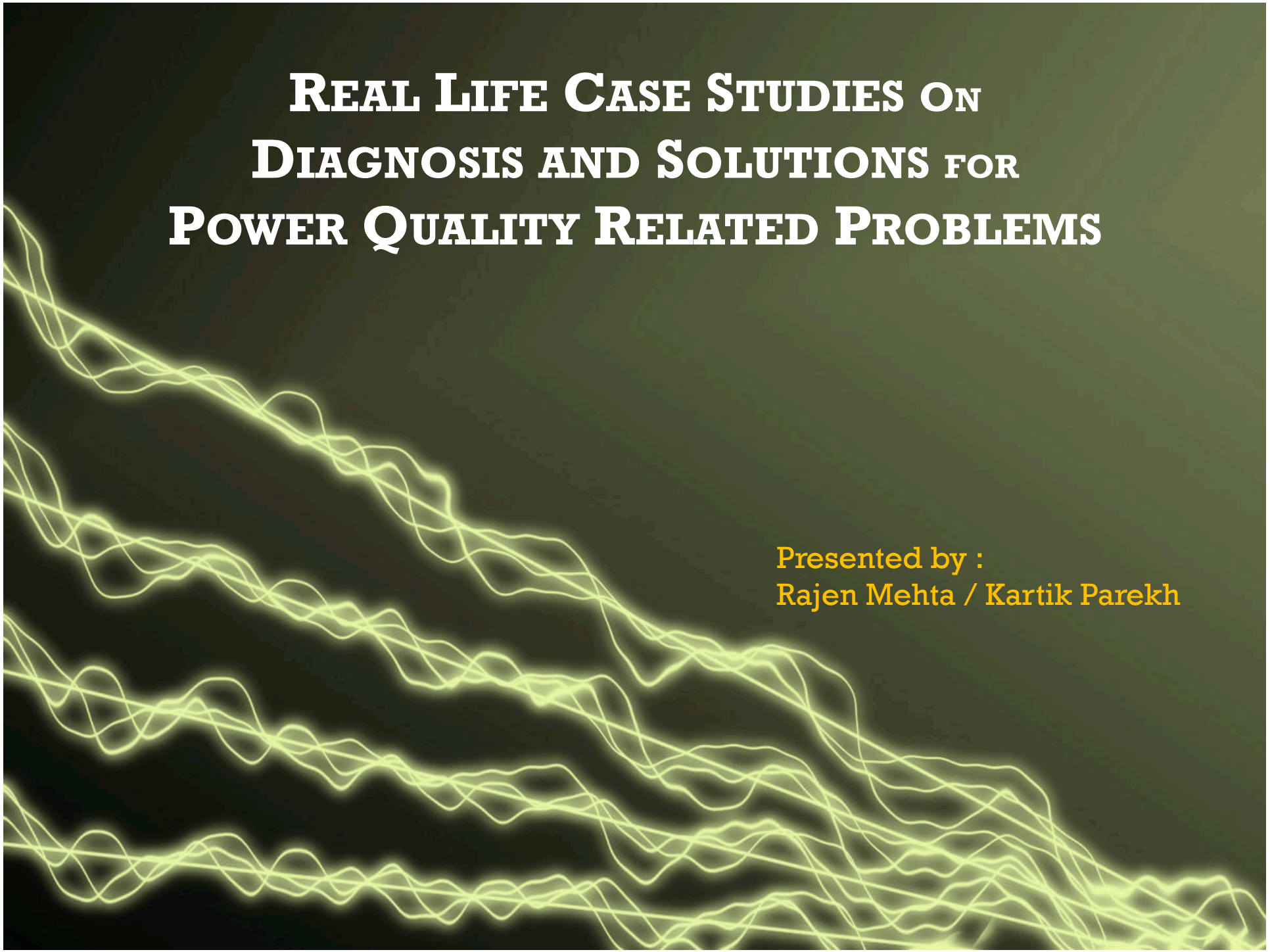

Real Life Case Studies On
Diagnosis and Solutions for
Power Quality Related Problems
Presented by :
Rajen Mehta / Kartik Parekh

OVER VIEW OF PRESENTATION

- Brief and Practical Introduction to Power Quality
- Effect of Coupling Channel[1] on Power Quality Problems
- Background & Theory on PQ Problems addressed in this presentation through case studies
- Three Case Studies discussed with a 4 point analysis
  - Client details
  - Symptoms & Observations
  - Recommendations
  - Post Implementation Results
- Conclusion

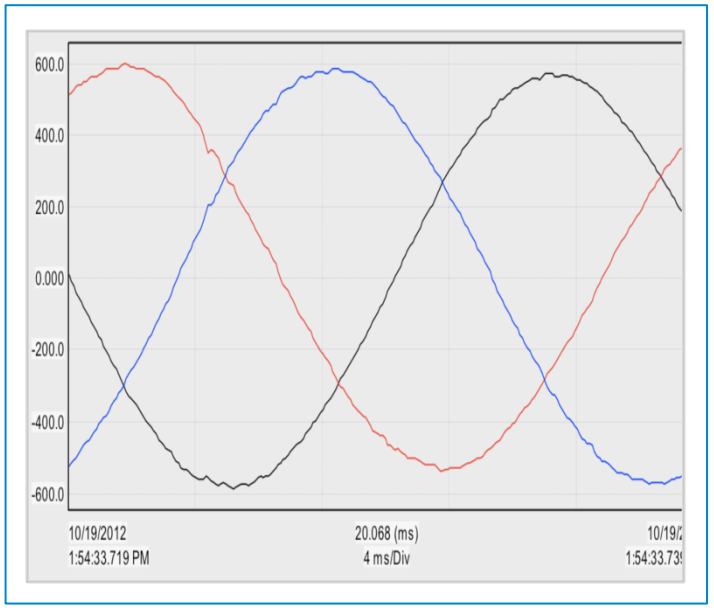
A PERFECT POWER SUPPLY

Always available and reliable

Within voltage and frequency tolerances and has a pure noise-free sinusoidal wave shape

Cost of power quality is determined by:

- the quality of the voltage supplied
- the types of load in the installation and the sensitivity of these loads to PQ disturbances such as voltage, imbalance, harmonics, high N-E voltages, overloaded neutrals



EFFECT OF COUPLING CHANNEL

- Isolated Power Quality phenomena alone may not cause all the damages
- Coupling Channel needed for power quality disturbance in any equipment

Power Quality phenomena + Coupling Channel > Compromised Safety and Eqpt Failures

EXAMPLES

voltage transient or spike	+	improper electrical installation	>	considerable damage
harmonics	+	Network Resonance	>	considerable damage

