	22	22	22	INR/kWh
Captive	12	12	12	INR/kWh
EB	7	7	7	INR/kWh
With SEB as base, annual loss:	**151,200,000.00**	**45,000,000.00**	**315,000,000.00**	**INR per year**

Case Study
Productivity Improvement and Reduction in Specific Energy Consumption (SEC)

Problems faced by the plant

- Regular failure in a Steel Wire Rope Mill
  - High Failure Rate of Motors
  - High Failure rate of control cards
  - Nuisance tripping of circuit breakers
  - Failure of SWG
- SEC was 173 kWh/Ton
- Production cost – INR 1064 per ton

Harmonics Before……

- High harmonic content – Vthd and Ithd

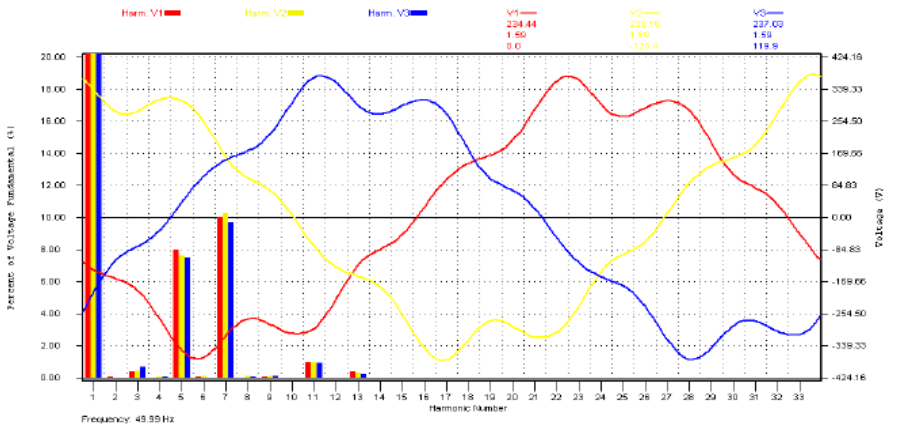
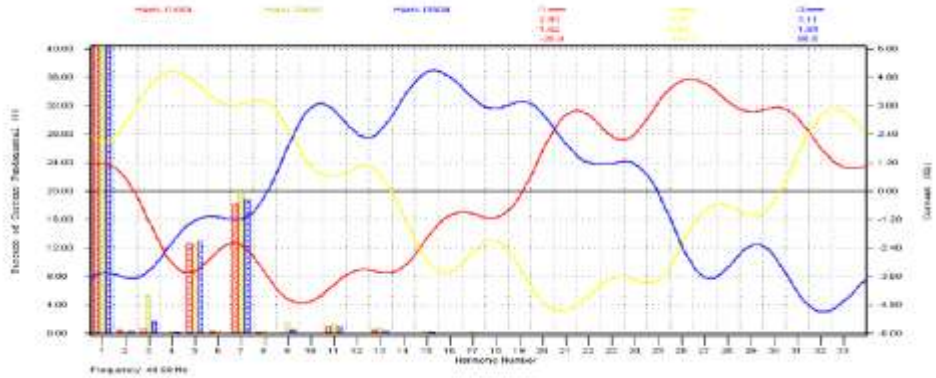


Figure – 3A Vthd and Voltage waveform without harmonic filter at

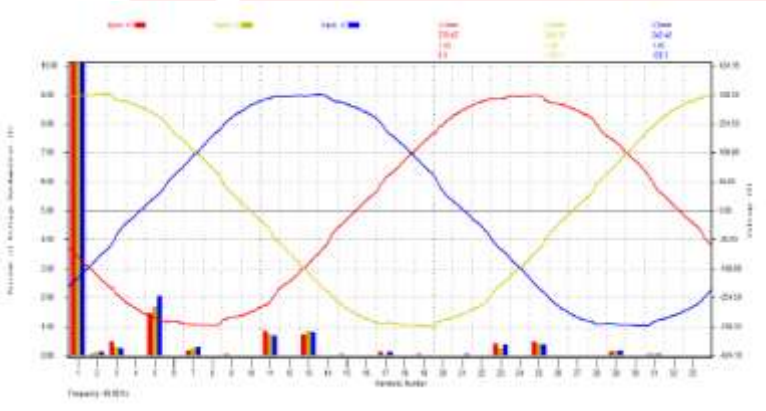
Vthd - Transformer A – 12%
Transformer B - 15%

