Harmonic Analysis report

FOR

A REPUTED RUBBER TRANSMISSION BELT MANUFACTURER

…………………………………………………………….

By

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Audit Period: July 2018

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1)

Objective and details of the equipment

Audit objective:

Carry out Independent Study of current harmonics at PCC between unit 1 of PRIVI organics Ltd and MSEDCL to check compliance of IEEE 519 1992 and MSEDCL Supply code 2005.

Details of Equipment Used:

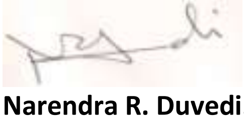
No	Name of the equipment	SR. No Model	Make	Use
1	Power Analyzer	1645 (CA 8335)	Chauvin Arnoux	Electrical Parameter Measurement
2	Power Analyzer	211642 (CA 8335)	Chauvin Arnoux	Electrical Parameter Measurement
3	Power Analyzer	211642 (CA 8336)	Chauvin Arnoux	Electrical Parameter Measurement

Audit team

SAS Powertech Pvt Ltd : Mr. Narendra Duvedi
Mr. Parimal Kaware
Mr. Prasad Paraskar

A REPUTED RUBBER TRANSMISSION BELT MANUFACTURER : Mr. Nilesh Soholkar
Mr. Amit Ambulkar

Certification:
Report Certified by:

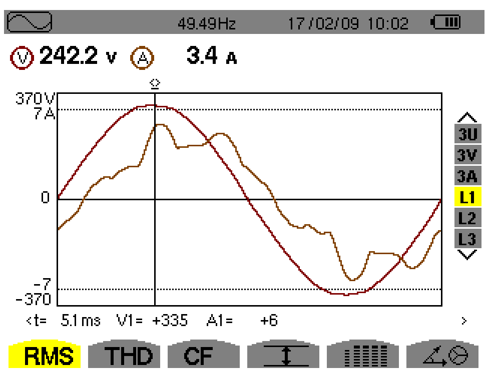


Narendra R. Duvedi.
B.E. Electrical and Certified Energy Auditor Reg No: EA 10859
Chartered engineer

A note on Power factor, current and voltage harmonic distortion

1. Power factor is characteristics of load and varies from -1 - 0 +1. Resistive loads like bulbs, heaters etc take current at unity power factor (i.e.1).Other loads like electric motors, computers, UPS systems, tube lights etc take current at power factors which are less than 1.
2. Electrical Power = $V \times I \times Cos\phi(PowerFactor)$
3. One can take 100 watts of electrical power at 100 volts by taking 1 Amp current, if power factor is 1, while if power factor is 0.5, then the current required will be 2 Amps for delivering same power of 100 watts.
4. One unit of electricity = 1Kilowatt x 1 Hr. If we use 1 KW for 1 hour then the utility meter advances by 1 unit.
5. It is clear from above that if power factor is low, utility company (Like MSEDCL) has to supply us more current while delivering same power but gets same revenue from us.
6. Infrastructure investment done by utility company is more for delivering more current, so for these commercial reasons, they insist on better power factor and offer incentives.

Non linear loads like computer power supplies, VFDs, UPS systems, electrical arc furnaces, Plating rectifiers, and Battery chargers take non sinusoidal current while sinusoidal voltage is applied to them. This is shown in waveforms bellow.



Mathematically it can be proved that these non sinusoidal currents are made up of sinusoidal currents having frequencies which are integral multiples of fundamental frequency i.e. 50 Hz. These (3^{rd} =150Hz, 5^{th} = 250Hz, 7^{th} = 350Hz etc) currents cause overheating of transformers, cables, switchgears etc due to increased losses requiring their derating for normal operation. Excessive current harmonics cause voltage harmonics distorting the voltage waveform. This can further cause harmonic currents in linear loads. This causes increased losses, vibrations in electrical motors, malfunctioning of electronic controls due to generated electromagnetic noise, Unwanted erratic tripping of circuit breakers due to over heating etc.