BACKGROUND & THEORY ON PQ PROBLEMS

Residual Ground Potentials

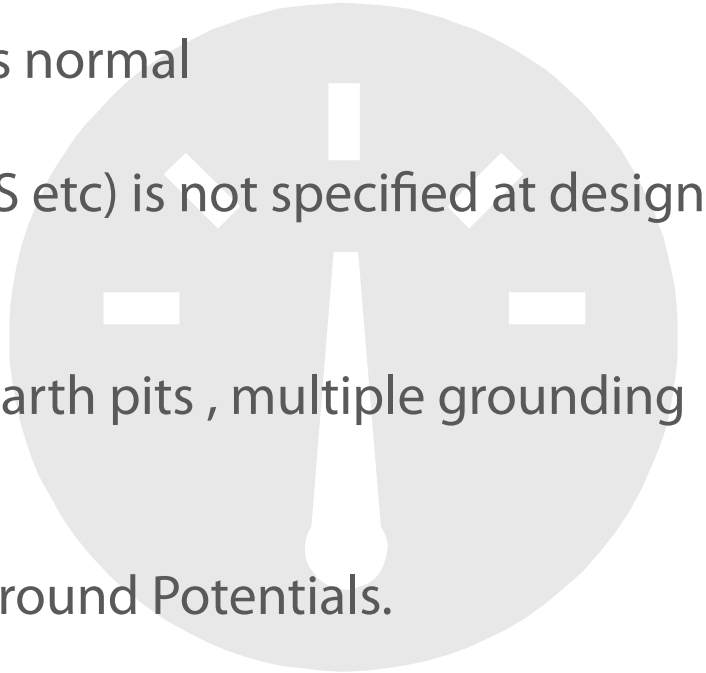
Voltage Disturbances

Earthing Practices

Harmonics Pollution

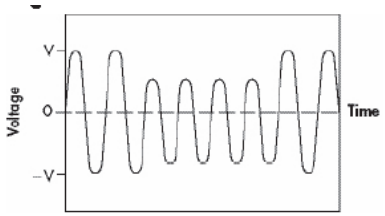
RESIDUAL GROUND POTENTIALS

- Varies with noise potentials/signals, dynamic loading patterns, ground resistivity, cancellation or formation of N-E V etc
- Difficult to pinpoint the exact source
- A small potential (typically N-E Voltage) is normal
- Usually earthing configuration (TNS,TNCS etc) is not specified at design stage or followed in later stage
- Measures to remove N-EV such as extra earth pits , multiple grounding etc. only complicate network installation
- Follow best practices to avoid Residual Ground Potentials.

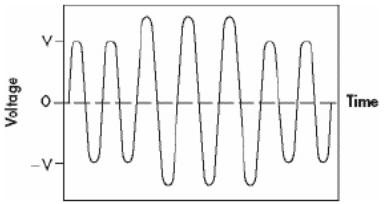


VOLTAGE DISTURBANCES

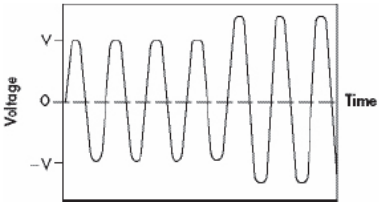
- Types of voltage disturbances - sags, swells, dips, spikes, brownouts, blackouts



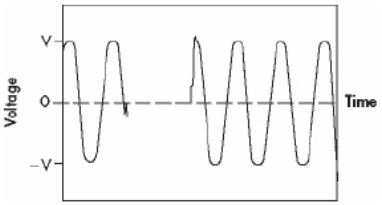
Sag



Swell



Overvoltage

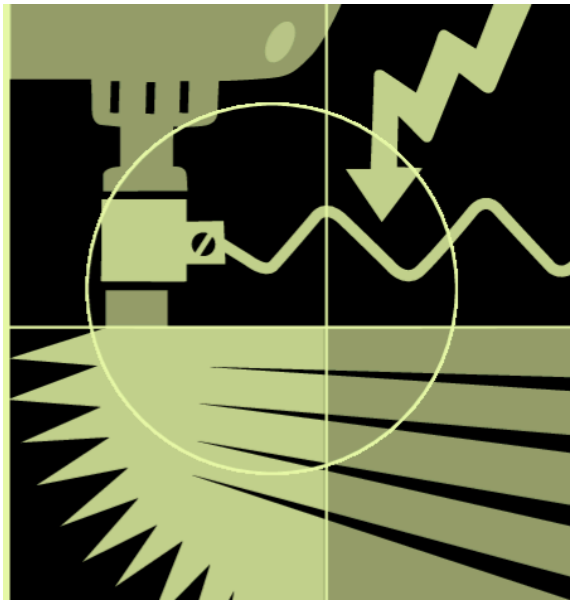


Blackout

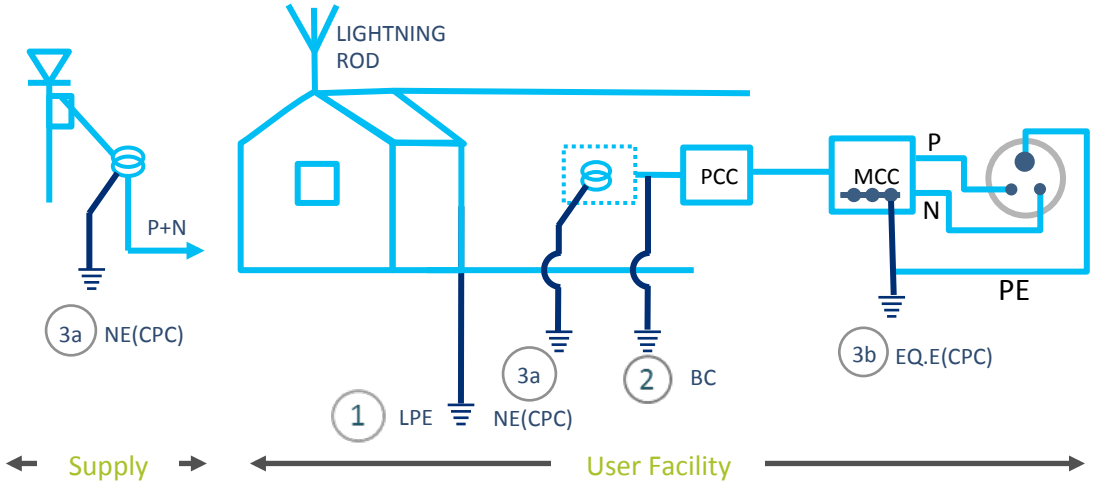
- Our focus for this presentation is Voltage transients due to HV Capacitor switching
- Caused due to the conventional compensation systems installed by utilities and large private industries for voltage regulation at various levels on HT side
- At MV level generally either fixed in nature or controlled through vacuum contactors, causing heavy switching transients

EARTHING PRACTICES

- No dearth of literature out there with respect to best earthing practices
- Actual understanding and implementation so as to help mitigate Power Quality disturbances
  - Woefully inadequate
  - Too detailed and descriptive for a field level technician to put into perspective and practice



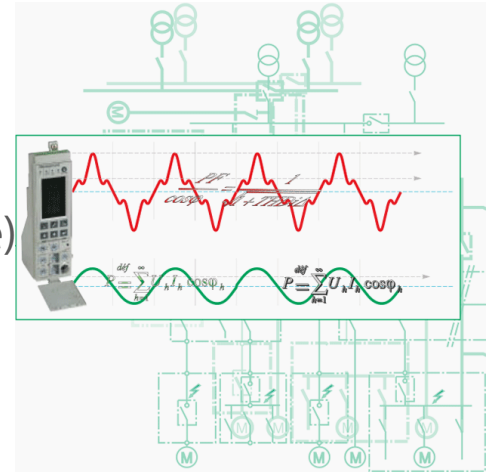
EARTHING PRACTICES



- Basic requirement of a sound earthing comprises of 3 components
  1. Lightning Protection Earth Conductor
  2. Bonding Conductor used for metal enclosure and metallic parts (Body earth conductor)
  3. Circuit Protective Earth Conductor (Potential Earth)
     a. Neutral Earth
     b. Equipment earth Conductor

- Depending on the site requirement either of the IT/TT/TNS/TNCS configurations can be chosen

HARMONICS POLLUTION



- Non-linear loads generator of pollution
- Coupled with the combination of (network resonance) and weak impedance sources can be severely damaging to equipment
- Harmonics generated by these loads affect other end-use equipment and not itself
- Harmonic mitigation equipment under slight overshooting from standards, is recommended only after detailed investigation of the situation such as:
  - Study of harmonic generating equipment
  - Effect on the network
  - Simulating the network resonance frequencies
  - Effect of PFC equipment
  - Loading patterns
  - Voltage distortions

CASE STUDY 1

The case of Frozen Consoles and UPS Tripping

Client Details

- One of the leading FM Stations' studio facility in Southern India
- Equipment consist of high end audio processing on-air studio equipment, amplifiers, transmitters, consoles, VSAT Terminals, computers, UPS, servers
- The facility was started in the year 2008
- The original grounding configuration in use was TNS

