Effective Harmonic Filter Designs for Commercial Implementation

Team Power Matrix, Sony Jacob

Power Quality

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Power Quality is a set of **ELECTRICAL BOUNDARIES** that allows a piece of equipment to **FUNCTION** in its **INTENDED** manner **WITHOUT** significant **LOSS** of **PERFORMANCE / LIFE EXPECTANCY**

Power Quality is very important in **Todays times**, as our requirements for **Extremely High Production Targets** has increased our usage of Electronic / Electrical Equipment's, very **sensitive to PQ Disturbances** and the consequences of **slight PQ Variations** can be very ***Expensive Repairs, Replacements and Lost Revenue***

Power Quality Problems Worldwide

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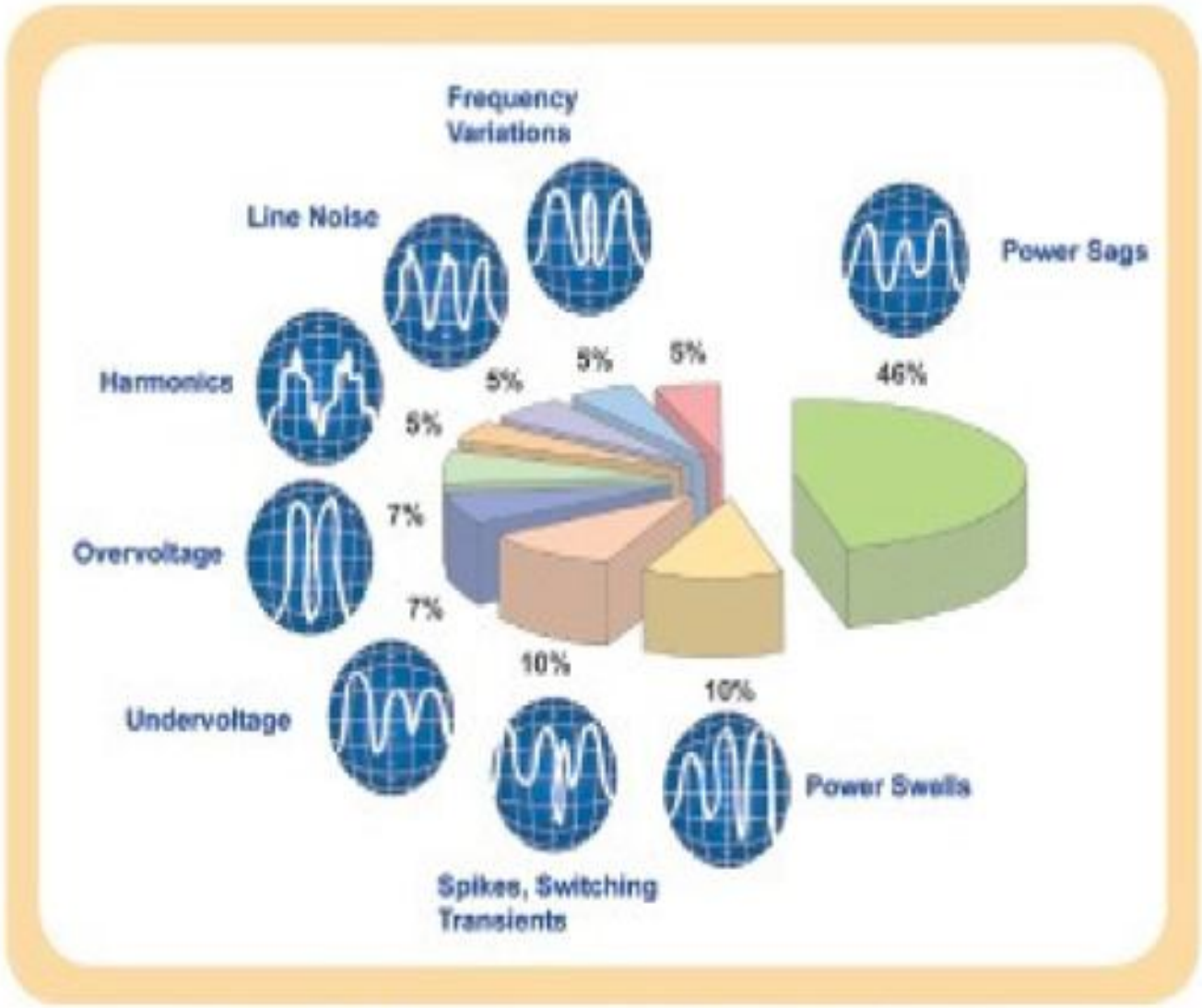

Power Quality Problems in INDIA

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- We will not solve a Problem unless there is a gain/loss associated with it.
- In India, Power Factor Incentives have been in existence for a while now.
- Recently some utility companies have started penalizing for harmonics.
- **Hence, only Power Factor And Harmonics are considered as PQ Problems and provided more than adequate attention.**

Power Quality Problems ≅ Harmonic Problems ?

- Content of **Non-Linear Load** as a proportion of the Total Load is increasing.

$$\frac{\text{Non Linear Load}}{\text{Total Load}} > 50\%$$

- High Neutral to Ground Voltages causes Equipment manufacturers to Void Warranty.

- Electricity Supply Companies are forcing for Harmonic Reduction measures

HARMONICS

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- @ PMX "HARM"onics.

- ***Technically, Harmonics*** *are a* ***MATHEMATICAL*** *way of describing* ***distortion*** *to a* ***Voltage / Current Waveform***

- ***Harmonics*** *occur in BOTH* ***VOLTAGE & CURRENT.***

- ***CURRENT Harmonics are Load Generated*** *and hence should be* ***the focus*** *of remedial measures.*

CREATORS OF HARMONICS

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Harmonics are created by *Non-Linear loads like*

- Electronic chokes in fluorescent lamps
- Single Phase UPS
- Three Phase UPS
- Computer Load, Printer,
- Electronic equipment with SMPS
- Battery Charger
- Thyristorised DC Drives
- Variable Frequency Drives / Adjustable Speed Drives
- SCR Controlled Industrial Heaters
- Smart Motor Controllers
- Welding Controls & Rectifiers
- Saturated Transformers & Motors
- Arc Furnaces

PROBLEMS OF HARMONICS

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- Skin Effect , Thereby causing higher I^2R losses and more cost
  - $R = \rho * L / A$
- Overheating of transformers (K-Factor) and rotating equipment and thus insulation deterioration and more frequent winding required
- Increased Hysteresis losses.
- Neutral overloading / unacceptable neutral-to-ground voltages.
- Distorted voltage and current waveforms
- Equipment de-rating costs to provide immunity to harmonics
- Increased failure of the capacitor banks, sensitive electronic equipment.
- Breakers and fuses tripping.
- Unreliable operation of electronic equipment and generators.
- Erroneous register of electric meters.
- Wasted KVA capacity - Inefficient distribution of power.
- Increased downtime, maintenance of equipment and machinery and thus leads to financial costs

HARMONICS – *How do you measure Harmonics ?*

- The terms TOTAL HARMONIC DISTORTION (THD) & TOTAL DEMAND DISTORTION (TDD) is used as a measure of Harmonics.

$$\%THD_I = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_1} \times 100$$

$$\%TDD = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_L} \times 100$$

Where,

I_h = Magnitude of the individual harmonic components (rms amps)

h = Harmonic Order

I_L = Maximum demand load current (rms amps) defined as a current value, at the PCC as the sum of the load currents corresponding to the maximum demand.

HARMONICS – *International Standards*

- IEEE 519-1992
- EN50160
- IEC 61000-4
- G5/4

In India, the most widely referred standard is the IEEE 519-1992 standard for harmonic limits.

IEEE 519-1992 Recommended Practice For Harmonics

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HARMONIC DISTORTION (%) LIMITS AS PER IEEE 519 - 1992

Current Distortion Limits for General Distribution Systems (120V through 69 000 V)

Maximum Harmonic Current Distortion in % of I_L						
Individual Harmonic Order (Odd Harmonics)						
Isc / I_L	<11	11 - 16	17 - 23	24 - 34	>34	%TDD
< 20*	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

Even harmonics are limited to 25% of the odd harmonics limits above.

Current distortions that result in a DC offset, e.g., Half wave converters are not allowed.

* All power generation equipment is limited to these values of current distortion, regardless of actual Isc / I_L.

Where Isc = Maximum short circuit current at Point of Common Coupling (PCC).

I_L = Maximum demand load current (fundamental frequency component) at PCC.

PCC = Point of common coupling.

Voltage Distortion Limits

Bus Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion THD (%)
69 KV and below	3.0	5.0
69.001 KV through 161 KV	1.5	2.5
161.001 KV and above	1.0	1.5

Implement IEEE 519-1992 ? Why ? When ?

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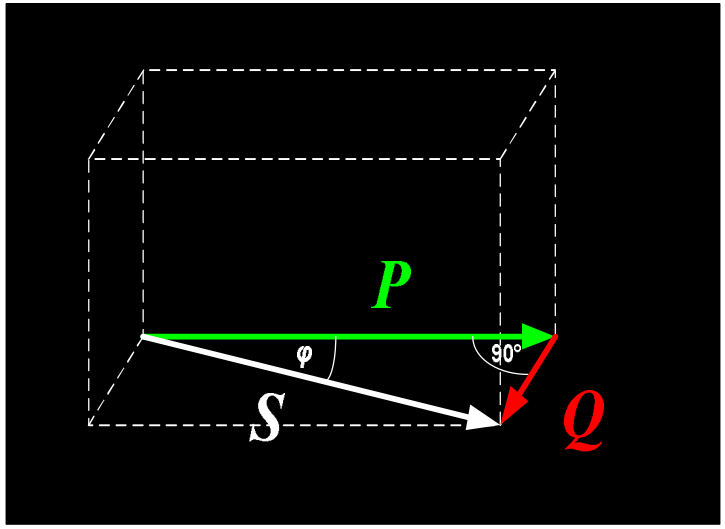
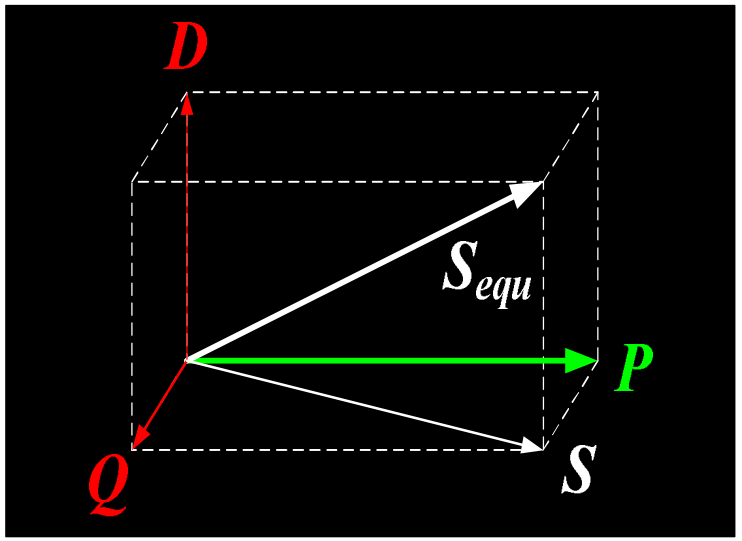
- Especially necessary when Non-Linear Load to Total Load ratio is greater than 40%
- Compliance with IEEE 519-1992 standards for harmonics, assures the reduction of Harmonics to **Acceptable Levels.**
- Implementation of harmonic filtering Solutions INCREASES the
  - **ELECTRICAL EFFICIENCY** of the distribution network
  - **ELECTRICAL RELIABILITY** of the system working components.