In electrical distribution networks, having presence of harmonic currents, if only capacitors are added to improve system power factor, there is a possibility of amplification of these harmonics due to resonance created by transformer inductance and these capacitors. This should be avoided by using detuned L – C filters or harmonic filters in place of capacitors. Utility companies also make it mandatory for consumer to control harmonics generated by his load as it improves their revenue potential by avoiding derating. Active filters also could be another solution to suppress harmonics. These are specially designed power electronic circuits, which take anti phase current from source which is equal and opposite of non linear component of load current. These filters are very costly and as such are not very popular as yet.

Executive Summary:

1) PIX Transmission Nagpur is a rubber processing plant manufacturing transmission belts. At present plant works on 1 x 3150KVA transformer. The contract demand is 1500KVA and average MD recorded is 1200KVA.

2) The process has 1 x 750KW DC drive which is exposed to continuously fluctuating loading cycle of approximately 3 mins each. Peak demand reaches 2500KVA. Current varies from 1000A to 3000Amps.

3) At present reactive power compensation is provided using FIXED capacitors. This is causing resonance of these capacitors and transformer impedance, as capacitors remain same even if reactive power requirement reduces. This gives rise to amplification of current harmonics and associated increase in voltage harmonics.

4) In view of avoiding this resonance and achieving reduction in current through last mile distribution cables, it is recommended that plant should use distributed reactive power correction using 7% detuned passive filters. This correction may be fixed in nature near
   - LBB1 – mixing mill – 150KVAR
   - LBB2 – 75KVAR
   - LBB3 – 125KVAR
   - PCC3 - 125KVAR
   - Utility – 75KVAR

   The correction at LBB1 main panel (800KVAR) and main LT panel (400KVAR) should be 7% detuned passive filters with suitable steps – to be switched using thyristor switches – for quick response.

5) Once above correction of total 1750KVAR @ 415V is installed, the harmonics levels should be rechecked and if required a decision regarding Active filters may be taken. This correction should reduce current harmonics bellow 15% and voltage harmonics bellow5%.

6) In detuned filters as above, we recommend capacitors rated for 525Volts for better life up to 6 years. This calls for increasing KVAR capacity to 1750 x 1.6 = 2800KVAR at 525volts.

7) As per our study, using ETAP and actual load measurements, we do not recommend increasing load on 3150KVA transformer as this will increase transformer loss and will increase operational cost. (Ref calculations in Table 2 based on ETAP simulation). Keeping this in view, we recommend to install another transformer of 2500KVA for new load.

8) We also recommend to have new 800KW DC drive with 12 pulse rectifier. It is recommended that present 750KW DC motor also should have 12 pulse rectifiers in near future. This arrangement drastically reduces generated current harmonics and improve internal power quality.

We have observed this at international level especially with rubber industry during our audits conducted abroad.

9) The MSEDCL current harmonics compliance limit (TDD) for plant is 15% where as the actual TDD from recorded data is 38%. This needs rectification.

Description of activities and present status of Electrical infrastructure:

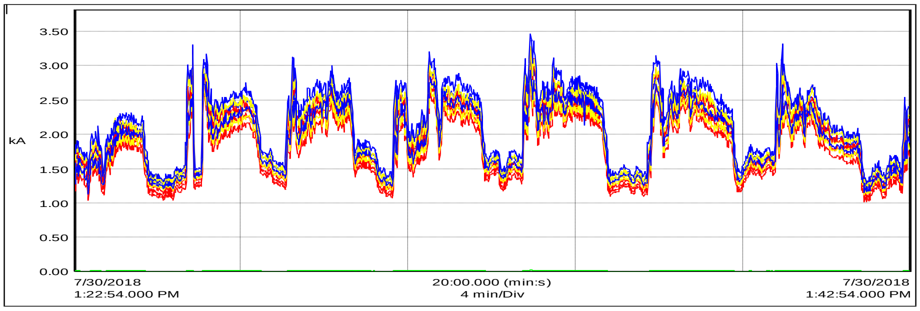
A REPUTED RUBBER TRANSMISSION BELT MANUFACTURER Nagpur is a Transmission belt manufacturing unit and main activity is processing Rubber. The electrical infrastructure is