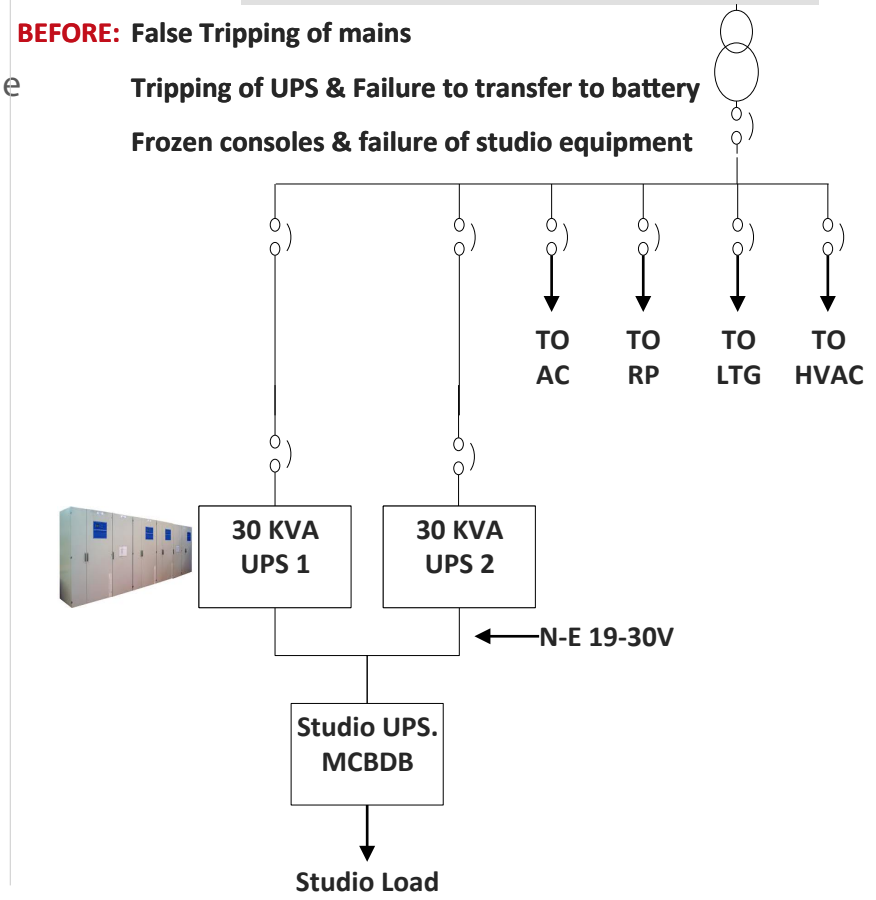
CASE STUDY 1

The case of Frozen Consoles and UPS Tripping

Symptoms and Observation

- Lot of noise signals observed in the transmission of the audio signals. Some direct symptoms were freezing of the consoles and UPS Tripping inadvertently.
- Study revealed that the Raw Power Neutral conductor potential was varying from 0.5Volt to as high as 30V between Neutral and Earth Conductor due to leakage potentials from neighbouring loads inspite multiple neutral grounding and equipment grounding.
- This floating Neutral-Earth Potential conditions was causing 2 issues :
  - bad power quality input to UPS
  - freezing of on-air studio equipment resulting in huge revenue loss
- Further the freezing was attributed to the earthing of UPS, servers, desktops and on-air studio equipments connected to a common earth junction.

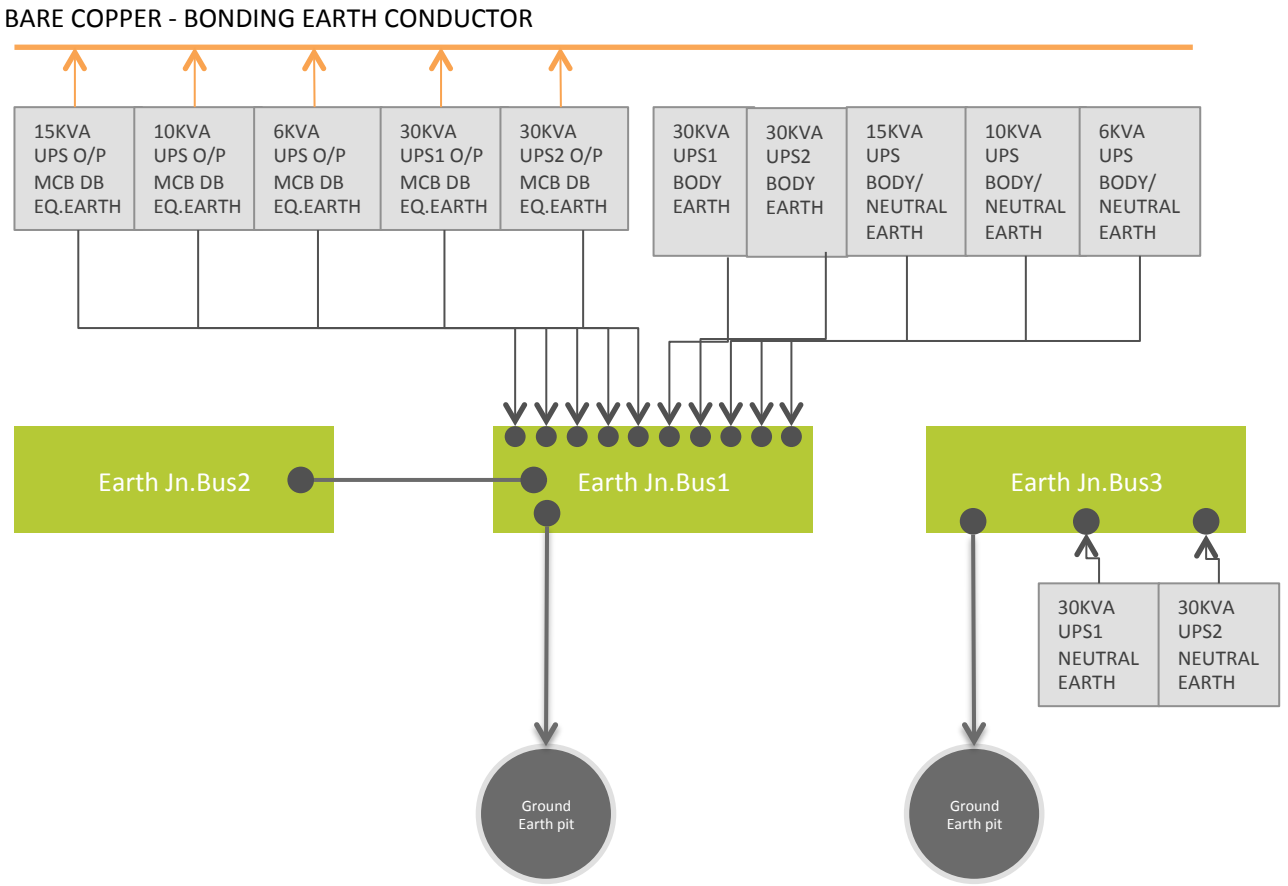
As Is Situation highlighting the Symptoms and Observations



CASE STUDY 1

The case of Frozen Consoles and UPS Tripping

UPS room earthing – Before



CASE STUDY 1

The case of Frozen Consoles and UPS Tripping

Recommendations

- Install zero sequence filter transformer with ultra isolation which would serve multiple purposes
  - of providing dedicated neutral
  - of effectively providing stable neutral under unbalanced voltage condition at the input side.
  - of reducing the N-E voltage and isolating the input Power quality problems.
- At the same time changes in earthing of neutral, body and equipment were also recommended
- Lastly Class 2 surge suppressors were also recommended to clamp the P-N peak voltages more than 500V (due to high neutral displacement conditions of upto 30V)