ELECTRICAL EFFICIENCY

- EFFICIENCY = RATE AT WHICH USEFUL WORK IS DONE.
- EFFICIENCY = OUTPUT / INPUT
- **ELECTRICAL EFFICIENCY = POWER FACTOR**
- **POWER FACTOR = KW / KVA**



$$S^2 = P^2 + Q^2$$



$$S_{equ}^2 = P^2 + Q^2 + D^2$$

Types Of Harmonics

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CHARACTERISTIC HARMONICS

- Related to circuit configuration
- Fairly predictable frequency spectrum
- Frequency spectrum provided by *k*p ± 1; k= 1,2,3,.....*
- *Therefore for 6 pulse, we have the 5^{th} and 7^{th} as the pre-dominant orders, and for 12 pulse, it is the 11^{th} and 13^{th}*

NON - CHARACTERISTIC HARMONICS

- Caused by Frequency Converters
- System Imbalance (Voltage & Impedance)

TRIPLEN HARMONICS

- Zero Sequence in Nature
- Accumulates in the Neutral Conductor
- 3* (2n+1) Order, *n= 0,1,2,..... (3^{rd}, 9^{th}, 15^{th},...)*

Typical Harmonic Spectrums

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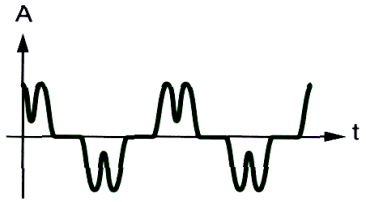
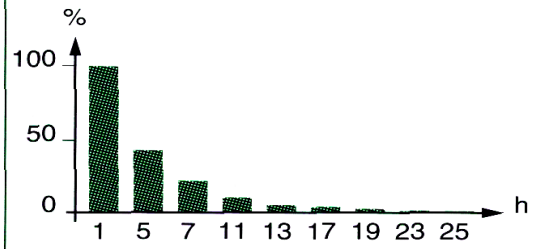
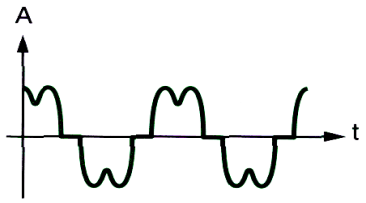
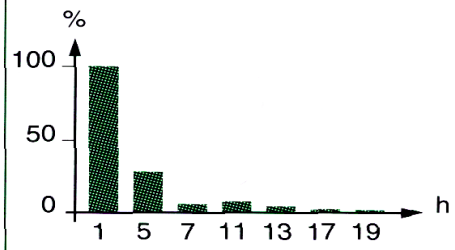
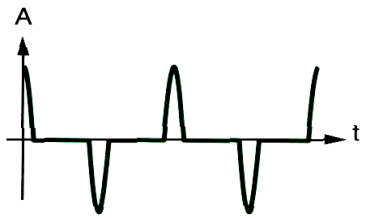
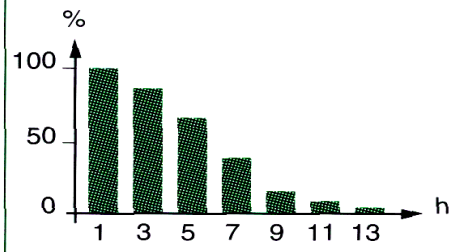
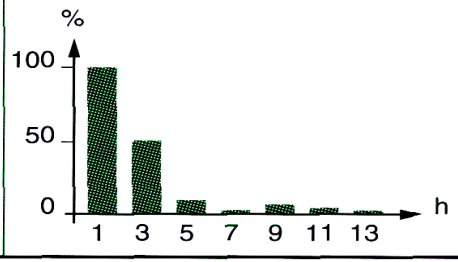
Non-linear loads	Current waveform	Spectrum	THDI
Adjustable speed drive			44%
Rectifier/charger			28%
Data processing load			115%
Fluorescent lighting			53%

Types Of Harmonic Filters

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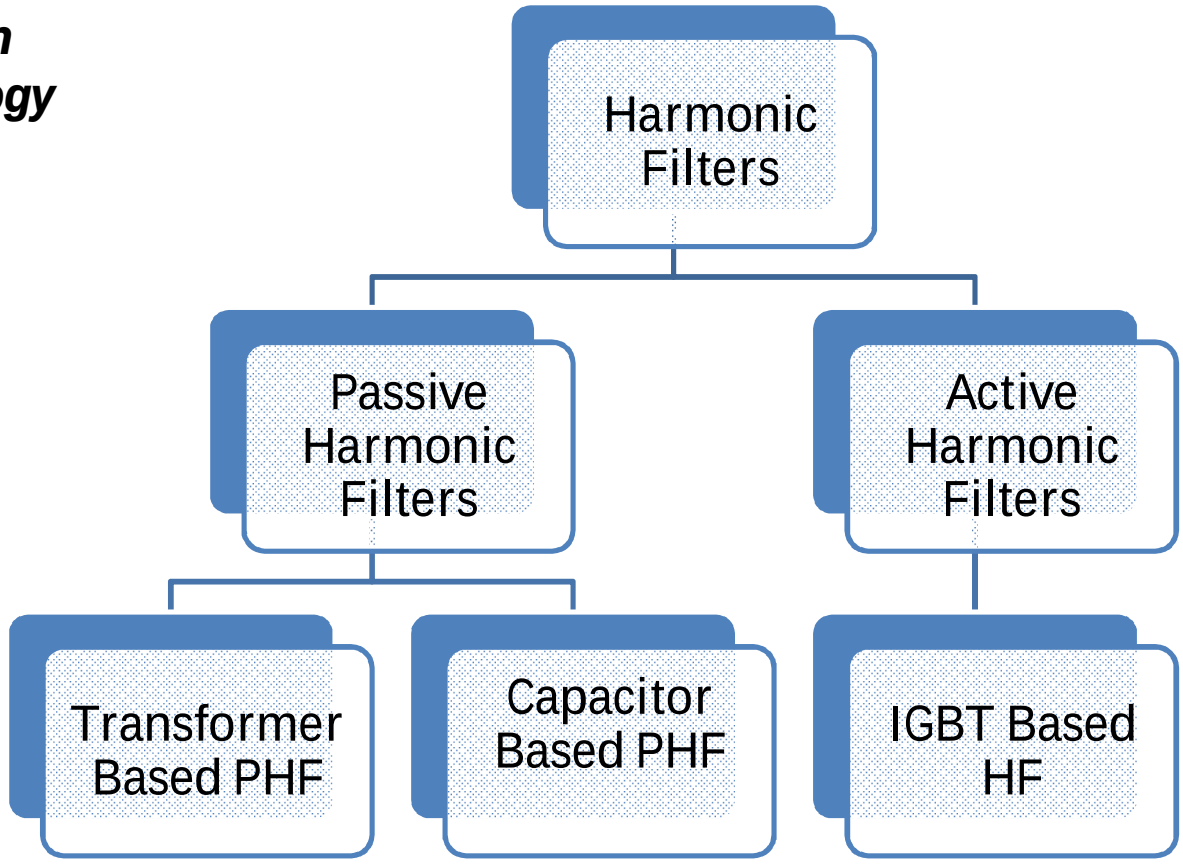
Based On Technology



Hybrid Harmonic Filters, which is a combination of the Passive Harmonic Filter & Active Harmonic Filter , can also be evaluated for installations

Types Of Harmonic Filters

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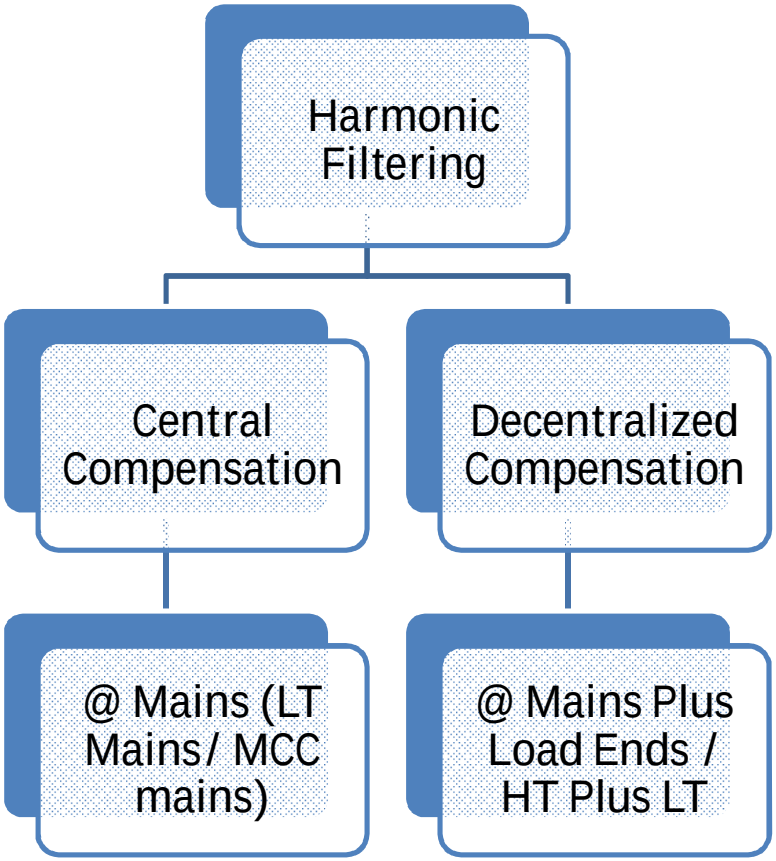
Based On Location Of Filters



Designing Effective Harmonic Filters

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- Designing effective Harmonic Filters and getting it right the first time itself requires –
  - Prior experience with Harmonics and network interferences.
  - Accurate data collection and data analysis.
  - Post Implementation, On-site fine tuning, to achieve the exact compliance
- Since, **no one size fits all**, every solution requires at least minimum 5% to 10% customization, PMX has developed its own Unique Process for deploying and **solving** harmonic problems **effectively and cost optimally.**

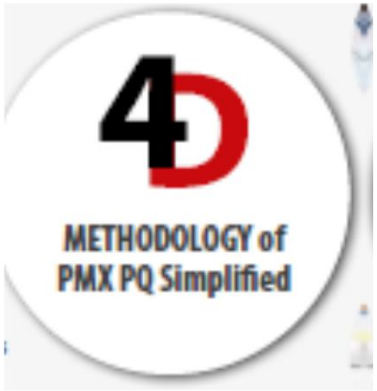
Diagnose

Design

Define

Document

PMX **PQ*Simplified*** 4D Methodology



pmx
Improving Power Quality

Hybrid Harmonic Filter Implementation @ M/s Bhushan Steel, Hosur, Tamil Nadu

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- Our client is an Indian Multinational Company engaged in the business of producing automotive grade steel.
- They have multiple steel plants in India, from stand alone units like this one to Fully Captive Power Integrated Steel Complex.
- The plant being discussed is a satellite unit, used majorly for finishing operations and being able to deliver in smaller lots to the Automobile Industries in and around Tamil Nadu.

D1 - Problem Definition

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- In Tamil Nadu, there is an order from the state electricity board to maintain Current THD < 8% , to avoid any penalties in Electrical Billing. If Current THD is not < 8%, then there would be a penalty of 15% levied on our clients on a monthly basis.

- Client Details
  - Industry – Steel Pipes
  - Transformer KVA – 2500 KVA
  - Incoming Voltage – 11 KV
  - Maximum Demand – 1200 KVA

- **GOAL** – ANALYSE THE FACILITY AND BRING CURRENT THD < 8%.