- 33KV incoming MSEDCL power is stepped down to 433V using 1 x 3150KVA transformer. Contract demand is 1500 KVA and billed demand is around 1250KVA.
- Billing power factor is not unity and there is loss of incentive every month.
- KWh consumption is between 300000 to 425000 per month

Present situation: Table 1

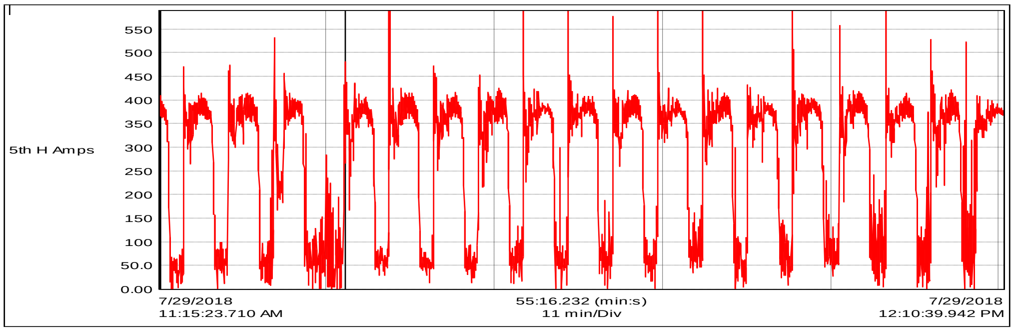
Sr	Feeder	KW	KVAR	ITHD %	UTHD %
	Installed capacitors – 1200 KVAR - APFC				
	Main incomer 33/0.433 KV – 6.53% - 3MVA sec -	1600	1500	43.5	11.7
1	LBB1 – 0.433/0.680 – 1MVA – 5.13% - 750KW DC Drive	655	1000		10 to 20
2	LBB1 Mixing Mill	308	200	30	10
3	LBB2 – 200KW+125KW - 0.433/0.380 – 630KVA	430	221	17	11
4	LBB3 - 200KW+125KW	306	165	20	10.5
5	Pump House	20	11	29	10
6	Lab Mill	30	16	23	11
7	PCC 3 – Acc LBB 1	78	60	20	11
8	135 – Utility	250	83	25	13
	Capacitors				
1	@ LBB1 in Main PCC		925		
2	@ Mill		200		
3	@ PCC 3		75		
	Peak Load KW	2077			
	Fixed Installed KVAR		1200		

- Major load of LBB 1 is large DC drive with 750KW rating presently fed through 433/680V – 1 MVA two winding transformer. The mixing cycle is of 3 mins and as such the load is continuously fluctuating.

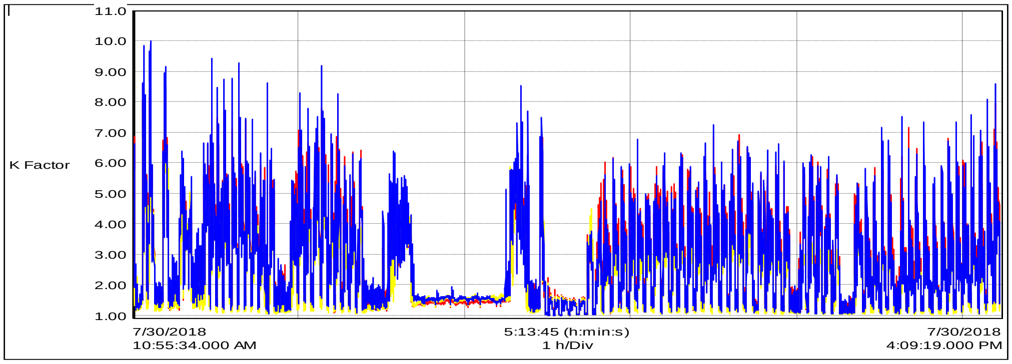


Due to this, plant load fluctuates between 1000Amps to 3500Amps as shown above. This results into similar demand variation in reactive power requirement.