Ithd - Transformer A – 21%
Transformer B - 60%



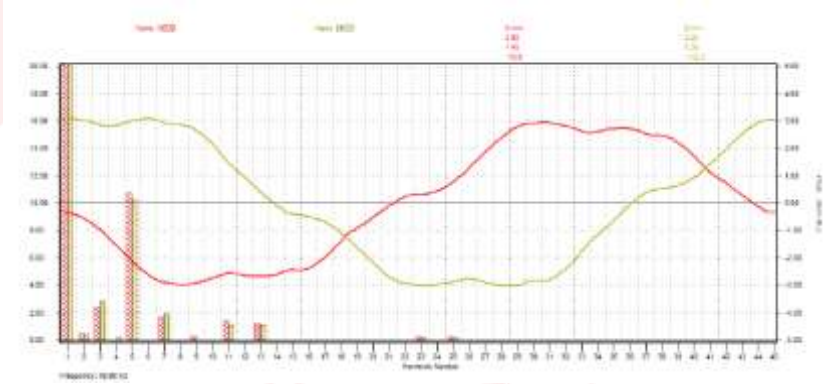
Harmonics
After ……

- After installation of passive filter



Vthd - Transformer A – 2.1%
Transformer B - 1.2%

Ithd - Transformer A – 11.2%
Transformer B - 7.2%



Copper Alliance

Break Down Analysis

Component Failure Trend										
		Before HF			After HF					
Component	Ratings	FY 13	APR 13	MAY 13	JUN 13	JUL 13	AUG 13	SEP 13	OCT 13	NOV 13
No of Motors Failed	< 3 KW	14	2	1	0	0	1	0	0	0
	3-5 KW	11	1	1	0	0	0	0	1	0
	5-10 KW	2	1	1	0	0	0	0	0	0
	10-25 KW	4	4	2	1	0	0	1	0	0
	>25 KW	2	3	1	0	0	0	0	0	0
	Total	**33**	**11**	**6**	**1**	**0**	**1**	**1**	**1**	**0**
No of Drives Failed	< 1 KW	4	0	0	0	0	1	0	0	0
	1-11 KW	45	2	1	0	1	0	1	0	0
	> 11 KW	7	1	1	0	0	1	0	0	0
	Total	**56**	**3**	**2**	**0**	**1**	**2**	**1**	**0**	**0**
No of PLCs Failed	< 1 KW	9	0	0	0	0	1	0	0	0
	1-11 KW	6	0	2	1	0	0	0	0	0
	> 11 KW	8	1	0	0	1	0	0	1	0
	Total	**23**	**1**	**2**	**1**	**1**	**1**	**0**	**1**	**0**

Summary of breakdown analysis

Component	Annual failure rate before Harmonic filter – FY 2012-13	June-Nov 2013 Failures	Extrapolated - Annual failure rate after harmonic filter	Change in failure rate	
Motors	43	4	8	-81%	Reduced by 81%
Drives	52	4	8	-85%	Reduced by 85%
PLC's	22	4	8	-64%	Decreased by 64%

- Average monthly cost saving of 240,000
- Average increase in production time 98 hours per month

Specific Energy Consumption & Productivity

SPECIFIC ENERGY CONSUMPTION			
Parameter	Monthly Average - FY13	Monthly Avg Jun-Oct13	% Change
Finish Machine Production in tons	10935	11632	↑ by 6.4%
KWH/Ton of Production (JSEB)	173	153	↓ by 11.6%
Rs/Ton of Production	1064	951	↓ by 10.6%