D1 - Problem Definition

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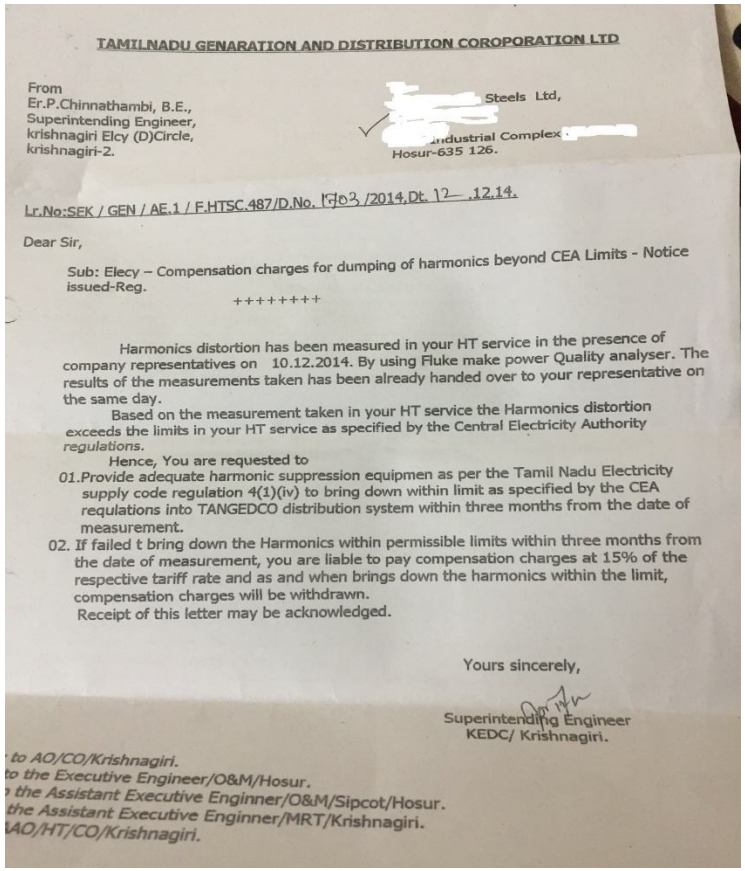


TAMILNADU GENARATION AND DISTRIBUTION COROPORATION LTD

From
Er.P.Chinnathambi, B.E.,
Superintending Engineer,
krishnagiri Elcy (D)Circle,
krishnagiri-2.

[redacted] Steels Ltd,
[redacted] Industrial Complex
Hosur-635 126.

Lr.No:SEK / GEN / AE.1 / F.HTSC.487/D.No. 1703 /2014,Dt. 12 .12.14.

Dear Sir,

Sub: Elecy – Compensation charges for dumping of harmonics beyond CEA Limits - Notice issued-Reg.

++++++++

Harmonics distortion has been measured in your HT service in the presence of company representatives on 10.12.2014. By using Fluke make power Quality analyser. The results of the measurements taken has been already handed over to your representative on the same day.

Based on the measurement taken in your HT service the Harmonics distortion exceeds the limits in your HT service as specified by the Central Electricity Authority regulations.

Hence, You are requested to

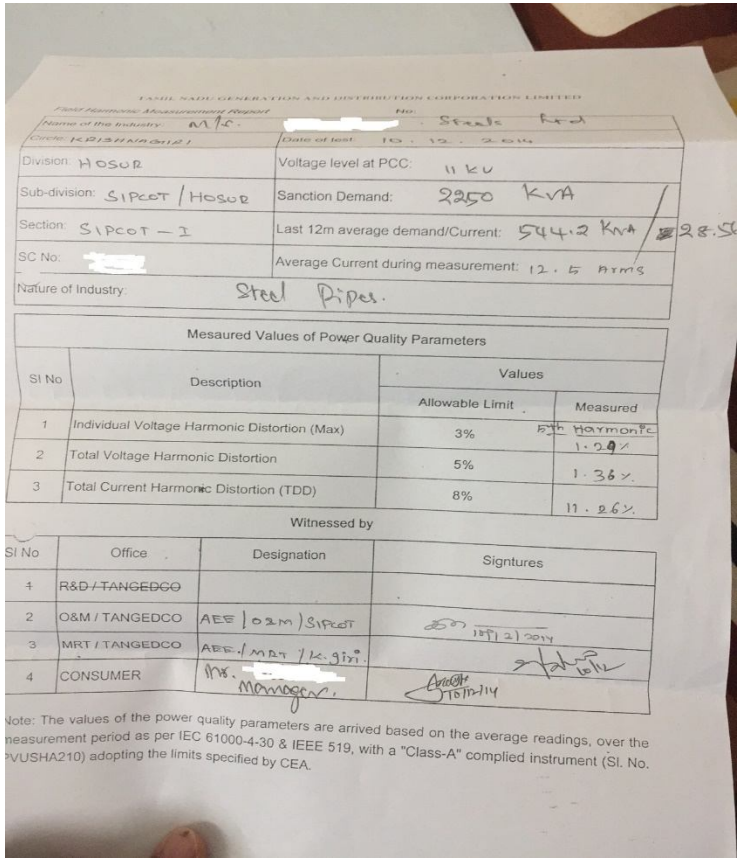
01. Provide adequate harmonic suppression equipmen as per the Tamil Nadu Electricity supply code regulation 4(1)(iv) to bring down within limit as specified by the CEA regulations into TANGEDCO distribution system within three months from the date of measurement.
02. If failed t bring down the Harmonics within permissible limits within three months from the date of measurement, you are liable to pay compensation charges at 15% of the respective tariff rate and as and when brings down the harmonics within the limit, compensation charges will be withdrawn.

Receipt of this letter may be acknowledged.

Yours sincerely,

Superintending Engineer
KEDC/ Krishnagiri.

to AO/CO/Krishnagiri.
to the Executive Engineer/O&M/Hosur.
the Assistant Executive Enginner/O&M/Sipcot/Hosur.
the Assistant Executive Enginner/MRT/Krishnagiri.
AO/HT/CO/Krishnagiri.



TAMIL NADU GENERATION AND DISTRIBUTION CORPORATION LIMITED

Field Harmonic Measurement Report No:

Name of the Industry: M/s. [redacted] Steels Ltd	
Circle: KRISHNAGIRI	Date of test: 10 . 12 . 2014
Division: HOSUR	Voltage level at PCC: 11 KV
Sub-division: SIPCOT / Hosur	Sanction Demand: 2250 KVA
Section: SIPCOT – I	Last 12m average demand/Current: 544.2 KVA / 28.5
SC No: [redacted]	Average Current during measurement: 12.5 Arms
Nature of Industry:	Steel Pipes.

Mesaured Values of Power Quality Parameters

Sl No	Description	Values	
		Allowable Limit	Measured
1	Individual Voltage Harmonic Distortion (Max)	3%	5th Harmonic 1.29%
2	Total Voltage Harmonic Distortion	5%	1.36%
3	Total Current Harmonic Distortion (TDD)	8%	11.26%

Witnessed by

Sl No	Office	Designation	Signtures
1	R&D / TANGEDCO		
2	O&M / TANGEDCO	AEE (O&M) SIPCOT	10/12/2014
3	MRT / TANGEDCO	AEE / MRT / Krishnagiri.	
4	CONSUMER	Mr. [redacted] Manager	10/12/14

Note: The values of the power quality parameters are arrived based on the average readings, over the measurement period as per IEC 61000-4-30 & IEEE 519, with a "Class-A" complied instrument (Sl. No. PVUSHA210) adopting the limits specified by CEA.

D1 - Problem Definition

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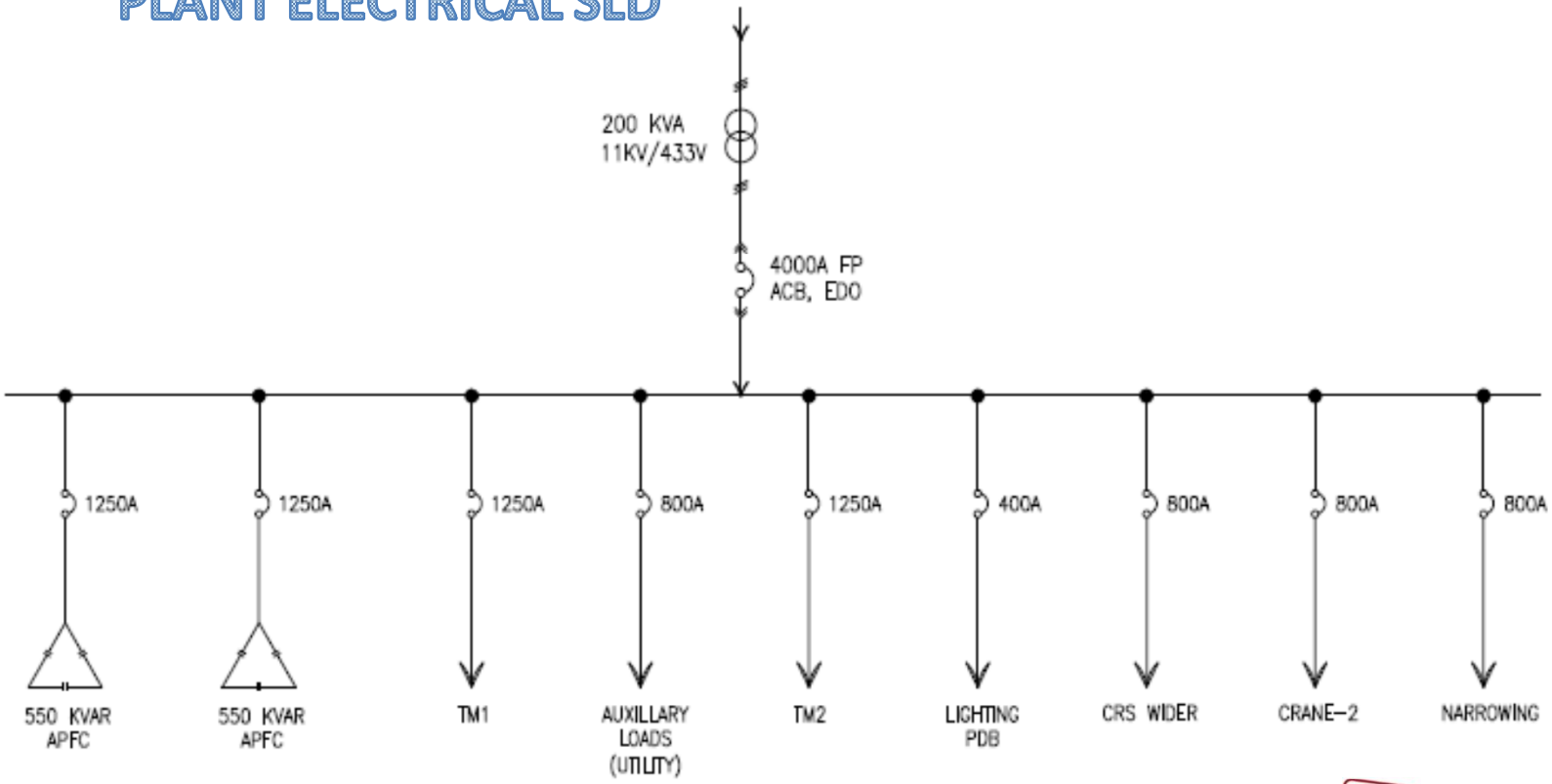
PLANT ELECTRICAL SLD



D2 – Diagnose ACCURATELY

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THE PLAN –

- ❑ Evaluation of the SLD and determining the points of study to do a thorough load flow analysis.
- ❑ Evaluate the downstream feeders and the loading on them.
- ❑ Understand the Harmonic Distortions at all major locations.