- Other load in this section is mill load and has 250KW slipring Induction motor. The section also includes 80KW of mill accessories load.
- LBB 2 has DC drive of 200KW fed through 433/380V – 630KVA transformer. Other load in this section is mill load and has 125 KW slipring Induction motor.
- Apart from this there are typical plant utilities and water pumping and illumination load.
- The KW load is fluctuating in nature as requirement of process. (400KW to 1200KW). The peak KVA demand is 2000KVA. Reactive power requirement is compensated using **FIXED CAPACITORS** at present. This gives rise to resonance and results into amplification of current and voltage harmonics.
- The resonance results into 36% current harmonics distortion and 12 to 13% voltage harmonic distortion, both beyond limits specified by various international power quality standards and beyond MSEDCL compliance requirements.
- The plant is also losing on power factor Incentive as power factor is not maintained at 0.999. On the other hand if capacitors are increased to achieve this, the harmonic levels will increase further and will cause further power quality issues.
- The pattern of 5^{th} harmonic current in LBB1 load is as follows:



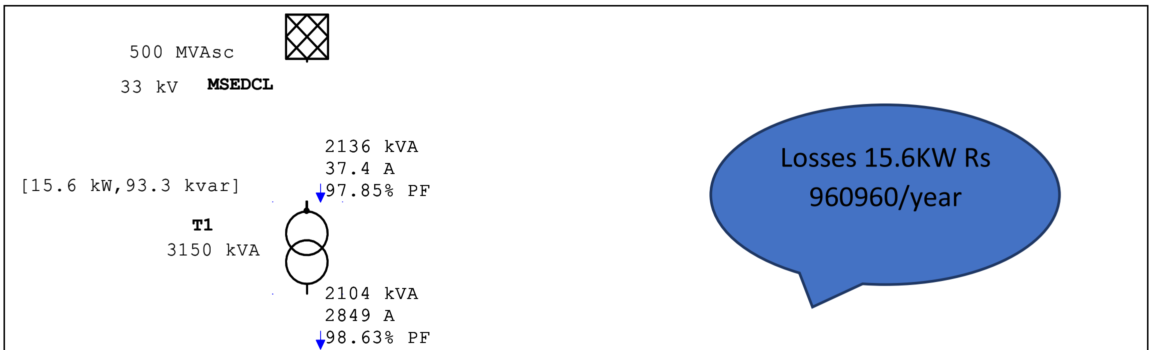
K Factor handled by transformer is as follows:



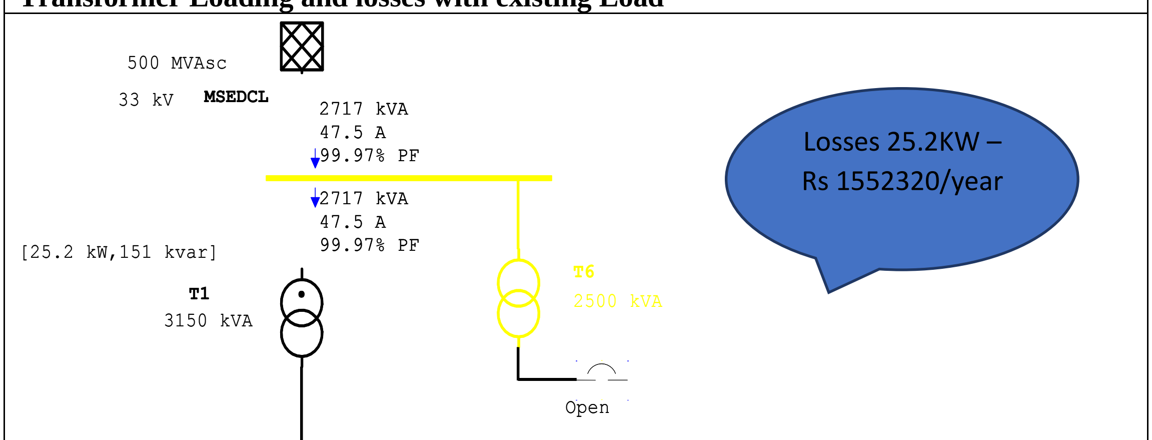
This indicates that the transformer handles about 400Amps of 5th harmonic current and K factor is around 10. This requires derating of the transformer.