Financial Analysis

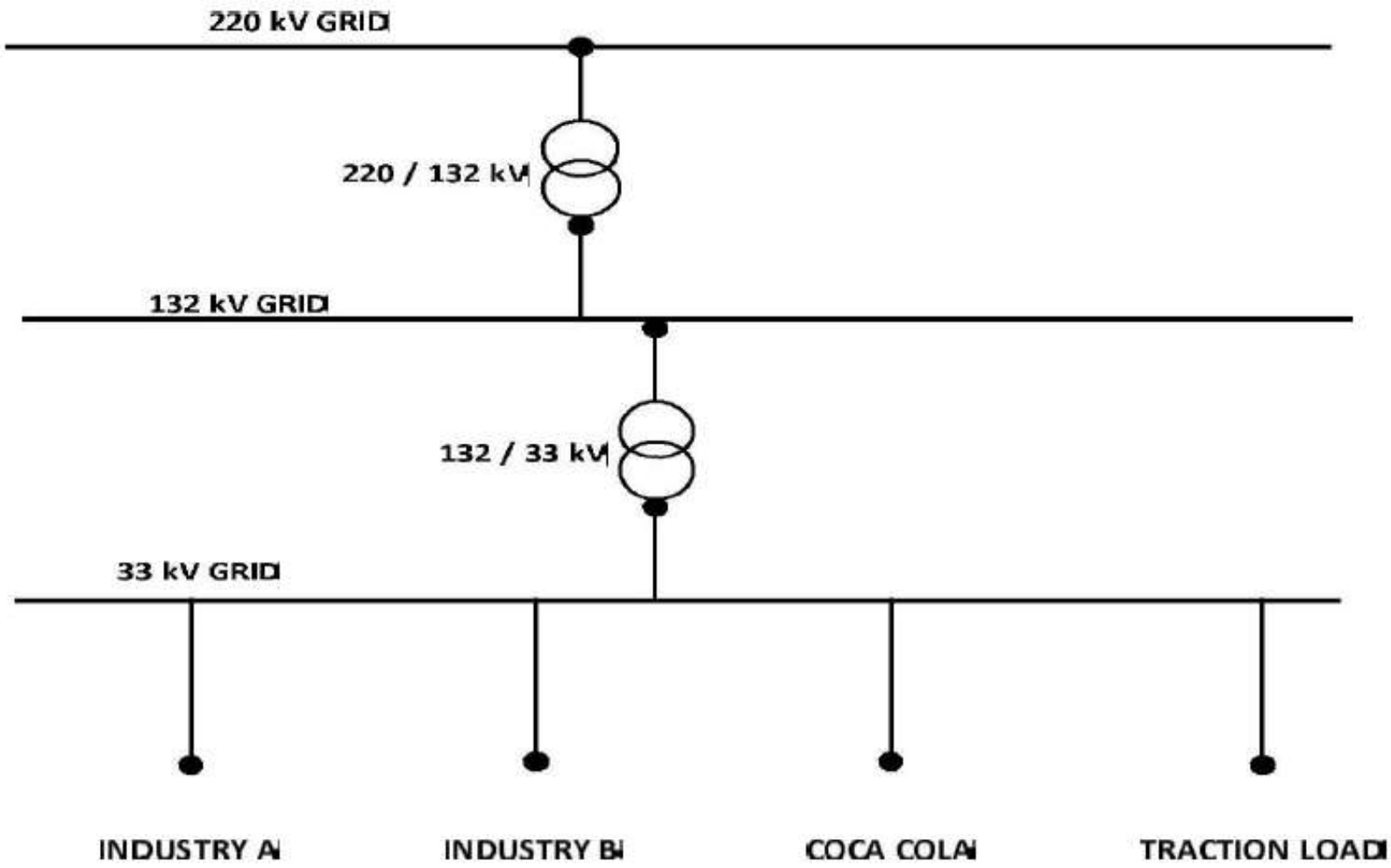
Financial Analysis		
Part A - Reduction in specific energy consumption		Unit of Measurement
Rs/Ton of Production in FY13	1,064.00	INR/Ton
Rs/Ton of Production on 31.10.13	951.00	INR/Ton
Net Gain in Rs/Ton of Production	113.00	INR/Ton
If Avg Monthly Production remains	11,000.00	Tons
Avg Monthly Monitory Gain	1,242,226.00	INR
Average annual monitory gain - A	**14,906,714.00**	**INR**
Part B - Reduction in maintenance, repair and replacement		
Average monthly reduction in maintenance cost	240,000.00	INR/Month
Annual reduction in maintenance cost - B	**2,880,000.00**	**INR/Year**
Total (A+B)	**17,786,714.00**	**INR/year**
Investment	9,800,000.00	INR
Simple Payback	7	Months