PQ ANALYSIS TO BE UNDERTAKEN AT

1. HT Mains with Capacitors Switched ON
2. HT Mains with Capacitors Switched OFF
3. LT Mains with Capacitors Switched ON
4. LT Mains with Capacitors Switched OFF
5. Downstream Feeders

D2 – Diagnose ACCURATELY

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OBSERVATIONS –

- Nearly 70% of the plant loads were Non-Linear in Nature.
- Total Harmonic Distortion in current without the APFC Panels was observed to be in violation of the IEEE 519-1992, on LT Mains and HT Mains.
- Diversity factor of the plant was found to be around 25% to 35%.
- The most dominant harmonic orders were the 5^{th} and 7^{th} orders.
- The Power Factor without the APFC's were observed to be around 0.8

D2 – Diagnose ACCURATELY

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LOAD STUDY DATA

#	Study Location	Voltage (V)	THD V(%)	Current (I)	THD I (%)	Power Factor
1	HT Mains, LT Caps ON	11.1 – 11.4 KV	2%	32 – 36 A	22% - 45%	0.97 – 1
2	HT Mains, LT Caps OFF	11.1 – 11.2 KV	1%	24 - 28 A	15% - 29%	0.82 – 0.93
3	LT Mains, LT Caps ON	410 – 433 V	2% - 4%	450 - 800 A	27% - 48%	0.96 – 1
4	LT Mains, LT Caps OFF	416 – 420 V	1% - 3%	450 - 565 A	16% - 23%	0.82 – 0.88
5	CRS Wider	417 - 421 V	2%	100 – 200 A	28% - 91%	0.81 -0.9
6	Narrow	415 – 424 V	3% - 5%	24 – 126 A	21% - 42%	0.6 – 0.9
7	Tube Mill 1	410 – 418 V	3% - 4%	213 – 321 A	17% - 36%	0.89 – 0.9
8	Tube Mill 2	415 – 423 V	3% - 4%	111 – 496 A	20% - 39%	0.80 – 0.87
9	Utility	410 – 430 V	2% - 4%	188 – 426 A	3% - 8%	0.80 - 0.87

D2 – Diagnose ACCURATELY

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IEEE 519-1992 COMPLIANCE REQMT FOR DIFFERENT LOADING CONDITIONS			
		High Loading	Low Loading
1	Transformer KVA	2500 KVA	2500 KVA
2	Transformer Impedance (Z%)	6%	6%
3	Network Operating Voltage (V)	440 V	440 V
4	Short Circuit Current for Xfmr (I_{SC})	54673 A	54673 A
5	Load Current (I_L)	1821 A	1462 A
6	Ratio (I_{SC} / I_L)	30	37
Hence as per IEEE 519-1992, for Ratio = 30(37) the compliance will be as under			
7	Limits for Voltage Harmonics (V_{THD})	5%	5%
8	Limits for Current Harmonics (I_{THD})	8%	8%

D3- Design – Harmonic Filtering Scheme for B-Steel

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Low Diversity Factor → Centralized System

Low Power Factor → Passive Harmonic Filter

High Harmonics → Active Harmonic Filter

Hence, Hybrid Harmonic Filter

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D3- Design – Harmonic Filtering Scheme for HHIPL

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A HYBRID HARMONIC FILTER of 1000 Amps was suggested for implementations and it was estimated that the same would cause the Current THD to be well under 8% post installations. Simulation models were developed and evaluated by our design team

D4 - Document – POST IMPLEMENTATION SLD AND BENEFITS

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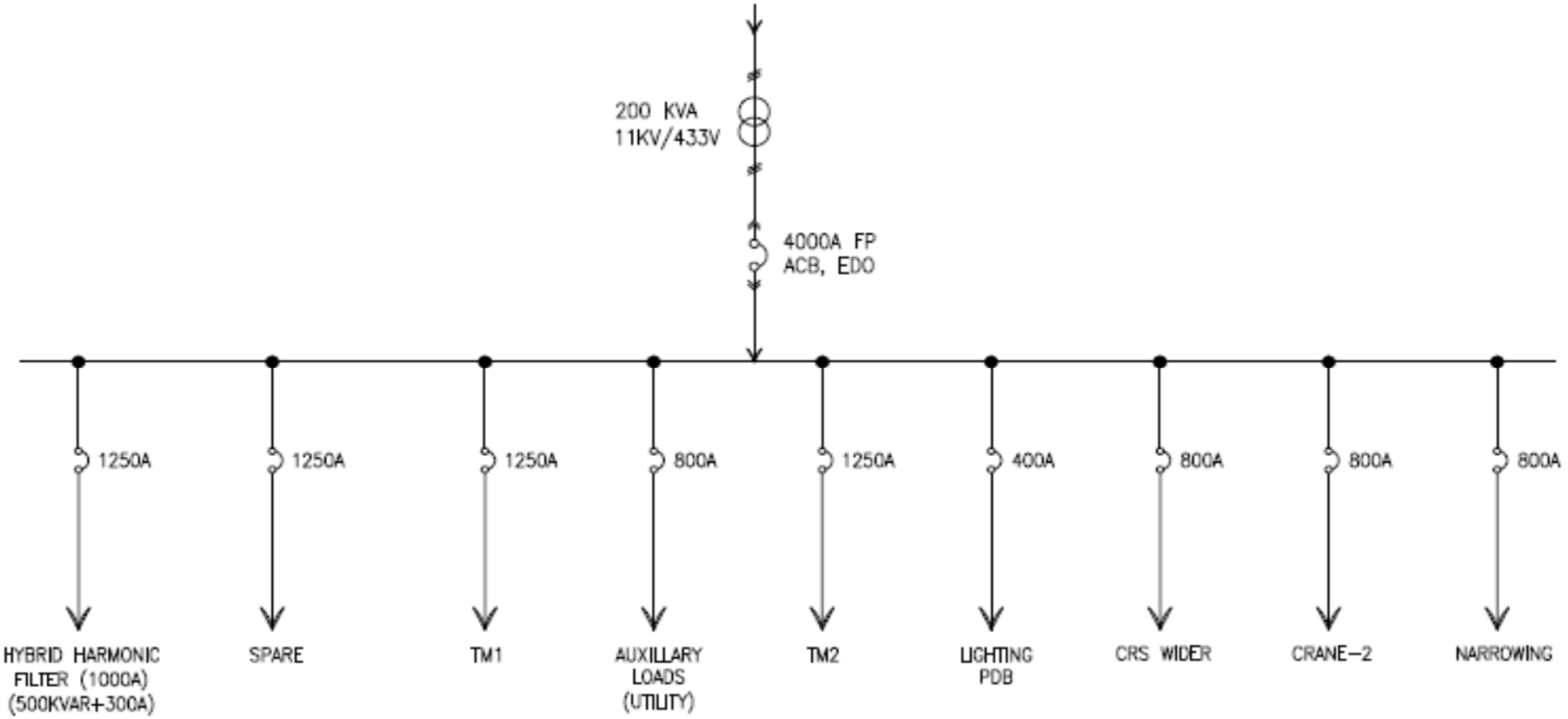
POST IMPLEMENTATION PLANT ELECTRICAL SLD



D4 - Document – POST IMPLEMENTATION SLD AND BENEFITS

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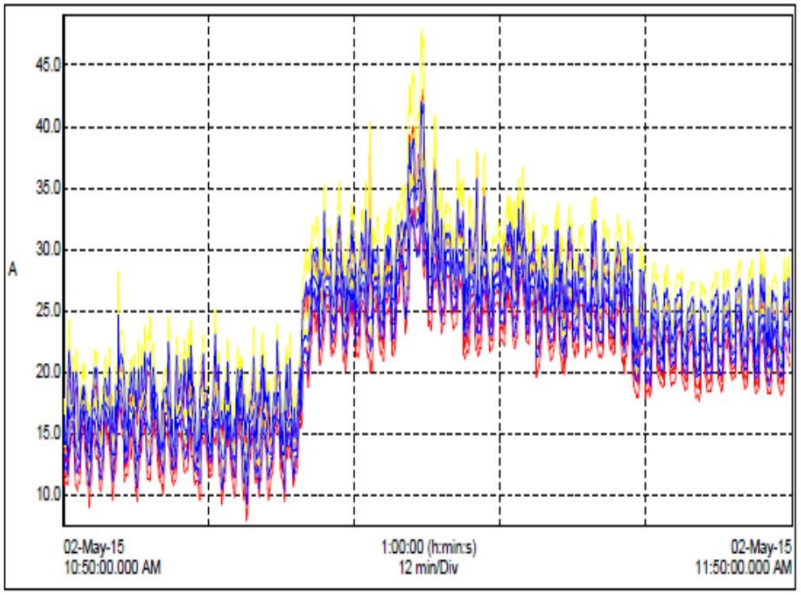
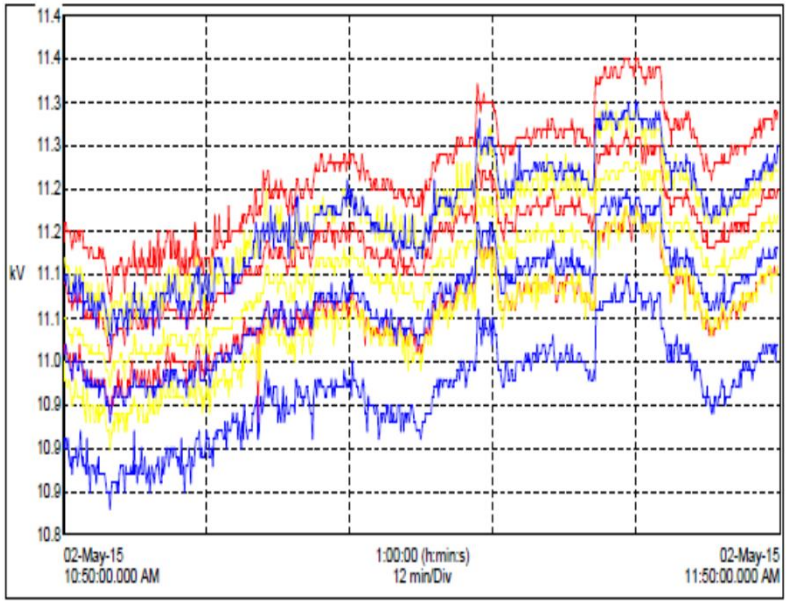
Name	Date	Time	Avg	Min	Max	Units	Duration	Units
A1 rms	02-May-15	10:50:00.000 AM	21.818	8.040	43.040	A	1:00:00	(h:min:s)
A2 rms	02-May-15	10:50:00.000 AM	24.472	9.960	47.760	A	1:00:00	(h:min:s)
A3 rms	02-May-15	10:50:00.000 AM	22.932	9.400	41.920	A	1:00:00	(h:min:s)



Name	Date	Time	Avg	Min	Max	Units	Duration	Units
U12 rms	02-May-15	10:50:00.000 AM	11.138	10.930	11.350	k V	1:00:00	(h:min:s)
U23 rms	02-May-15	10:50:00.000 AM	11.105	10.900	11.300	k V	1:00:00	(h:min:s)
U31 rms	02-May-15	10:50:00.000 AM	11.068	10.830	11.300	k V	1:00:00	(h:min:s)



D4 - Document – POST IMPLEMENTATION SLD AND BENEFITS

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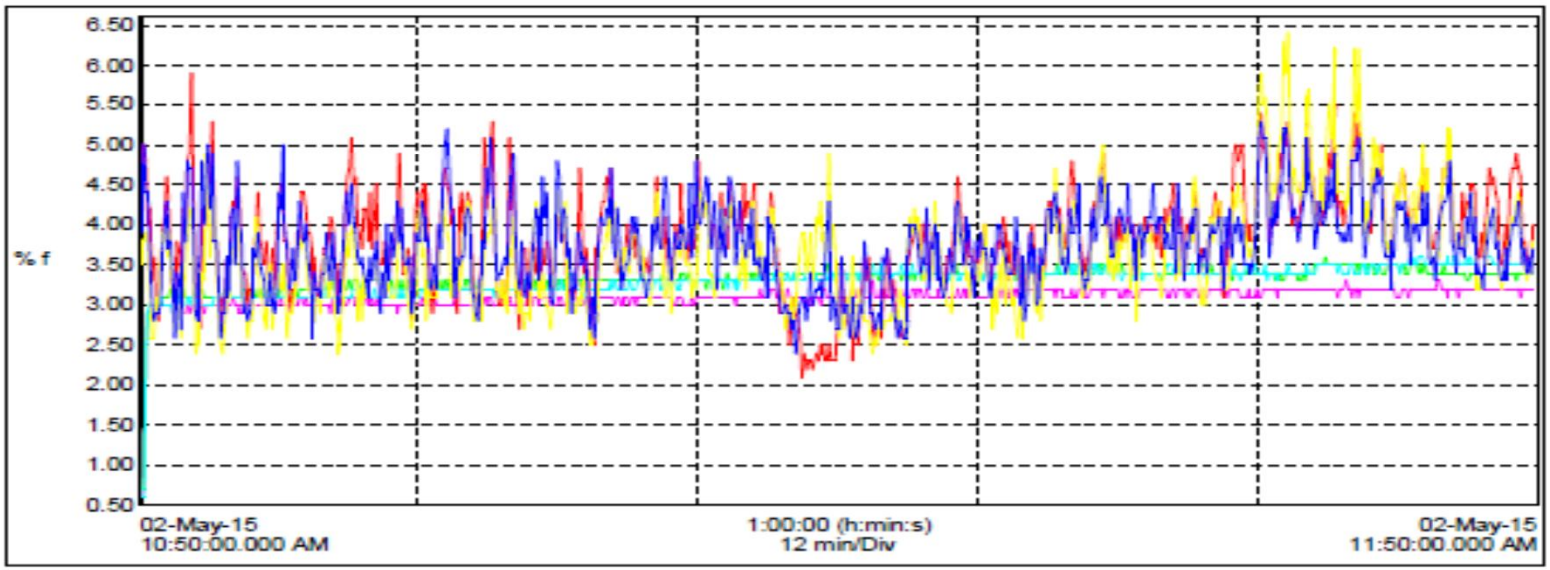
Name	Date	Time	Avg	Min	Max	Units	Duration	Units
A1 THDf	02-May-15	10:50:00.000 AM	3.835	2.100	5.900	% f	1:00:00	(h:min:s)
A2 THDf	02-May-15	10:50:00.000 AM	3.642	2.400	6.400	% f	1:00:00	(h:min:s)
A3 THDf	02-May-15	10:50:00.000 AM	3.736	2.400	5.300	% f	1:00:00	(h:min:s)
V1 THDf	02-May-15	10:50:00.000 AM	3.095	0.600	3.300	% f	1:00:00	(h:min:s)
V2 THDf	02-May-15	10:50:00.000 AM	3.320	0.700	3.600	% f	1:00:00	(h:min:s)
V3 THDf	02-May-15	10:50:00.000 AM	3.299	0.600	3.600	% f	1:00:00	(h:min:s)