Assessment of accommodating NEW Proposed Load and recommendations

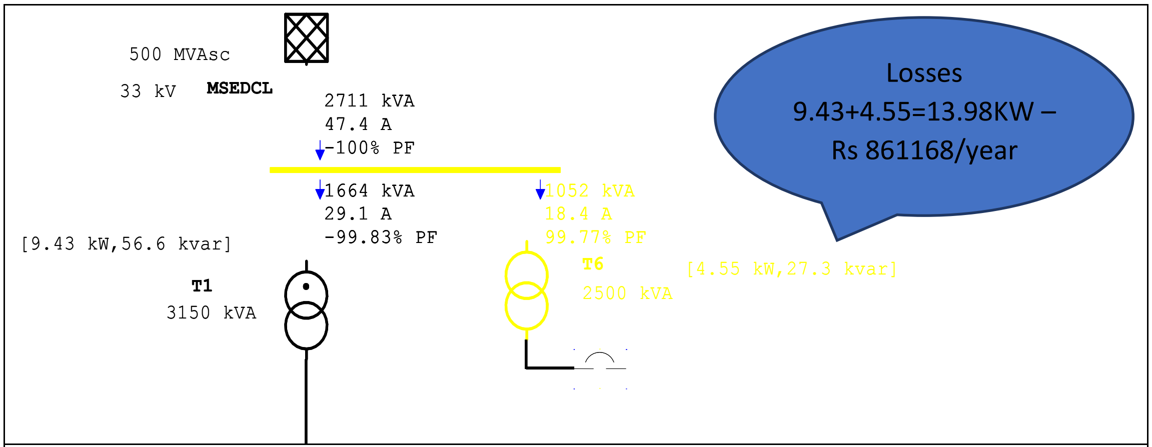
Table 2



Transformer Loading and losses with existing Load



Transformer Loading and Losses with New load on Same transformer



Transformer loading and Lossess with new load connected to new 2.5MVA transformer.

Above ETAP simulation results show that

a. Present transformer loading is 68% and losses are 15.6KW
b. If new load is put on same transformer the loading would be 86% and losses are 25.2KW.
c. If new load is supplied through new 2500KVA transformer, the loading of both would be 52 and 42% and the total losses would be 13.98KW This will give saving of about Rs.6.9Lacs/year over option b above.

Proposed solution for accommodating new Load.

- Not to load 3150 KVA transformer any further to avoid fast deterioration of insulation due to handling excessive harmonics and EXTRA loss. *(Kindly note that transformer losses increase in square proportion of current they handle)*
- On any immediate future opportunity 750KW DC drive panel should be replaced with 3 winding (Delta / Delta- Star) transformer and a 12 pulse DC drive to reduce generation of harmonics drastically.
- Plant is expecting addition of another mill with connected load of almost 1200KW. This should be fed with another transformer of 2500KVA and the main motor DC drive should be with 3 winding (Delta / Delta- Star) transformer and a 12 pulse DC drive to reduce generation of harmonics drastically. As shown above this will also ensure reduction in reduction in losses (see table below calculating differential operating cost for both the options.)