Case Study
Distribution Network Voltage Related Power Quality Issues

Distribution Network Voltage Issues Coca Cola

- Coca Cola – Leading beverage manufacturer, one of the plant at Khurda, Orissa
- Receives power from 220 kV grid – 25 KM from plant
- Same grid also supplies to traction load

SLD of Grid Distribution System



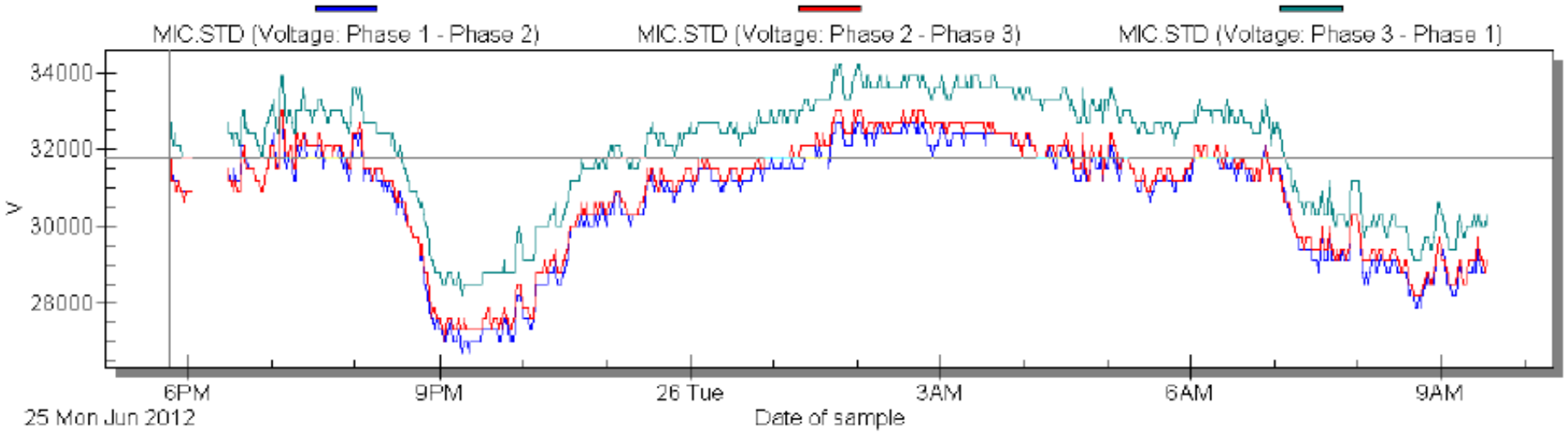
Problem Faced

- Unscheduled power cuts and voltage unbalance
- Un balanced voltage

Month	Unscheduled Power cut	Unbalanced Voltage	Total No of Occurrences
	No. of Occurrences	No. of Occurrences	
January'14	10	9	19
February'14	17	8	25
March'14	45	42	87
April'14	68	51	119

Problem Faced …contd

- Voltage variation – On 33 kV incomer variation is from 26.7 to 34.2 kV



Selected Variable: MIC.STD (Voltage: Phase 1 - Phase 2)