D4 - Document – POST IMPLEMENTATION DETAILS

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B Steel India Ltd		
LOCATION	INITIAL STATE	Post HHF Implementation @ LT Mains
11 KV HT Mains	Current – 24 A – 36 A	Current – 22 A – 35 A
	I_{THD} = 22% - 45%	I_{THD} < 6%
	V_{THD} = 2% - 4%	V_{THD} < 3%
	PF = 0.97	PF = 0.97 – 0.99

Hybrid Harmonic Filter Implementation @ M/s TCS (Eserve), Mumbai

www.powermatrix.in

- Ranks amongst the top 10 software development companies in the world.
- Multiple locations in India. Major load being computers, UPS and HVAC.
- The facility under discussion is a Business Process Outsourcing unit based in Mumbai, India.
- The facility receives power from M/s Tata Power Ltd at 22 KV and is stepped down to 440 V, using two transformers, 1250 KVA and 1600 KVA.

D1 - Problem Definition

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- Problems of capacitors blasting faced in the existing capacitor panels.
- Power Factor being maintained @ 0.93 and hence unable to collect incentives available from the Electrical Utility Company for maintaining a power factor > 0.95

- **GOAL** – ANALYSE THE FACILITY AND MAKE THE REQUIRED CHANGES TO ACHIEVE A POWER FACTOR OF 1, & ELEMINATE ANY FURTHER FAILURES IN CAPACITORS.

D2 – Diagnose ACCURATELY

www.powermatrix.in

THE PLAN –

- ❑ Verification of the design Single Line Diagram with the actual facility load distribution.
- ❑ Evaluate the UPS installed capacities and the loading on them.
- ❑ Understand the Harmonic Distortions at all major locations.

PQ ANALYSIS TO BE UNDERTAKEN AT

1. LT Mains Tr 1, With Capacitors Switched On
2. LT Mains Tr 1, With Capacitors Switched Off
3. LT Mains Tr 2, With Capacitors Switched On
4. LT Mains Tr 2, With Capacitors Switched Off
5. Measure and document the capacitor currents accurately.

D2 – ACTUAL DIAGANOSIS

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THE PLAN –

- Verification of the design Single Line Diagram with the actual facility load distribution.
- Evaluate the UPS installed capacities and the loading on them.
- Understand the Harmonic Distortions at all major locations.

PQ ANALYSIS TO BE UNDERTAKEN AT

1. LT Mains Tr 1, With Capacitors Switched On
2. LT Mains Tr 1, With Capacitors Switched Off
3. LT Mains Tr 2, With Capacitors Switched On
4. LT Mains Tr 2, With Capacitors Switched Off
5. Load Feeders PQ Study for a brief time period
6. Measure and document the capacitor currents accurately.

D2 – ACTUAL DIAGANOSIS - EXISTING SLD

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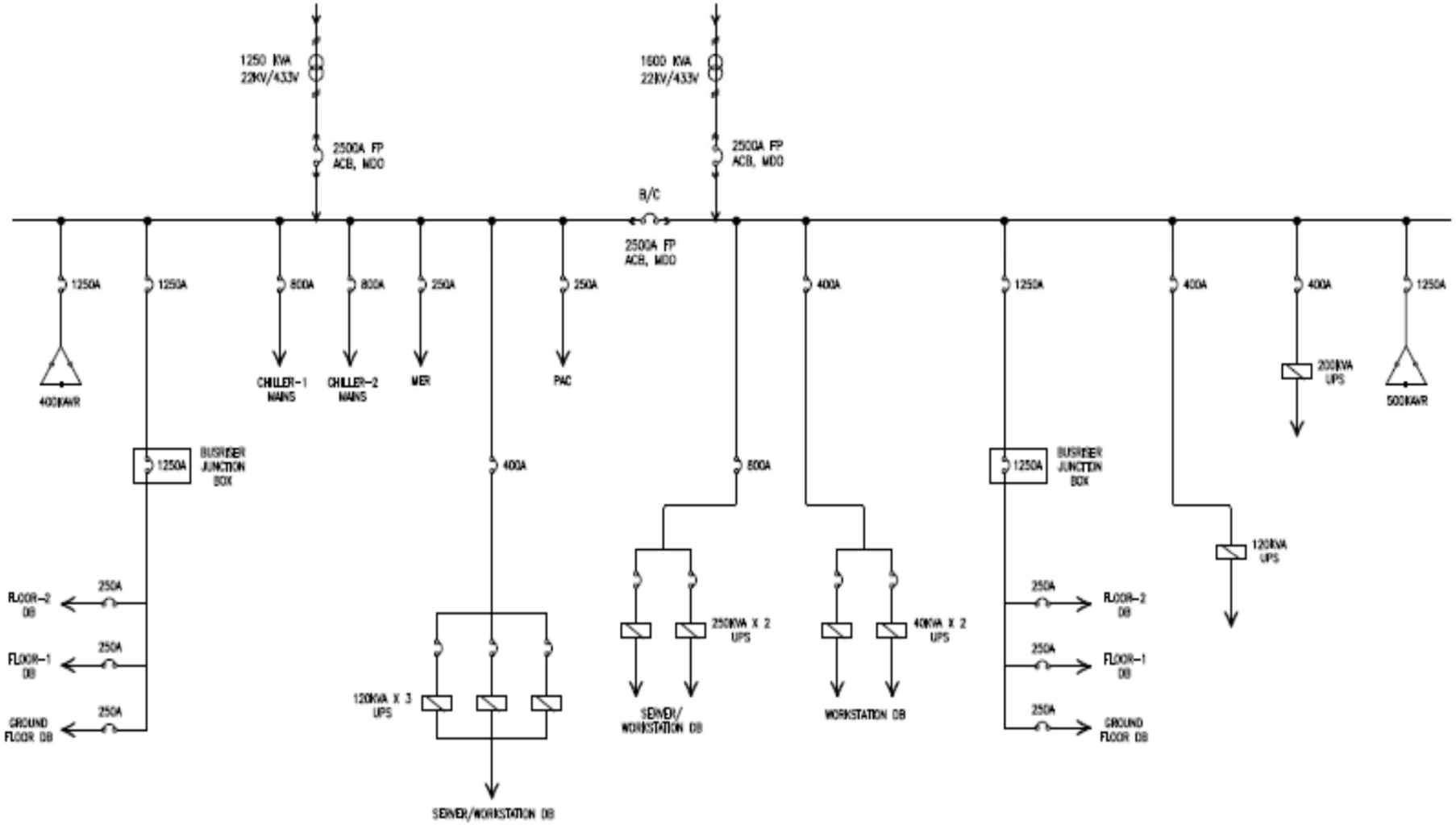

D2 – ACTUAL DIAGANOSIS –KEY OBSERVATIONS

THE OBSERVATIONS –

- The installed capacity of the UPS Systems was much higher than the actual requirements of Controlled Power Supply.
  - UPS Installed Capacity – **Total 1260 KVA, (Max Demand for the entire facility = 1200 KVA)**
    - Tr 1 - 120 KVA * 3
    - Tr 2 - 200 KVA * 1, 250 KVA * 2, 40 KVA *2, 120 KVA * 1
- The UPS Systems were present in both the Transformers and was one of the major contributors of Harmonic Distortions to the Grid.
- On discussion, it was understood that the UPS systems were implemented post the Project Handover and have come up in stages.
- Parallel Resonance is observed.

D2 – ACTUAL DIAGANOSIS –KEY OBSERVATIONS

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THE OBSERVATIONS On Transformer 1 Mains, with Capacitors ON

Location	Current	Current THD	Voltage THD
TR 1 Mains	687 Amps	13%	2.2%
120 KVA * 3 UPS Input	182 Amps	44%	5.90%
PAC	17 Amps	3%	1%
MER	39 Amps	68%	1%

D2 – ACTUAL DIAGANOSIS –KEY OBSERVATIONS

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THE OBSERVATIONS On Transformer 2 Mains, with Capacitors ON

Location	Current	Current THD	Voltage THD
TR 2 Mains	690 Amps	25%	5.2%
200 KVA UPS Input	199 Amps	57%	8.4%
250 KVA * 2 UPS Input	187 Amps	46%	5.1%
40 KVA *2 UPS Input	23 Amps	34%	5.9%
120 KVA UPS Input	35 Amps	70%	3.9%
PAC Mains	52 Amps	6.4%	4.1%

Total UPS KVA	Total Load on UPS (Amps)
1260 KVA	626 Amps

D3- Design – Harmonic Filtering Scheme for TCS (Eserve)

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- It was discussed with the clients to redistribute the loads and provide for all the Controlled Power Loads in Transformer 2, through a central UPS Distribution Panel , having input as 250 KVA * 3 No's UPS.

- Post the same,
  - Detuned Harmonic Filters should be installed for Transformer 1 , 600 KVAR @ 525V

  - Detuned Harmonic Filters and Active Harmonic Filter should be installed on Transformer 2, 450 KVAR @ 525 V, 300 Amps AHF

D3- Design – Harmonic Filtering Scheme for TCS (Eserve)

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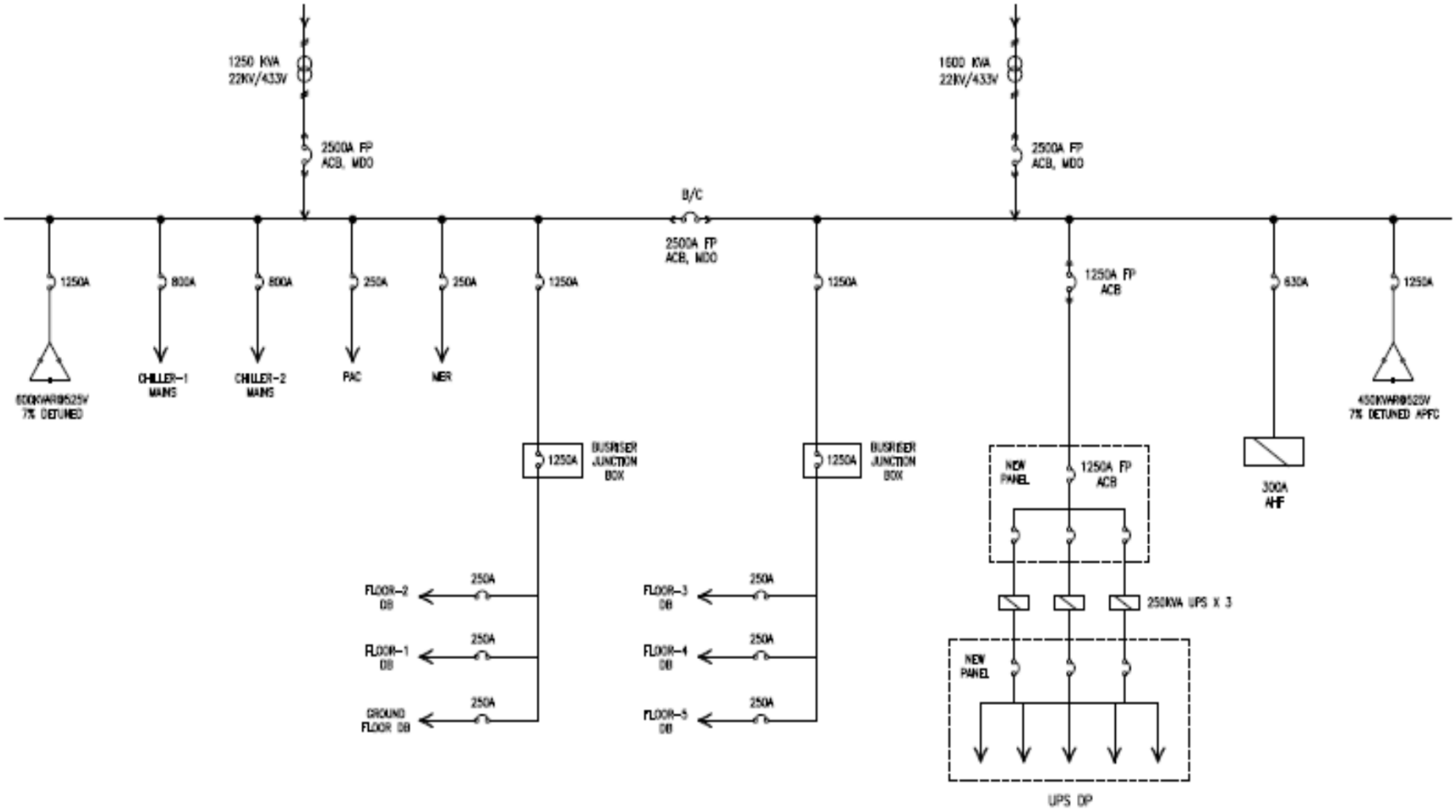