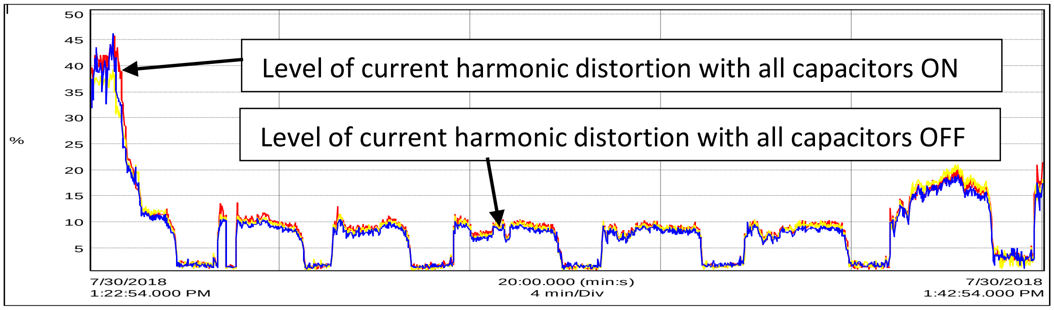
Table 3

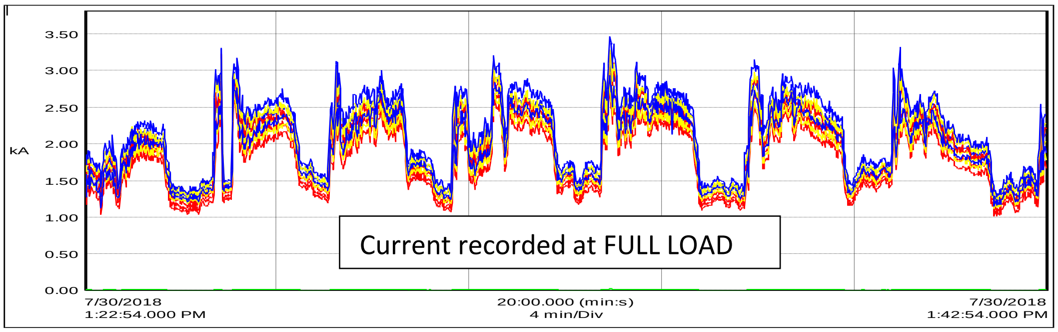
Option 1	**Option 2**
Run Existing + New Load on 3150KVA transformer	Run existing load without LBB2 on 3150 KVA transformer and install new 2500KVA transformer for New load.
Transformer Losses = 25.2KW	Transformer Losses = 13.98KW
Assuming 22hrs x 350 days working and unit rate of Rs.8/Kwh, cost of losses for 5 years 25.2KW x 22 hrs x 350 x 5 x 8=Rs 7761600.	Assuming 22hrs x 350 days working and unit rate of Rs.8/Kwh, cost of losses for 5 years 13.98KW x22hrs x 350 x 5 x 8=Rs 4305840.
Savings due to option 2 in five years = Rs 3455760. This arrangement will also result into increase in transformer life by at least 5 years. This arrangement will ensure Good and acceptable power quality through out the plant, resulting into other benefits like drastic reduction in abrupt shutdowns and maintenance of electrical and mechanical system components. Above financial calculations show that this option will pay for itself in less than 5 years.	

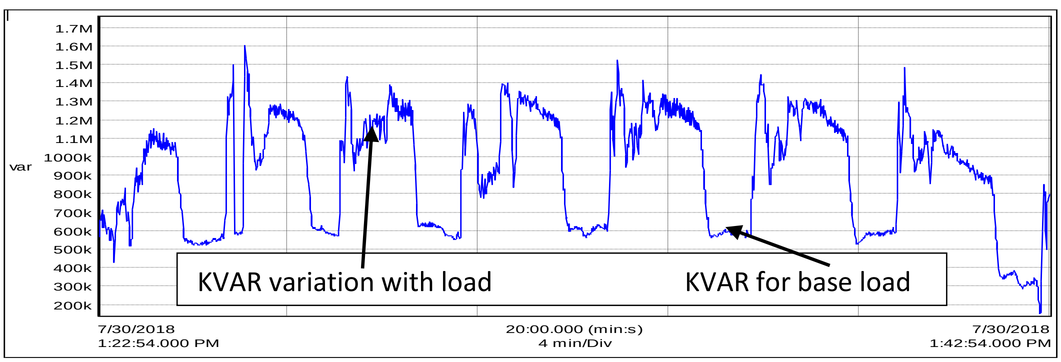
The above recommendation may prove to be some what costly initially, but there is no point in saving cost at present and then spending same at a latter date on harmonic mitigation. Our exposure to rubber industry at international level endorses this view. Electromagnetic solutions deployed for harmonic mitigation will have 25 to 30 years life where as detuned capacitors and electronic active harmonic filters will have life less than 10 years.