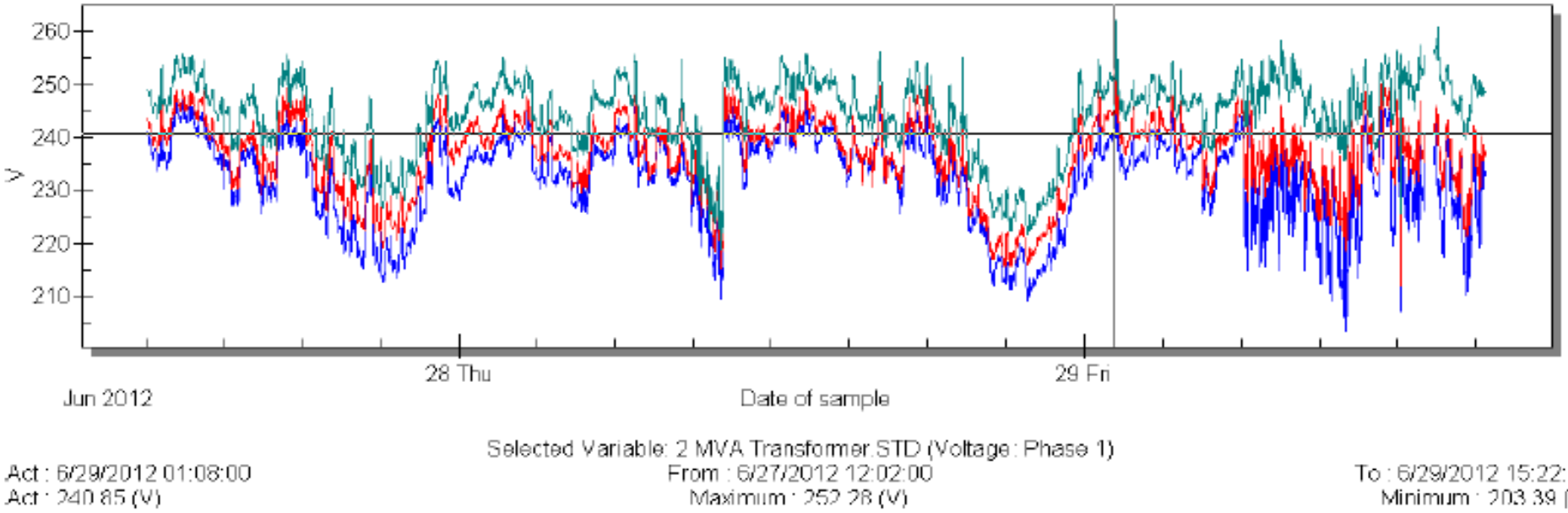
Act : 6/25/2012 17:47:35
Act : 31800 (V)

From : 6/25/2012 17:47:35
Maximum : 33000 (V)

To : 6/26/2012 09:33:00
Minimum : 26700 (V)