D4 - Document – POST IMPLEMENTATION SLD AND DETAILS

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- Transformer 1 – STEPS FOR PMX ***PQSIMPLIFIED***
  - Initial PQ Study @ Transformer 1 Mains and Load Ends
  - Redistribution of the loads and moving the non –linear load out of Tr 1 and shifting it to Tr 2
  - Complete a review study @ Tr 1 Mains
  - Install Detuned APFC, 600 KVAR @ 525 V

- **Post Installation Of PMX Solutions ,**
  - **Transformer 1 –**
    - **The Current THD ≤ 5%**
    - **The Voltage THD ≤ 1%**

D4 - Document – POST IMPLEMENTATION SLD AND DETAILS

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TRANSFORMER 1 (TR 1)			
LOCATION	INITIAL STATE	POST REDISTRIBUTION	FINAL STATE
TR 1 (Mains)	Current – 687 A	Current – 600 A	Current – 600A
	I_{THD} = 13%	I_{THD} = 5%	I_{THD} = 5%
	V_{THD} = 2.2%	V_{THD} = 1.0%	V_{THD} = 1.0%
	PF = 0.865	PF = 0.899	PF = 0.999

D4 - Document – POST IMPLEMENTATION SLD AND DETAILS

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- Transformer 2 – STEPS FOR PMX ***PQSIMPLIFIED***
  - Initial PQ Study @ Transformer 2 Mains and Load Ends
  - Redistribution of the loads and using Central UPS Output Panel 250 KVA * 3 No's to supply all computing requirements.
  - Complete a review study @ Tr 2 Mains
  - Install Detuned APFC, 450 KVAR @ 525 V
  - Install 300 Amps Active Harmonic Filter.

D4 - Document – POST IMPLEMENTATION SLD AND DETAILS

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TRANSFORMER 2 (TR 2)			
LOCATION	INITIAL STATE	POST REDISTRIBUTION WITHOUT AHF AND DETUNED ON	POST REDISTRIBUTION WITH AHF AND DETUNED ON
TR 2 (Mains)	Current – 690 A	Current – 600 A	Current – 600A
	I_{THD} = 25% to 30%	I_{THD} < 25%	I_{THD} < 5%
	V_{THD} = 5.2%	V_{THD} = 4%	V_{THD} = 1.0%
	PF = 0.965	PF = 0.96	PF = 0.98

- **Post Installation Of PMX Solutions ,**
  - **Transformer 2 –**
    - **The Current THD ≤ 5%**
    - **The Voltage THD ≤ 1%**

Hybrid Harmonic Filter Implementation @ M/s SIPL, Andhra Pradesh

www.powermatrix.in

- Our client is a Multinational Pharmaceutical Company Head Quartered in USA.
- The project being discussed is a Greenfield project coming up @ Vishakhapatnam, Andhra Pradesh, India.
- The facility receives power from M/s AP State Electricity Board at 66 KV and is stepped down to 440 V, using six transformers each of 2500 KVA. The SLD is provided for reference.

D1 - Problem Definition

www.powermatrix.in

- Problems of capacitors blasting faced in the existing capacitor panels immediately within 6 months of commissioning.

- Being billed on KVAH basis, it was mandatory to maintain a power factor of 0.99 to 1.

- **GOAL** – ANALYSE THE FACILITY AND MAKE THE REQUIRED CHANGES TO ACHIEVE A POWER FACTOR OF 1, & ELEMINATE ANY FURTHER FAILURES IN CAPACITORS.

D2 – Diagnose ACCURATELY

www.powermatrix.in

THE PLAN –

- ❑ Verification of the design Single Line Diagram with the actual facility load distribution.
- ❑ Evaluate the downstream feeders and the loading on them.
- ❑ Understand the Harmonic Distortions at all major locations.

PQ ANALYSIS TO BE UNDERTAKEN AT

1. LT Mains Tr 3, With Capacitors Switched On
2. LT Mains Tr 3, With Capacitors Switched On And Without the Chiller Load.
3. Measure and document the capacitor currents accurately.

D2 – Diagnose ACCURATELY

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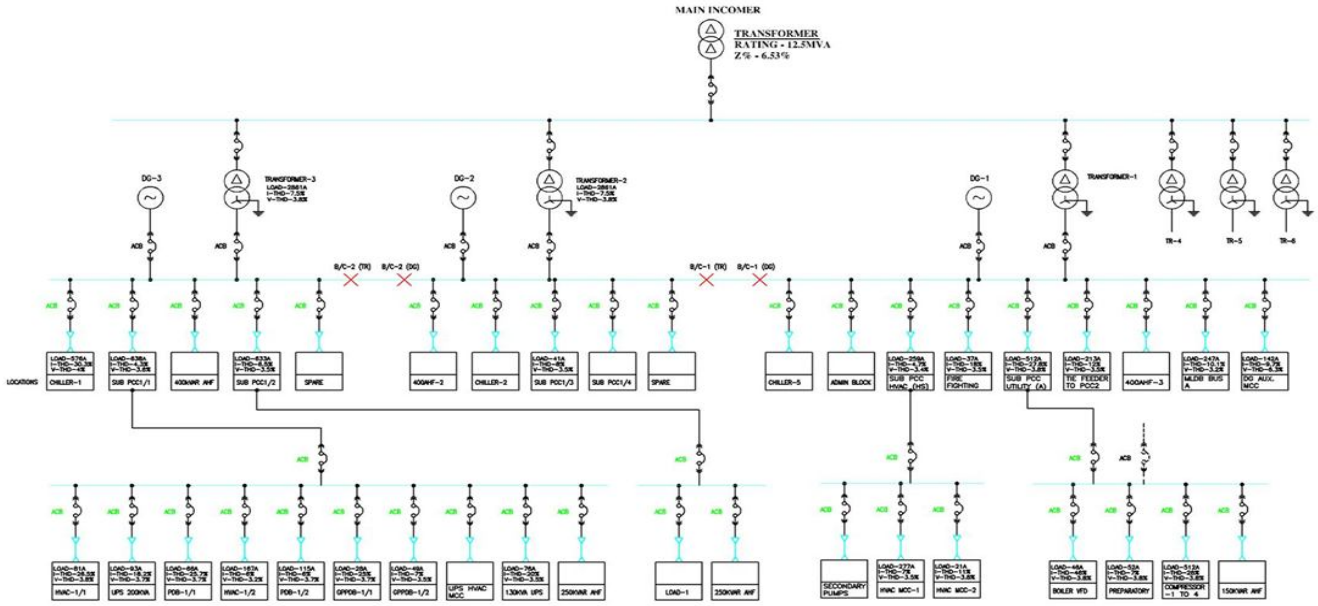

D2 – Diagnose ACCURATELY

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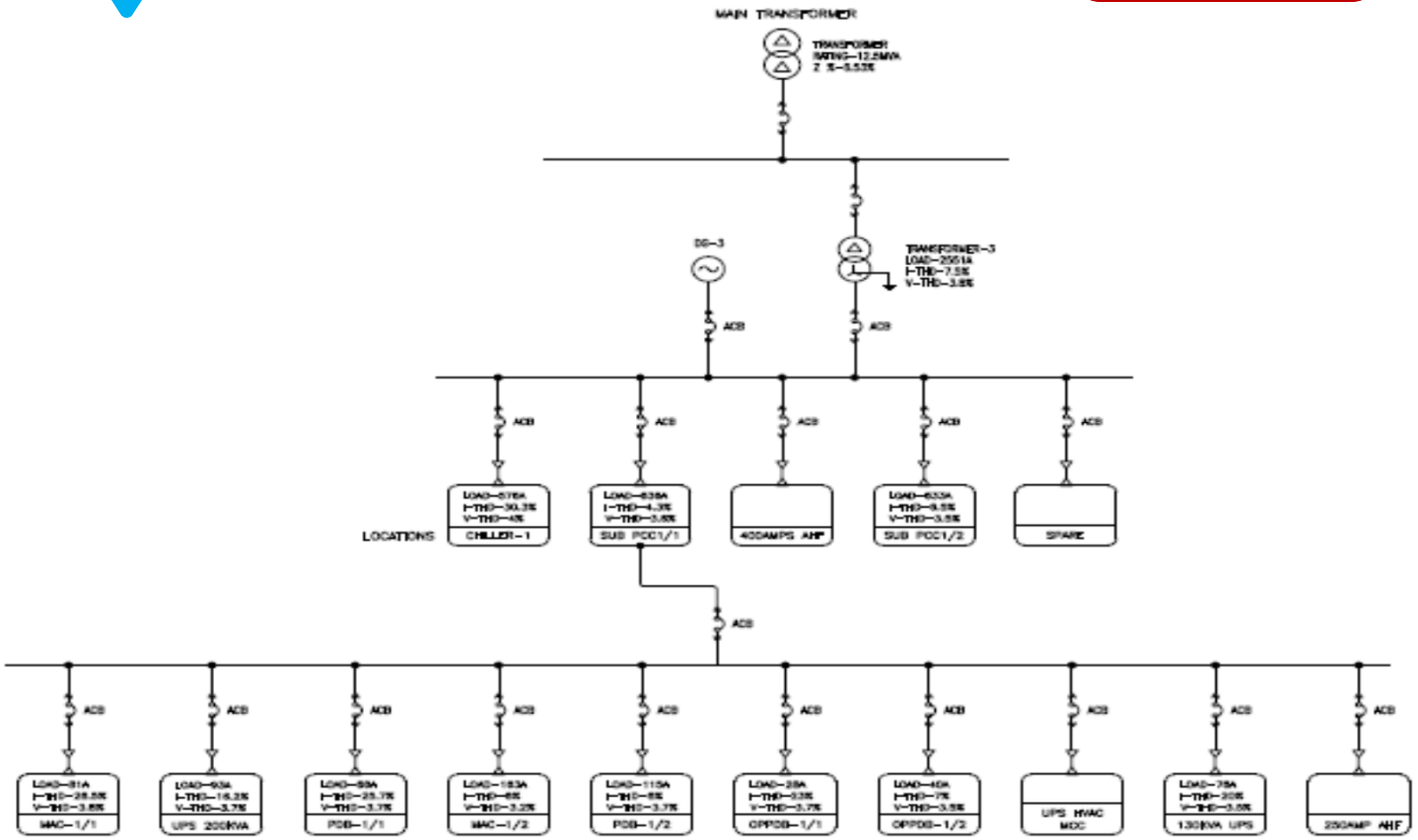