Case Study 1

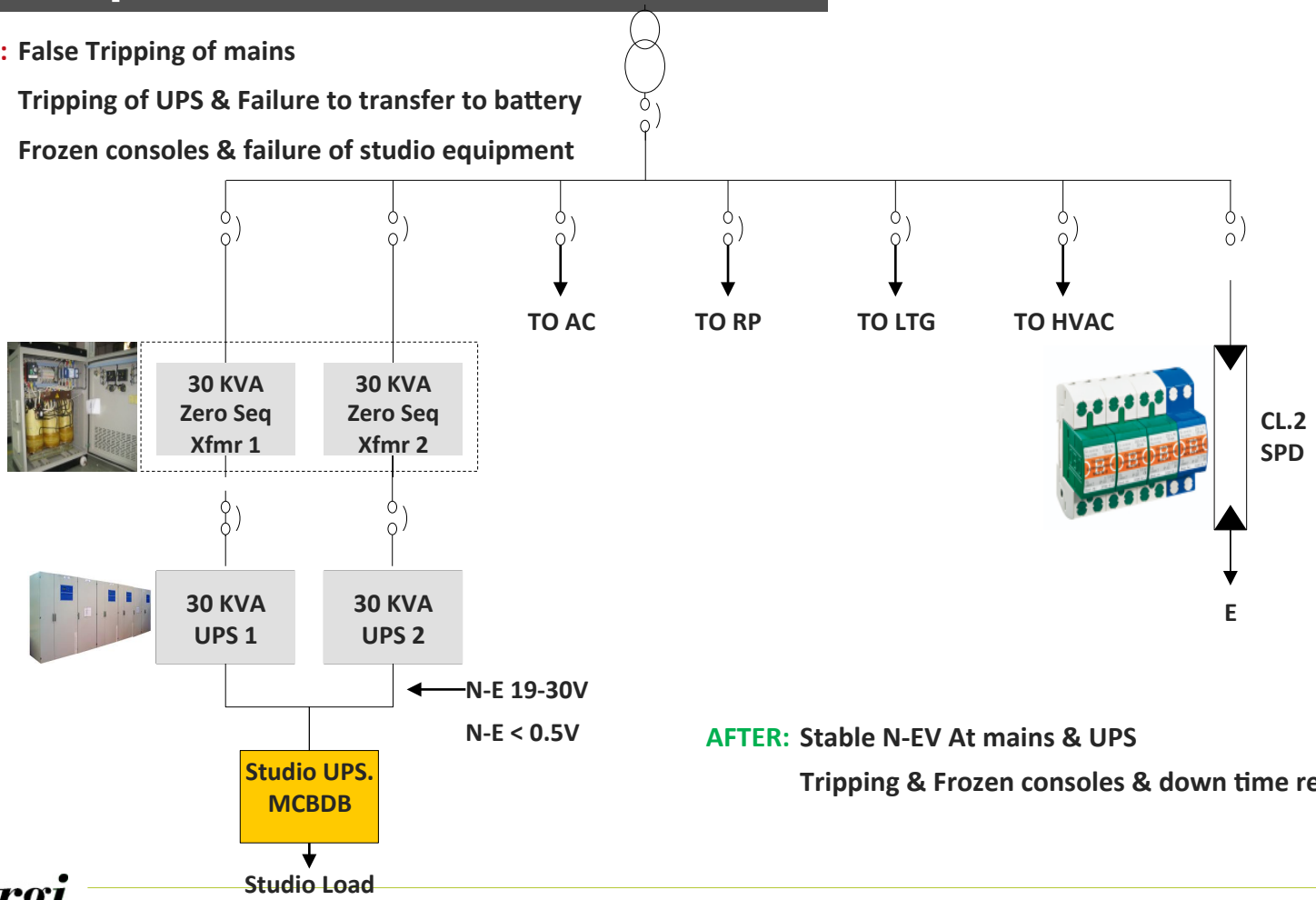
The case of Frozen Consoles and UPS Tripping

Post Implementation of recommendation

BEFORE: False Tripping of mains

Tripping of UPS & Failure to transfer to battery

Frozen consoles & failure of studio equipment



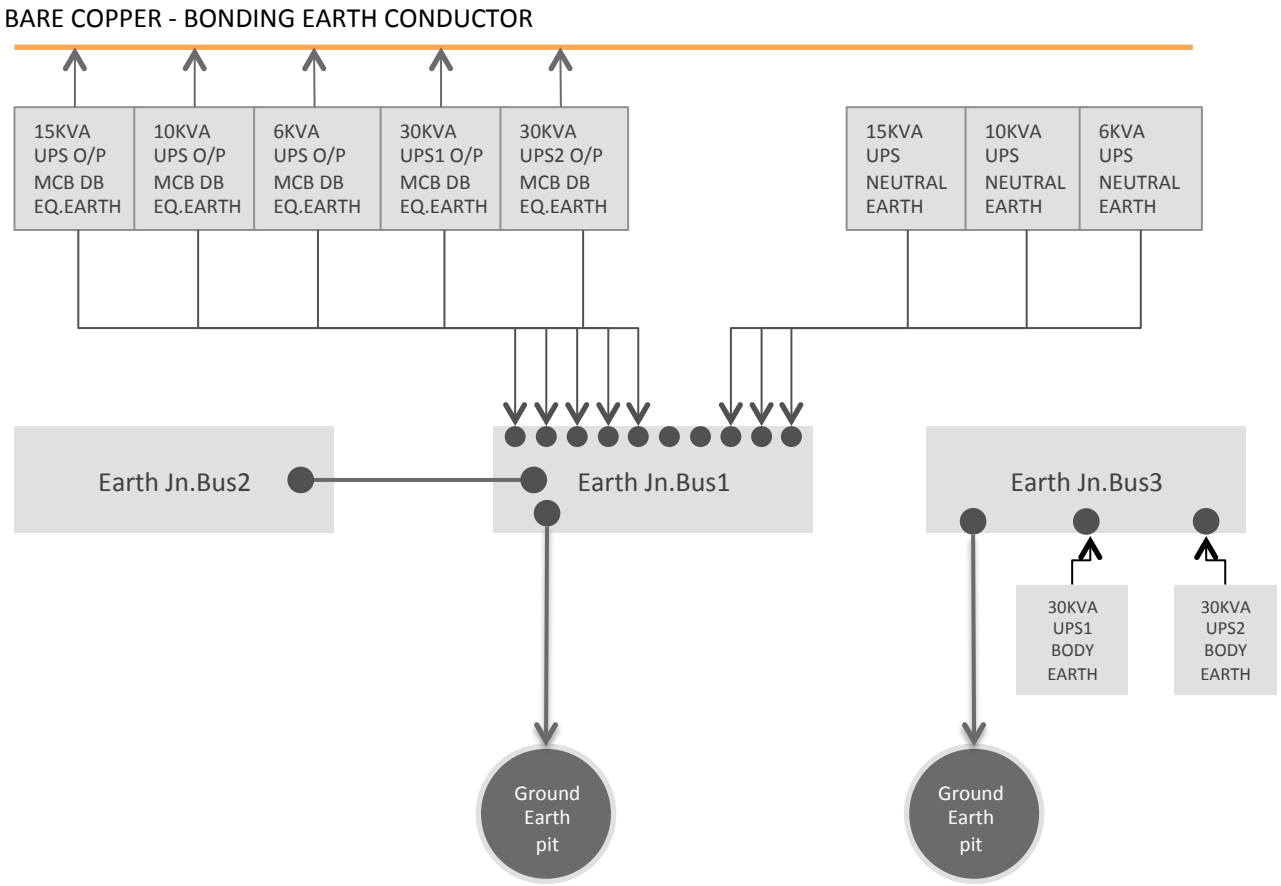
AFTER: Stable N-EV At mains & UPS

Tripping & Frozen consoles & down time reduced

CASE STUDY 1

The case of Frozen Consoles and UPS Tripping

UPS room earthing – After



CASE STUDY 1

The case of Frozen Consoles and UPS Tripping

Measurements

BEFORE

- **30KVA** UPS 1 – Neutral earth: 100mA – 600mA
- **30KVA** UPS 1 – Neutral earth: 100mA – 600mA
- All UPS MCBDB Equipment earth: 0 to **<200mA**
- Zero Sequence Xfmr– output Neutral earth: **100mA – 300mA**
- Zero Sequence Xfmr – output Body earth: **<300mA**
- Neutral to earth voltage: **18-30V**
- Phase voltages: **240 V to 245V**