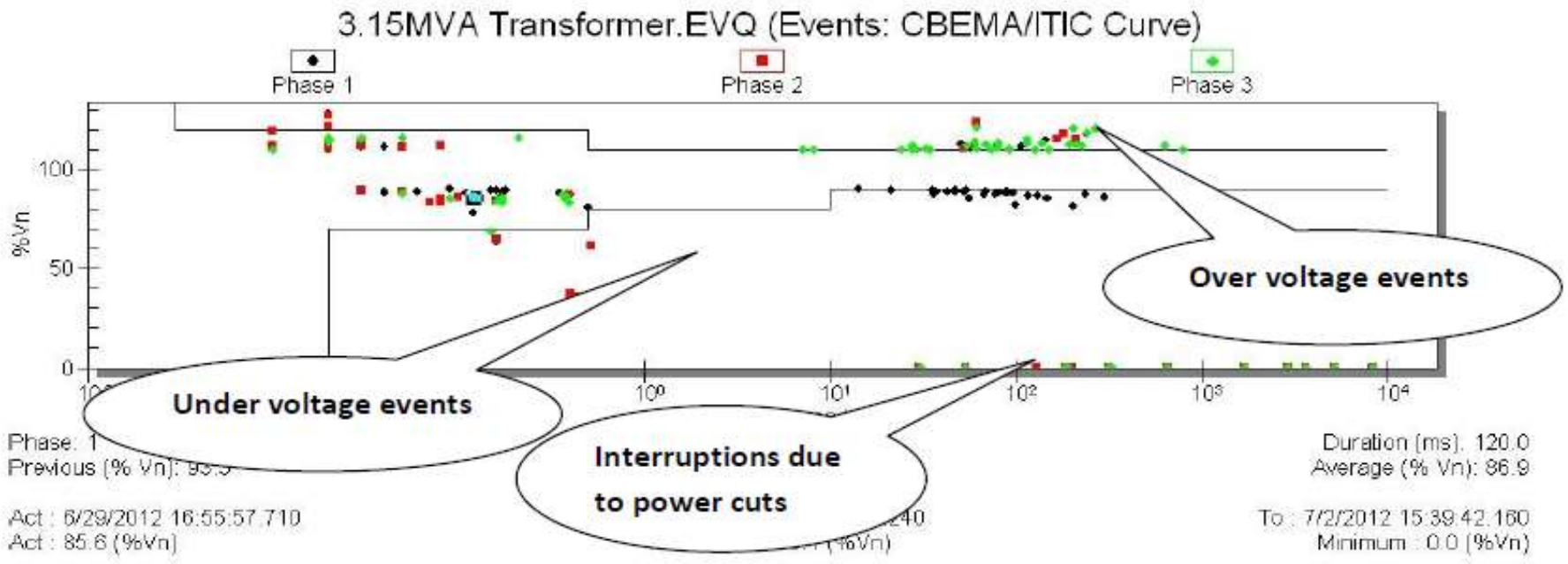
Problem Faced …contd

- Voltage variation – On LT Side incomer variation is from 203 to 252 V
- SCADA recorded voltage dips as low as 20 Volts



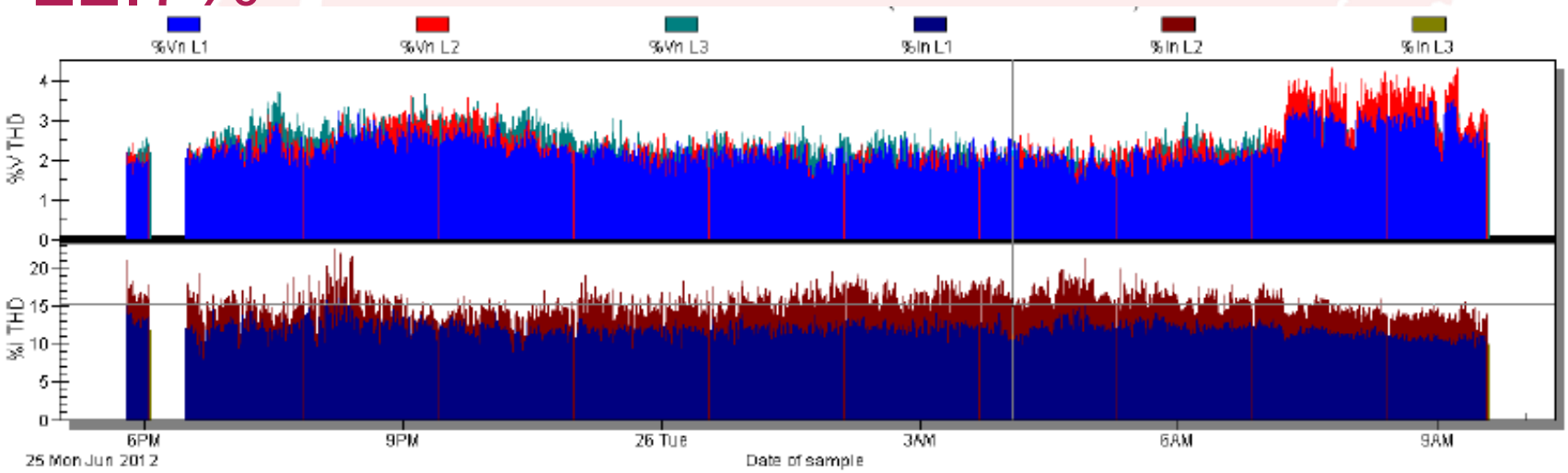
Problem Faced …contd

- Voltage Sags and Swells



Problem Faced …contd

- Voltage & Current Harmonics 4.3% & 22.7%



- Voltage harmonics close to limit specified by IEEE – 519 as 5%
- Current Harmonics on higher side

Impact on Productivity and Financial Loss

- With each interruption and event of power quality, plant was facing production loss

Sl No	Line	Line running time after power resume in mins	Production Capacity per hour (No of cases per hour)	Load factor	Actual Cases Lost	Monetary Loss in Rs per event
1	Krones	15	1500	80%	300	3168
2	Maaza	12	1500	80%	240	2534.4
3	RGB	10	1500	80%	200	2112
4	Kinley	10	300	80%	40	422.4
5	PET-140	15	933	80%	187	1970.496
Total Loss						10207

Temporarily PQ Mitigation Adopted

- Use of DG set instead of grid power
- Use of UPS for critical machines – almost 1.8 MVA

Annual Monetary Loss

- Annual loss is through:
  - Loss in productivity
  - Additional cost due to continuous operation of DG set
- Annual loss suffered by plant in terms of loss in productivity and higher energy cost is **INR 62.5 Million** per year.