D2 – Diagnose ACCURATELY

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	Tr 3 Mains	Sub PCC 1/1	Sub PCC ½	Sub PCC HVAC
Voltage$_{(LL)}$	433 Volts	433 Volts	433 Volts	433 Volts
Current$_{(SC)}$ $I_{(SC)}$	49779 A			
Current$_{(Load)}$ $I_{(L)}$	2861 A	638 A	633 A	259 A
Current$_{(THD)}$(%)	8%	4%	7%	5%
$I_{(SC)}$ / $I_{(L)}$	17.4			
$I_{(TDD)}$ Limits	< 5%	Here it is seen that the Current TDD is beyond the acceptable limits of 5% and hence filtering solutions have to be adopted.		
$V_{(THD)}$ Limits	< 5%			

	Sub PCC Uty	MLDB	Chiller 1	HVAC 1/1
Voltage$_{(LL)}$	433 Volts	433 Volts	433 Volts	433 Volts
Current$_{(SC)}$ $I_{(SC)}$				
Current$_{(Load)}$ $I_{(L)}$	168 A	247 A	576 A	81 A
Current$_{(THD)}$(%)	41%	10%	30%	27%

D2 – Diagnose ACCURATELY

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	UPS 200 KVA	PDB 1/1		
Voltage$_{(LL)}$	433 Volts	433 Volts		
Current$_{(SC)}$ $I_{(SC)}$				
Current$_{(Load)}$ $I_{(L)}$	95 A	66 A		
Current$_{(THD)}$(%)	18%	39%		

Simulated Value of Current THD based on Data Collected for all Feeders	14.98%
But Actual Observed Current THD @ Mains	8%

This indicates the Harmonic Cancellation Effect @ PCC Mains, due to which the actual Current THD for the total load is lower than the estimated Current THD, as a sum of the Current THD's of the individual loads.

D3- Design – Harmonic Filtering Scheme for HHIPL

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- Based on the PQ Study data, harmonic simulations have been carried out at our end and we have concluded that the most effective and cost optimal solution would be to place a 300 Amps Active Harmonic Filter At the Chiller mains.

- The Reactors And Capacitors in the Existing Detuned APFC Panels would be replaced with Heavy Duty Detuned Reactors and APP Capacitors

D4 - Document – POST IMPLEMENTATION SLD AND DETAILS

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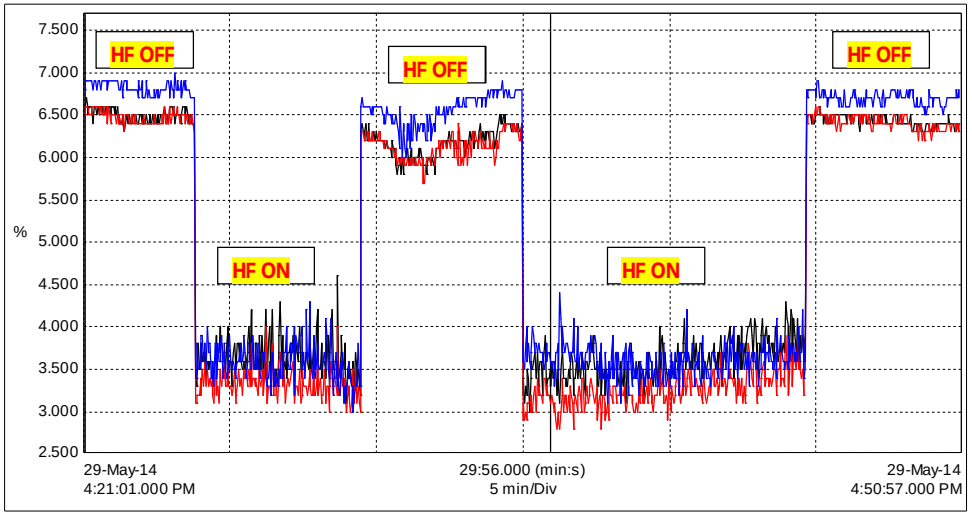
VOLTAGE THD WITH AHF ON AND AHF OFF At Chiller Mains



D4 - Document – POST IMPLEMENTATION SLD AND DETAILS

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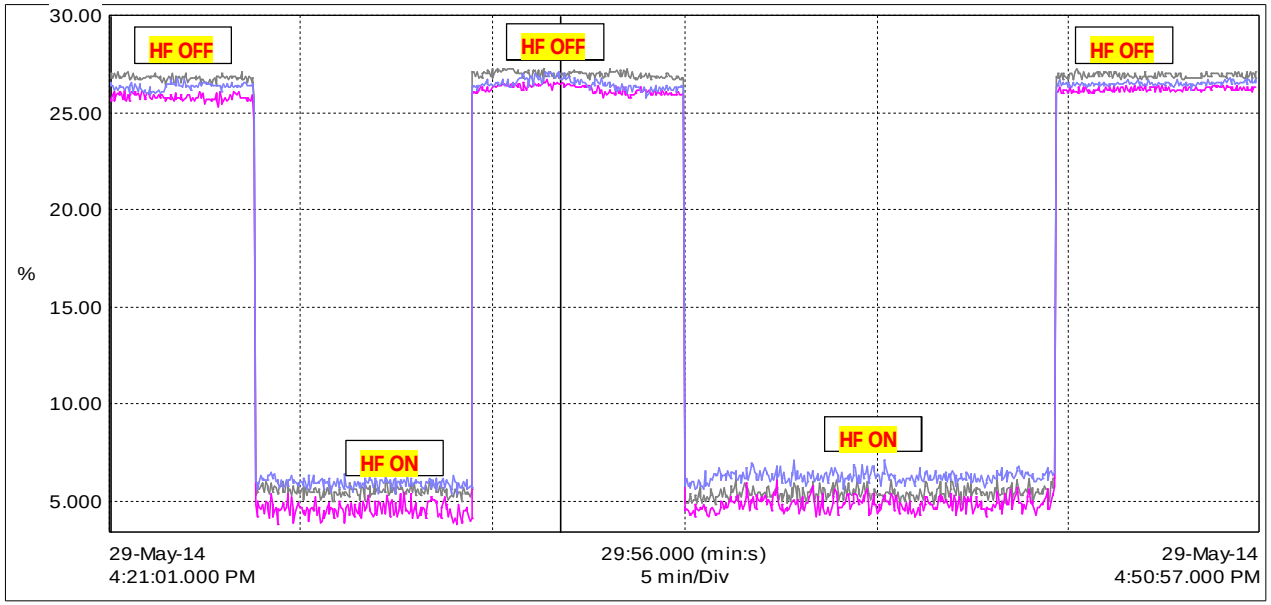
CURRENT THD WITH AHF ON AND AHF OFF At Chiller Mains



D4 - Document – POST IMPLEMENTATION DETAILS

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TRANSFORMER 3 (TR 3)		
LOCATION	INITIAL STATE	Post AHF Implementation @ Chiller Mains
TR 2 (Mains)	Current – 1890 A	Current – 1890 A
	I_{THD} = 8% to 10%	I_{THD} < 5%
	V_{THD} = 6%	V_{THD} < 5%
	PF = 0.97	PF = 0.99

- **Post Installation Of PMX Solutions ,**
  - **Transformer 3 –**
    - **The Current THD ≤ 5%**
    - **The Voltage THD ≤ 5%**
    - **Power Factor = 0.99 to 1**
    - **Capacitor Failures have been eliminated.**

Harmonic Mitigating Transformer Implementation @ M/s iGate Global, India

www.powermatrix.in

- Our client is a Multinational Software Development Company.
- The project being discussed is an IT Park based in Airoli, Navi Mumbai, India.
- The facility receives power from M/s MSEDCL at 33 KV and is stepped down to 440 V, using four transformers each of 2000 KVA.

D1 - Problem Definition

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- Problems of high Voltage between Neutral & Ground was highlighted in a routine Testing Report carried out by the company auditors.
- The Neutral Currents on the UPS DB's were also found to be higher than the normal and in line with the phase currents.

- **GOAL** – ANALYSE THE FACILITY AND MAKE THE REQUIRED CHANGES TO ELEMINATE THE NEUTRAL CURRENTS AND REDUCE V_{NG}.

D2 – Diagnose ACCURATELY

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THE PLAN –

- ❑ Verification of the design Single Line Diagram with the actual facility load distribution.
- ❑ Understand the Harmonic Distortions at the measured locations

PQ ANALYSIS TO BE UNDERTAKEN AT

1. UPS Input Panel
2. UPS Output Panel

D2 – Diagnose ACCURATELY

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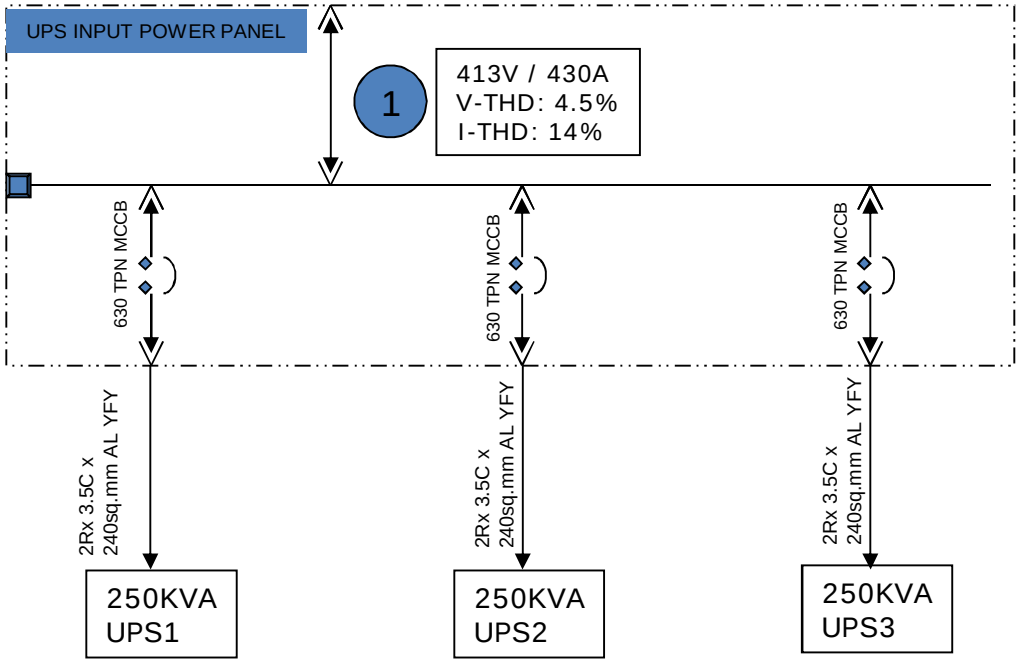

D2 – Diagnose ACCURATELY

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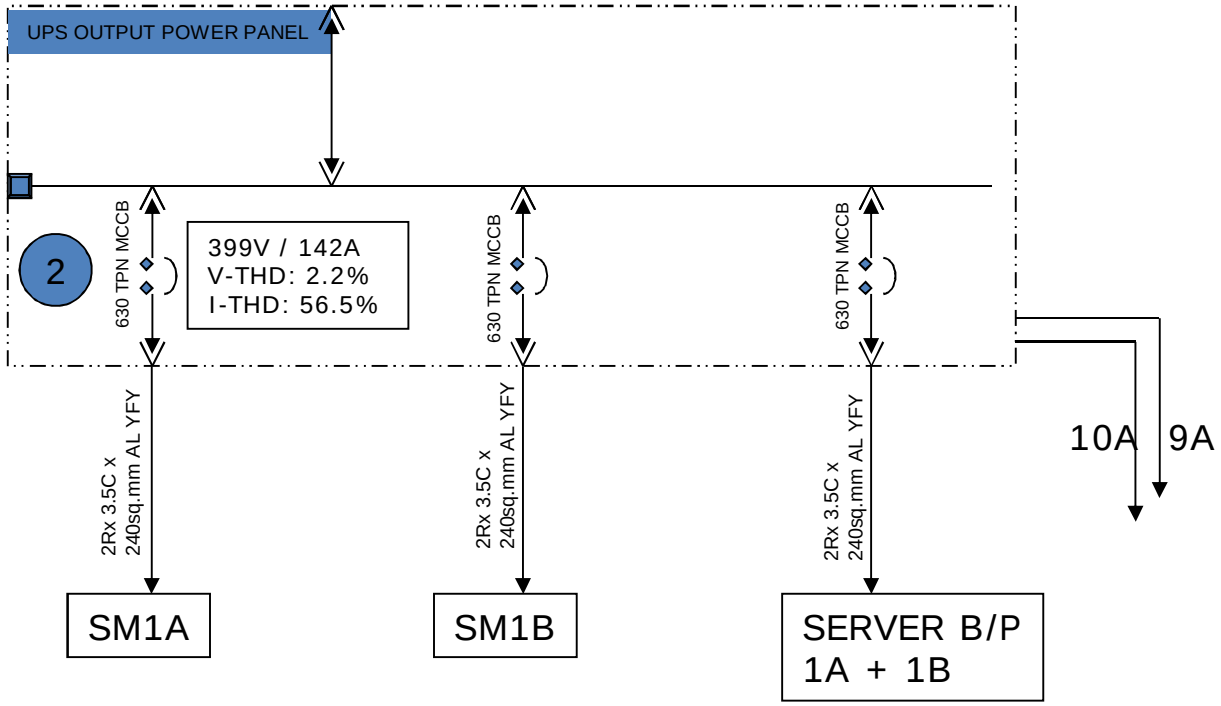

D3- Design – Harmonic Filtering Scheme for iGate Global

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PQ Data reveals TRIPLEN HARMONICS

PQ Data reveals 3rd Harmonic most DOMINANT

Loads on UPS DB's low at 30 A (Max).