AFTER

- **30KVA** UPS 1 – Neutral earth: 50mA – 200mA
- **30KVA** UPS 1 – Neutral earth: 50mA – 200mA
- All UPS MCBDB Equipment earth: 0 to **<100mA**
- Zero Sequence Xfmr – output Neutral earth: **10mA – 50mA**
- Zero Sequence Xfmr – output Body earth: **<300mA**
- Neutral to earth voltage: **0.5Volt**
- Phase voltage: **240V to 245V**

CASE STUDY 2

The case of failing Rectifier Power Modules

Client Details

- One of the regional hubs of a multinational into communications capabilities deliverance situated in Western India
- Equipment consist of high end tele-communication processing equipment, such as DC rectifiers, Routers, Gateway Switches, UPS, SMPS, Server Racks, etc.
- The facility has been operational since last 10 years
- The grounding configuration in use was TNS
- Most of the critical equipment were of 3Ph+PE type

CASE STUDY 2

The case of failing Rectifier Power Modules

Symptoms and Observation

- In Feb 2010 all of a sudden, critical rectifier power modules started failing at a rate of 1 module every 2-3 days

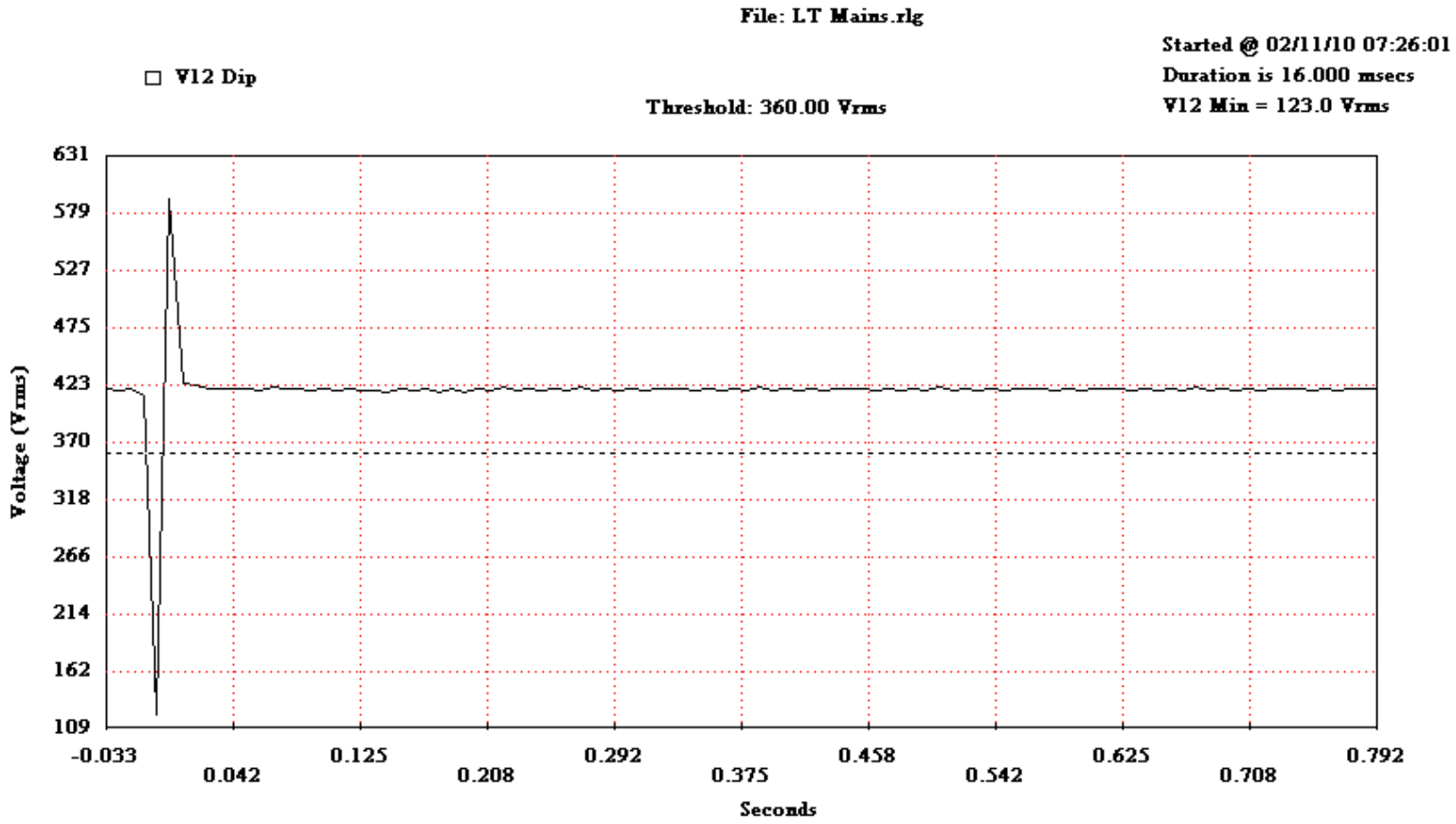
- To assess the root cause a detailed study was conducted by our team in the following areas :
  - Frequency Disturbances:
  - Amplitude Disturbances: Time > 1 cycle
    - Transients & Periodic
      - Slow voltages / over voltages / voltage dropouts
    - Periodic
      - Voltage Fluctuations & flickers • EMI/RFI/DC–fields
  - Amplitude Disturbances: Time < 1 cycle
    - Transients
      - Fast voltage changes / voltage spikes & notches
    - Periodic
      - Harmonics
  - Three Phase Symmetry

CASE STUDY 2

The case of failing Rectifier Power Modules

Findings

Over Voltages (+10% to +25%) & Voltage swells
Voltage dropouts (-10% to – 100%) & Voltage dips