Case Study
Neutral Current Compensator (NCC)
and
Reliability Improvement

Neutral Current Causes, Effect and Mitigation

- Causes
  - Unbalanced fundamental active and/or reactive current
  - Unbalanced current harmonics
  - Triplen Harmonics

Neutral Current Causes, Effect and Mitigation

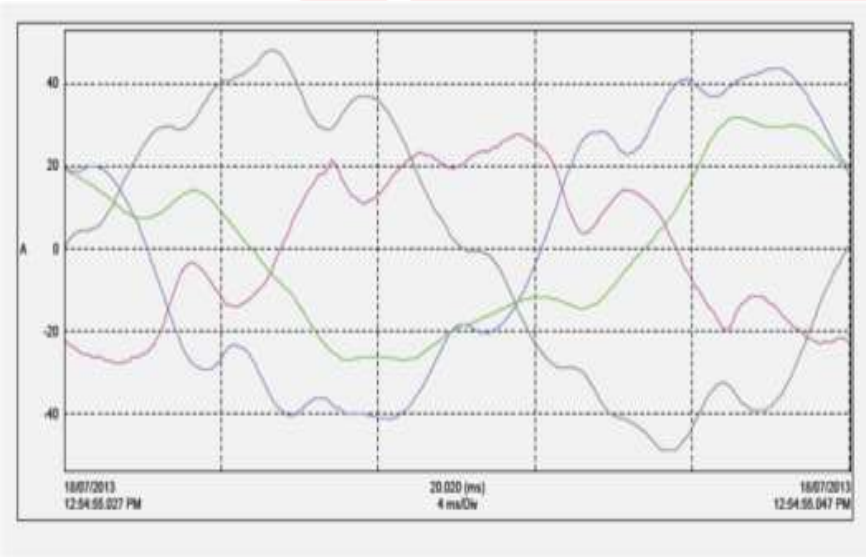
- Effects
  - Heating of neutral busbar or burning/ insulation failure of neutral cables
  - Shifting of supply neutral potential with respect to earth potential based on earth resistance and the neutral current
  - Unacceptable unbalance or asymmetry in phase to neutral voltages damaging
  - sensitive loads such as in medical applications

Neutral Current Causes, Effect and Mitigation

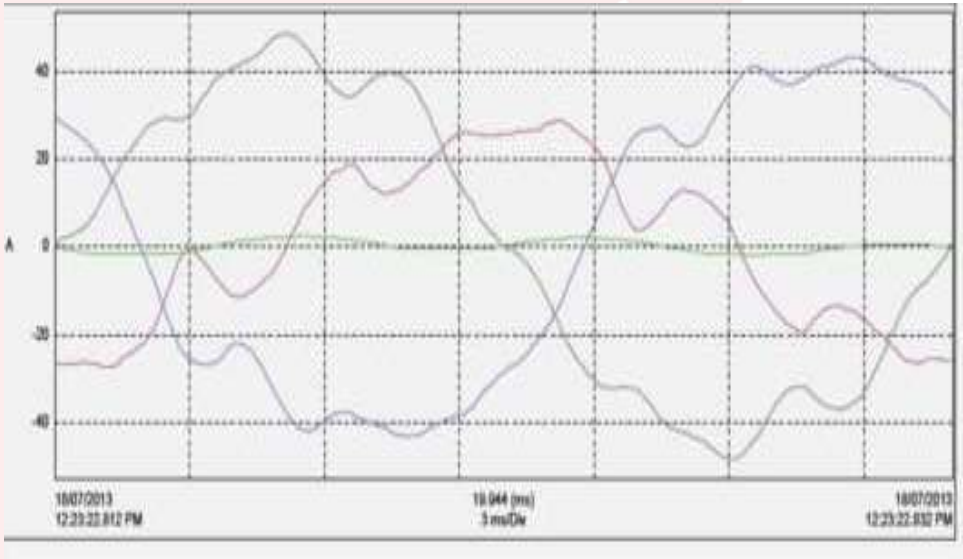
- Effects
  - Disconnection from supply neutral point or earth resulting in phase to phase voltages appearing across loads and subsequently causing damage to loads (example: LEDs , CFLs, Tube Lights, Bulbs, Fans, TVs, Refrigerators, and other household appliances)
  - Disturbances in synchronization voltages for connected active power converter
  - Large unbalanced loads causing voltage disturbances to other loads connected on same bus, sometimes resulting in visible flicker
  - Reduction in life of incoming supply transformer