High Neutral Currents & High V_{NG}

- ✓ 3P4W ACTIVE HARMONIC FILTER
- ✓ HARMONIC MITIGATION XFMR

D3 – Design

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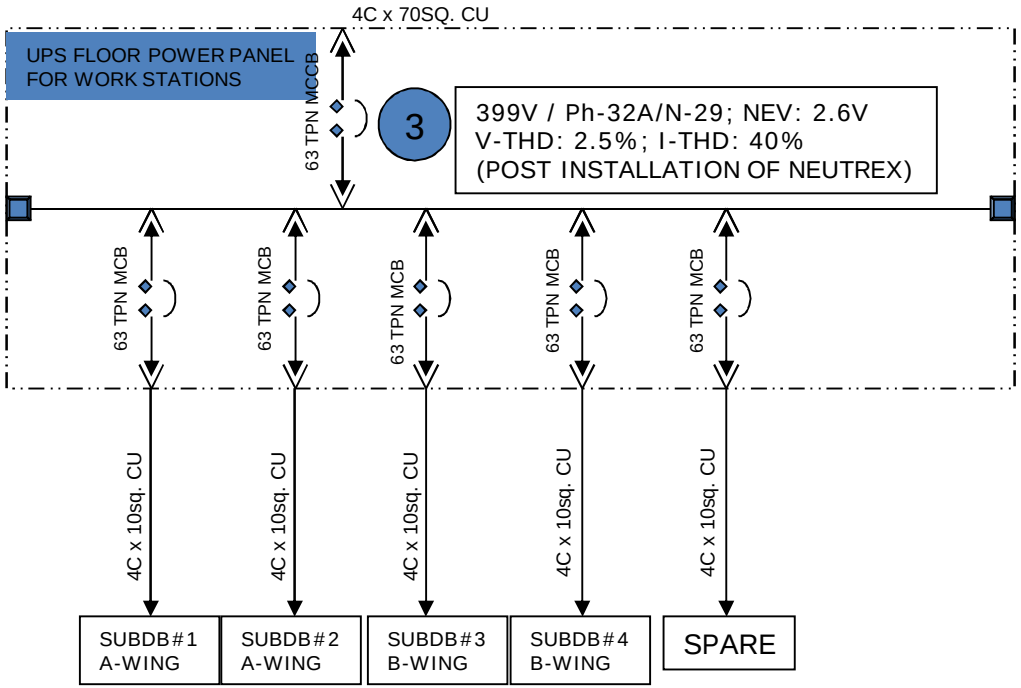

D4 - Document – POST IMPLEMENTATION SLD AND DETAILS

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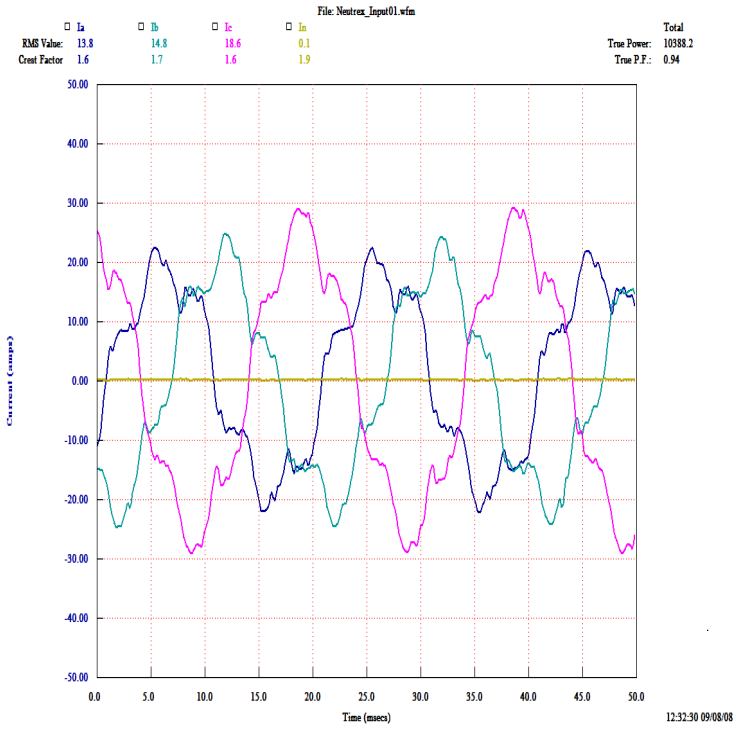
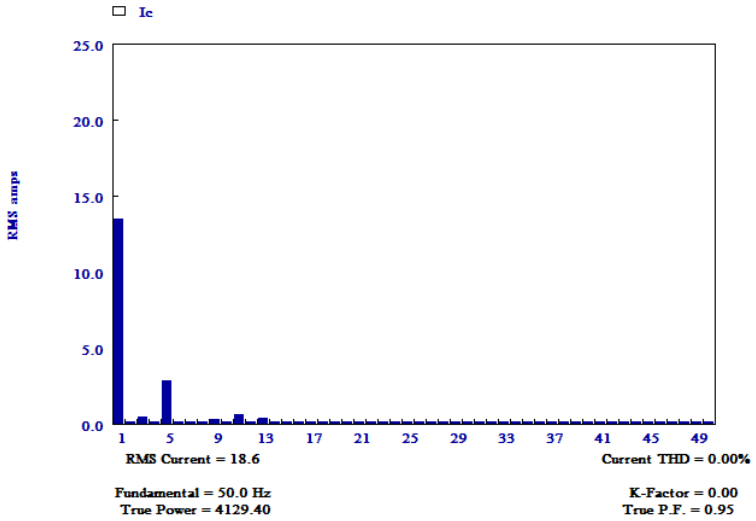
Current Waveform & Harmonic Spectrum @ Neutrex HMT Input Side





D4 - Document – POST IMPLEMENTATION SLD AND DETAILS

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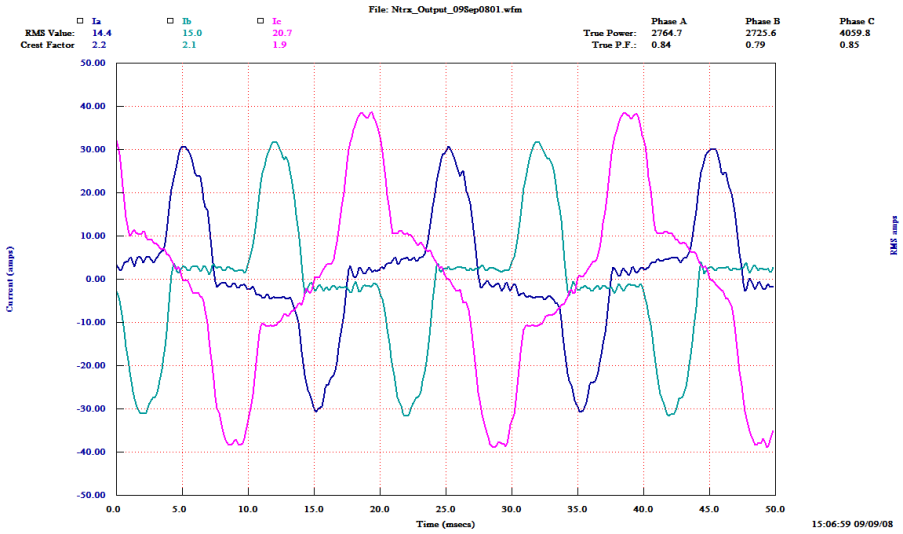
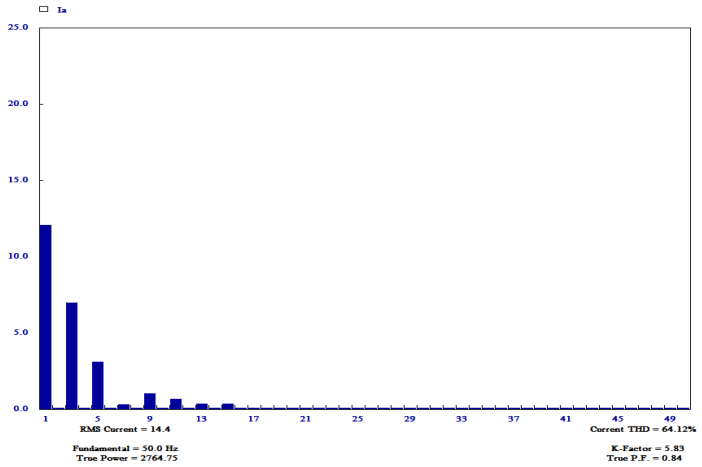
Current Waveform & Harmonic Spectrum @ Neutrex HMT Output Side





D4 - Document – POST IMPLEMENTATION DETAILS

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	Neutrex HMT Input Side	Neutrex HMT Output Side
Voltage Phase A (Max)	405.2 Volts	399.7 Volts
Voltage Phase B (Max)	405.7 Volts	397.9 Volts
Voltage Phase C (Max)	406.5 Volts	399.3 Volts
Current Phase A (Max)	18.6 A	26.1 A
Current Phase B (Max)	17.2 A	26.6 A
Current Phase C (Max)	20.7 A	31.6 A
Current Phase N (Max)	0.1 A	40.3 A
Voltage THD, Phase A	2.5%	1.8 %
Voltage THD, Phase B	1.9%	1.9 %
Voltage THD, Phase C	1.6%	1.0 %
Current THD, Phase A	25.7%	63.4 %
Current THD, Phase B	27.7%	75.2 %
Current THD, Phase C	26.9%	42.3 %
Total Power Factor	0.95	0.83

D4 - Document – POST IMPLEMENTATION DETAILS

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- **Post Installation Of PMX Neutrex HMT –**
  - **The Current THD has decreased**
  - **The Voltage THD has decreased**
  - **Power Factor has improved**
  - **The Neutral Current is drastically reduced**
  - **The Voltage between Neutral And Ground is reduced to less than 1.5 V**

Harmonic Mitigating Transformer Implementation @ Asiana Hotel, India

www.powermatrix.in

- M/s Asiana Hotels experienced LED failures immediately after Commissioning or Powering UP.
- PQ Study conducted revealed very high Neutral Currents, V_{NG}, and dominant Triplen.
- Hence we suggested and implemented a 60 KVA Zero Sequence Harmonic Mitigation Transformer on the Buss Riser Mains.

Post Installation Benefits

- Drastic Reduction in Neutral Current
- $V_{NG} < 1.5$ V
- Measurable reduction in LED Light Failures.

Improving Power Quality

Thank You !

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