CASE STUDY 2

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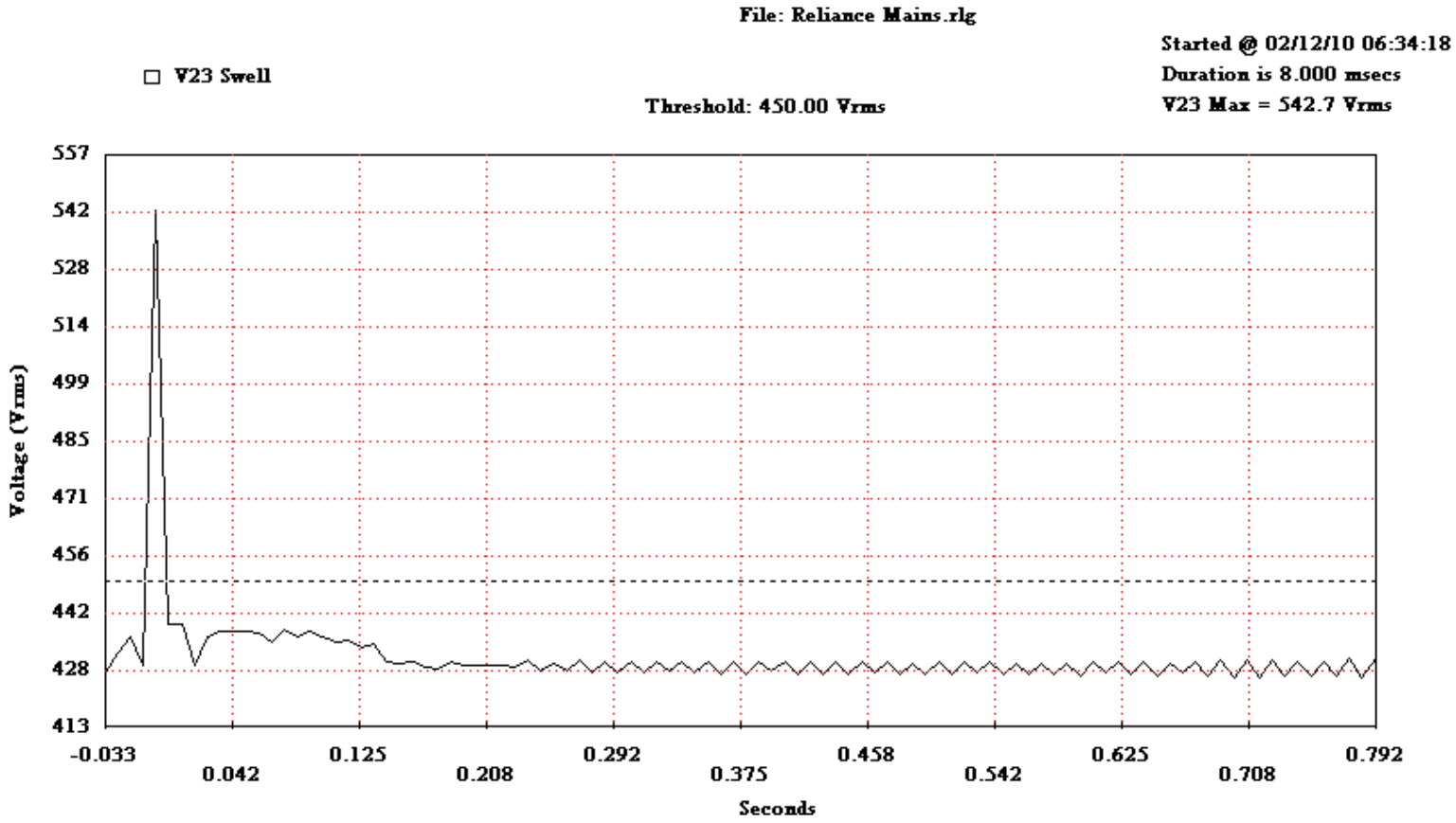
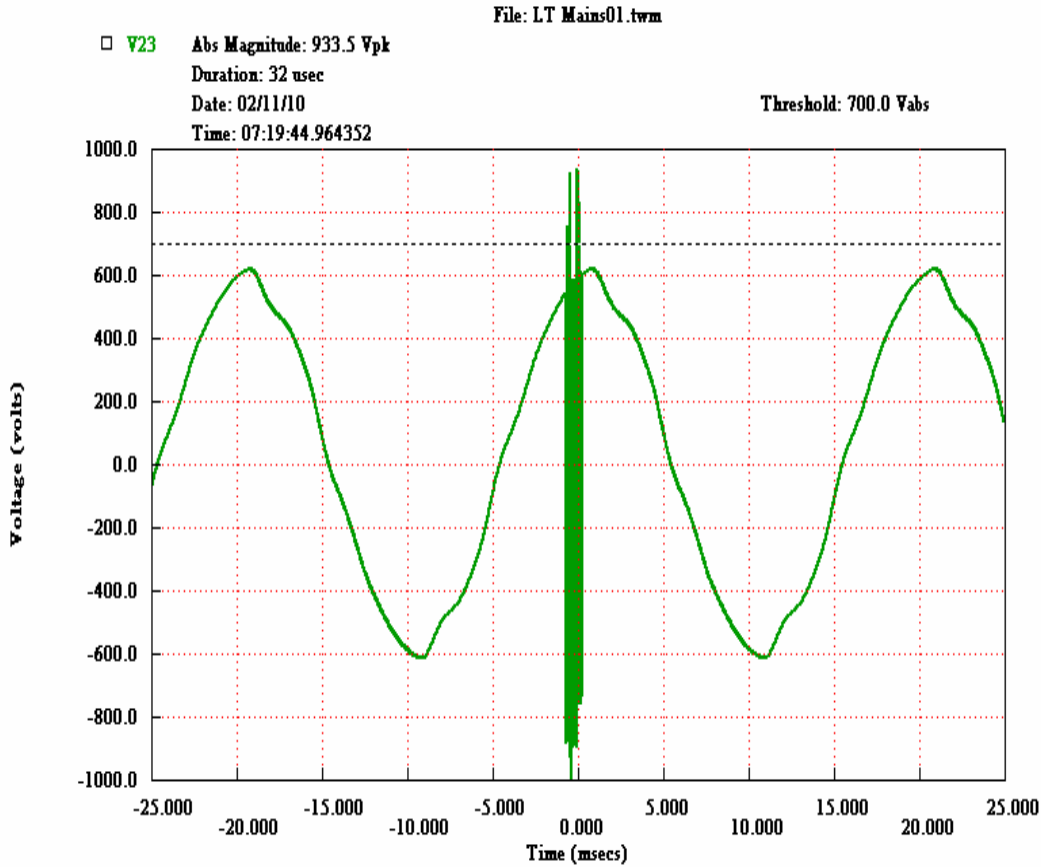


CASE STUDY 2

The case of failing Rectifier Power Modules

Findings

Fast Voltage Changes (steps with high dV/dt)
Spikes & Notches (pulses with high dV/dt)



Spikes & Notches				
RELIANCE MAINS	Time	Ph	Duration	Magnitude
11/02/2010	07:19:44	V23	32 usec	**933.5**
12/02/2010	06:34:18	V31	873 usec	833.1
12/02/2010	11:46:24	V23	8 usec	-976
12/02/2010	12:16:36	V31	89 usec	971
12/02/2010	16:05:20	V23	8 usec	-747.1
13/02/2010	08:22:11	V31	609 usec	-710

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CASE STUDY 2

The case of failing Rectifier Power Modules

Findings

- **External Disturbance** - The disturbances were external particularly because a detailed analysis of client load patterns did not reveal any major fluctuating load patterns or any changes recently made.

- **Ineffective voltage clamping** – Installed TVSS were ineffective in clamping the fast voltage changes that were recorded. It was able to record the transient, but unable to filter the same.

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CASE STUDY 2

The case of failing Rectifier Power Modules

Findings

- **HT Capacitor switching problem** – A more detailed second study revealed the source of disturbance to be the HT Capacitor switching. It was also observed that the occasional high voltage transients did not affect the equipment.

- **Unstable network** - Further detailed study of the earthing system, earth pit impedances and ground resistivity revealed high neutral-earth resistance, hence a weak source neutral. So in effect the network was unable to sustain the high dv/dt HT transients since the neutral was unstable on LT side and that got coupled with a network having leading PF condition making it capacitive in nature which was amplifying the high dv/dt from HT side.