Neutral Current Causes, Effect and Mitigation

Before:



After:



Quick Fact Check.

Have you faced an inexplicable DOWNTIME?

Has your facility attracted any non-compliance PQ PENALTIES ?

Is voltage quality a concern?

Have you faced sensitive equipment MALFUNCTIONS?

Some action on harmonics – on your agenda?

Facts that fast become norms to “live with”...

Improving Network Quality = Managing Collective Responsibility!

Projects and Consultants

- PQ compliant Equipment, PQ Standards
- Network Quality Monitoring, Performance obligations on OEMs
- Awareness building regards PQ contractual obligationss

EPC and Contractors

- Pre/Post Installation/Commissioning checks, Sensitization of all project stakeholders

End Use and Maintenance

- Electrical Network Quality Data Monitoring frameworks

OEMs

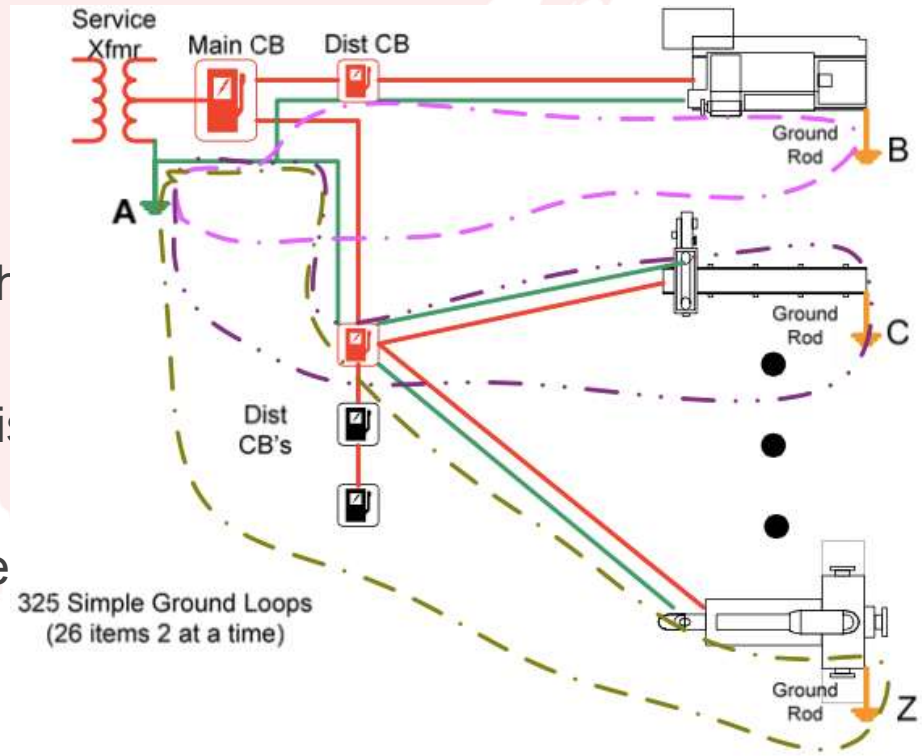
- Publish PQ Compliance/Standards, Align to meet PQ goals for the electrical network

PQ = Lot's of Myths

PQ myths that need corrections

- PQ ≠ (just) PF correction
- Harmonics ≠ Always harmful
- Oversized System ≠ Better PQ
- UPS/SVR/Harmonic Filter ≠ "Th
- PV/Wind Generation ≠ No PQ i
- Additional earthing stns ≠ prote

…and many more



Thank You

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