CASE STUDY 2

The case of failing Rectifier Power Modules

Findings

Date	Time	Duration (mSec)	Signal	Type	Peak
TRANSFORMER MAINS					
20/02/10	04:50:23	199	V31	Swell	585.3
20/02/10	04:50:23	71	V12	Swell	571.3
20/02/10	04:50:23	24	V23	Swell	560.3
21/02/10	08:46:26	8	V31	Swell	454.1
22/02/10	06:26:36	8	V31	Swell	452.7
23/02/10	04:48:20	16	V12	Swell	498.0
23/02/10	04:48:20	8	V23	Swell	542.3
24/02/10	05:33:43	291	V23	Swell	692.8
24/02/10	05:33:43	333	V12	Swell	542.2
25/02/10	05:35:11	8	V23	Swell	464.8
28/02/10	08:32:41	8	V1N	Swell	911.1
01/03/10	08:37:00	12	V2N	Swell	747.2
02/03/10	07:10:41	28	V3N	Swell	956.5
03/03/10	06:56:22	8	V2N	Swell	801.1
05/03/10	08:34:57	8	V31	Swell	522.1
06/03/10	06:05:47	8	V12	Dip	179.6
06/03/10	06:05:47	8	V23	Swell	501.8
06/03/10	06:05:47	8	V31	Swell	516.5
06/03/10	07:36:34	8	V12	Swell	462.3
07/03/10	07:31:49	8	V12	Swell	531.8
07/03/10	08:16:41	16	V23	Dip	270.4
07/03/10	08:16:41	16	V31	Dip	154.1
08/03/10	06:23:27	24	V23	Swell	510.6

HT Capacitor Switching Times

Date	Time
27-02-10	08.30
28-02-10	08.32
01-03-10	08.35
02-03-10	07.10
03-03-10	07.00
04-03-10	07.05
05/3/2010	08.35
06/3/2010	07.38
07/3/2010	07.32
08/3/2010	06.22
09/3/2010	07.21

The cells highlighted in yellow match with the times of HT Capacitor switching as shown in the adjacent table

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CASE STUDY 2

The case of failing Rectifier Power Modules

Recommendations

EXTERNAL

- Company to ensure switching of the capacitors was done in stages to prevent transients of high magnitude
- To evaluate possibility to route the client supply through a more robust feeder

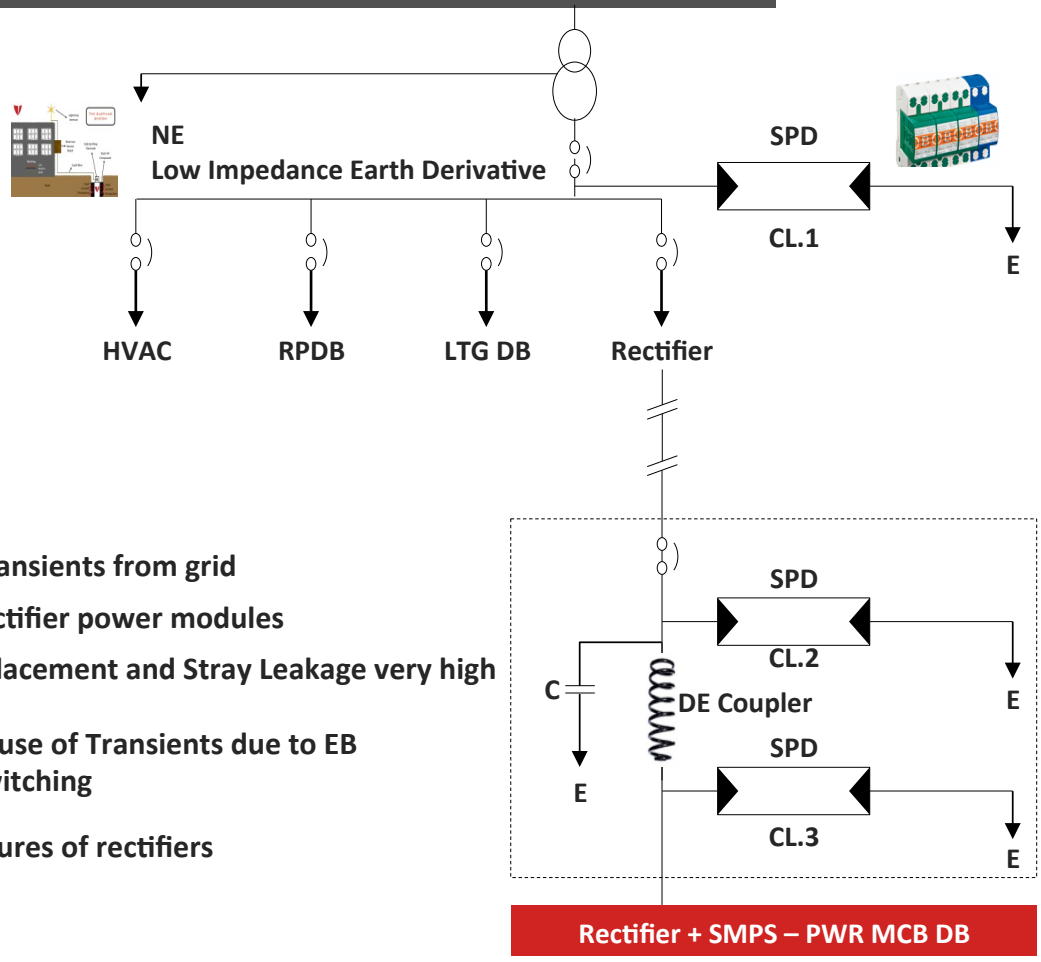
INTERNAL

- Mitigation equipment for arresting such transients were suggested at the facility mains and near the submains and equipment sub DBs.
- Decoupling inductance, k-30 rated were recommended
- Mitigating coupling channel effect by:
  - tuning PF compensation equipment
  - Installing a low impedance earth derivative to provide the stable neutral under transient state of the network at the transformer secondary so that damaging effect of transients was avoided.

CASE STUDY 2

The case of failing Rectifier Power Modules

Post Implementation of recommendation



BEFORE: Damaging transients from grid

Failure of rectifier power modules

Neutral displacement and Stray Leakage very high

AFTER: Identified cause of Transients due to EB Capacitor switching

Arrested failures of rectifiers

CASE STUDY 3

The case of Harmonic Pollution due to drives

Client Details

- One of India's largest Paint Manufacturer's plant situated in Northern India
- The plant is a fully automated plant with a capacity of 200,000 kL / year.
- It is a newly constructed facility, commissioned recently in the year 2009-10.
- The major loads are drives, automation, warehousing cranes, induction motors.

CASE STUDY 3

The case of Harmonic Pollution due to drives

Symptoms and Observation

- Motor locking or process stoppages and humming noise from capacitor banks
- The 7% detuned PF compensation equipment remained ON when plant ran frequently on DG set
- 7-9% voltage distortion due to non-linear load with 6 pulse rectifiers, during the times of DG running
- This caused extreme stress on the detuned banks and causing in a short period of time premature derating of the capacitor banks and further tuning them towards the predominant 5th harmonic resulting in humming of the reactors.
- With respect to the process stoppages, flat topping of the voltage waveforms (due to high voltage distortion) lowered the output DC link voltage and thus confusing the drive and causing it to shunt between precharge mode and normal and in the process causing stoppage of output to motor.

CASE STUDY 3

The case of Harmonic Pollution due to drives

Recommendations

- Recommendations involved taking into consideration the PQ problems and the coupling channel

  - Upgrade the Detuned PF compensation equipment to a Hybrid Harmonic Filter (Active + Passive) due to the variable source impedance as well as very high distortions near load end due to majority of non-linear load

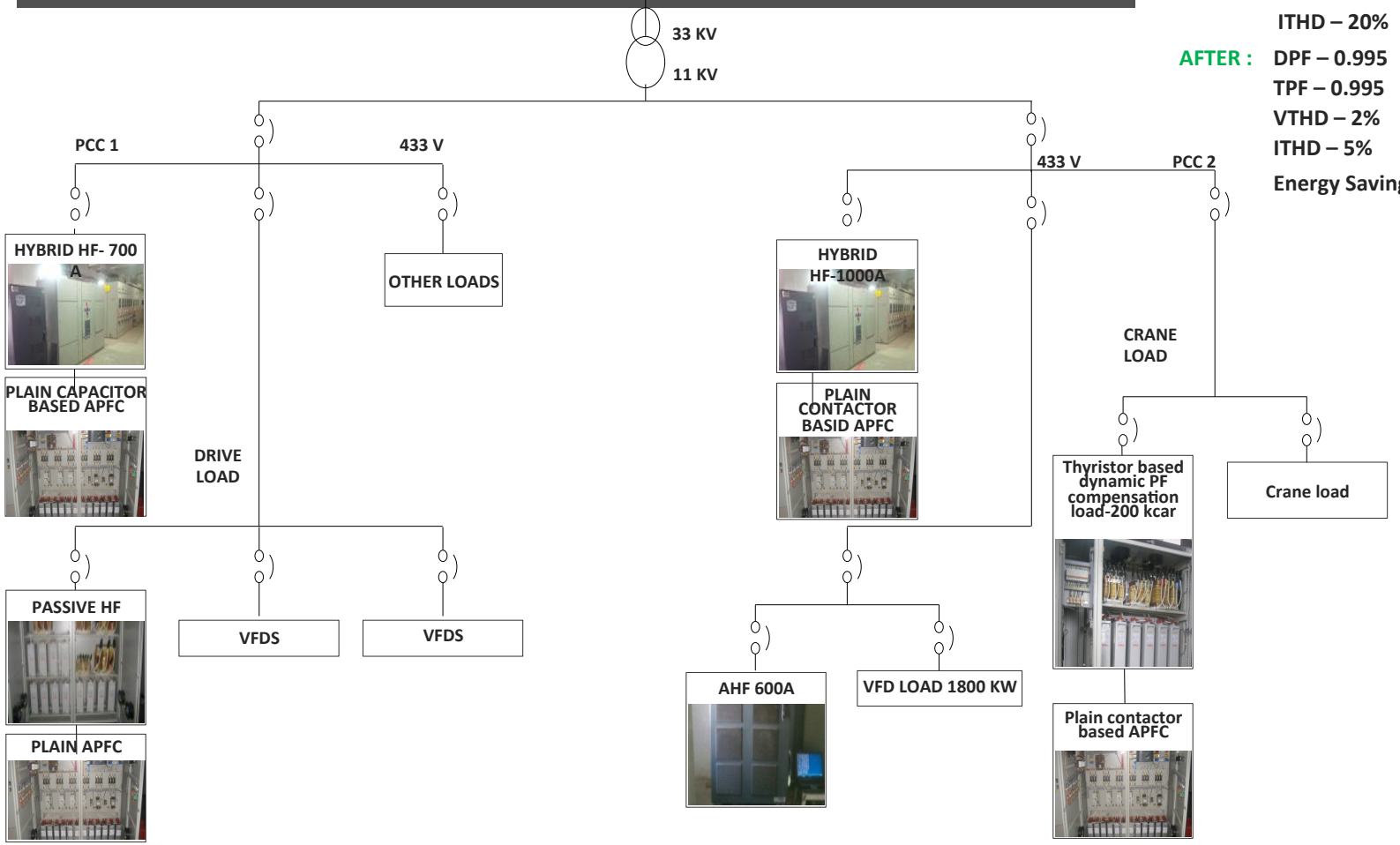
  - Distribute load such that a single generator would not be loaded with more than 25-30% of non-linear load

  - Consult Drive manufacturer to modify control such that generator feedback could be incorporated

CASE STUDY 3

The case of Harmonic Pollution due to drives

Before and After Implementation of Recommendatio



BEFORE : DPF – 0.99
TPF – 0.95
VTHD – 6-7%
ITHD – 20%

AFTER : DPF – 0.995
TPF – 0.995
VTHD – 2%
ITHD – 5%

Energy Savings of about 5-6%

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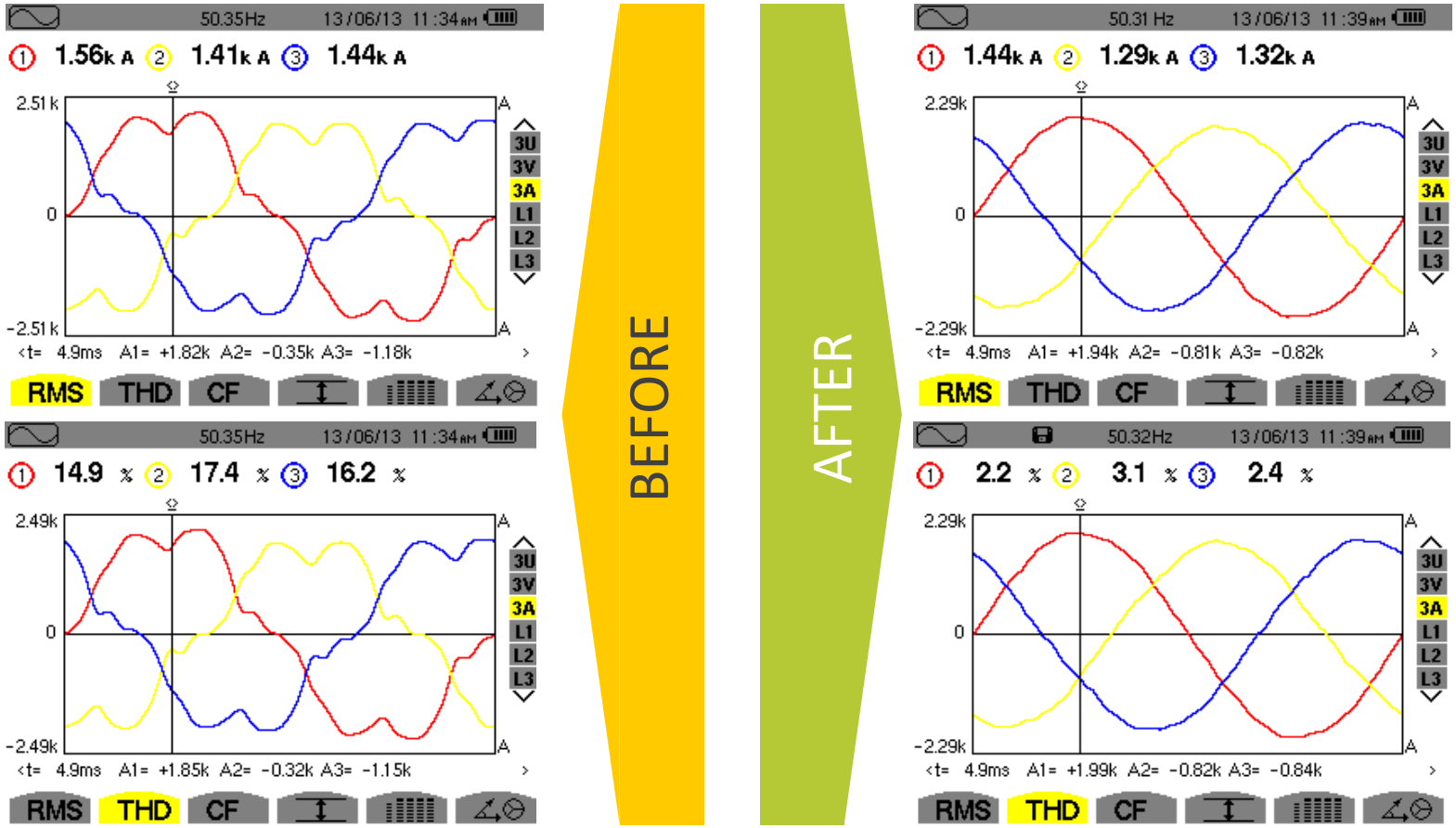
CASE STUDY 3

The case of Harmonic Pollution due to drives

Hybrid Harmonics Filter Before and After Snapsh



CONCLUSIONS

Relying upon expert investigators

Equipment fail due combination of network behaviour, wiring practices, poor design philosophy and lack of the right mitigation equipment or methods

State of the art Power Quality Monitoring systems to assist in problem solving.

Danger in over simplification and need for more research on a case to case basis.

THANK YOU