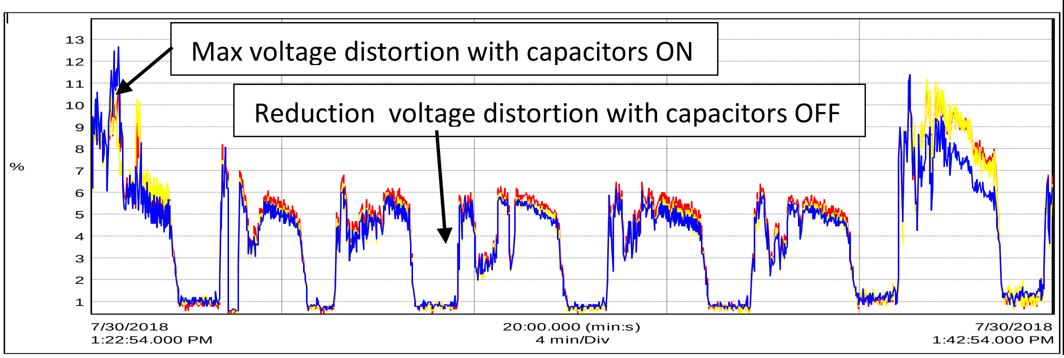
- Eventually both 750 and 800KW DC drives should have 3 winding transformers to reduce generation of harmonics.

Assessment of harmonics and reactive power at Main incomer – 3150KVA transformer secondary









This indicates resonance due to fixed capacitors.

This indicates variation of required kvar as per load. 600KVAR being fixed requirement. Loading cycle is about 2 mins.

Voltage distortion is also related load due to large harmonic currents

Table 4:
Proposed solution for reactive power compensation and harmonic mitigation.

Sr	Feeder	KW	Recommended solution
	Main incomer 33/0.433 KV – 6.53% - 3MVA sec -	1600	400KVAR@415V – 7% detuned with Thyristor switching + 200Amps AHF
1	LBB1 – 0.433/0.680 – 1MVA – 5.13% - 750KW DC Drive	655	800KVAR@415V – 7% detuned with Thyristor switching + 200Amps AHF
			@415V – 7% detuned - fixed
2	LBB1 Mixing Mill	308	150KVAR
3	LBB2 – 200KW+125KW - 0.433/0.380 – 630KVA	430	75KVAR
4	LBB3 - 200KW+125KW	306	125KVAR
5	Pump House	20	
6	Lab Mill	30	
7	PCC 3 – Acc LBB 1	78	125KVAR
8	135 - Utility	250	75KVAR
	Capacitors		
	Peak Load KW	2077	
	Total KVAR proposed		1750
Recommendations for extra load will depend upon your choice of adding 2500KVA transformer and opting for 12 pulse rectifier for new proposed load.			

Based on above assessment, following are main recommendations:

- Power factor correction should be distributed and to be installed as close to the load as possible – up to 600KVAR. This should be provided in the form of fixed detuned banks to be connected whenever particular load is ON.
- The correction for LBB1 should be with detuned – thyristor switched harmonic filters. They will damp the resonance. Thyristor switching will offer fast correction required for fluctuating load and avoid over correction. This should be 800KVAR RTPFC panel.
- Main bus should have a 400KVAR RTPFC panel with detuned thyristor switched steps. This will ensure real time correction and will avoid over correction and associated resonance.
- After damping the resonance and achieving close to unity power factor at most upstream point, requirement of active filter if any may be assessed by measurements and then the same may be installed. If this arrangement improves the situation within acceptable limits, active harmonic filters may not be required.
- In any case increasing load on present transformer is not recommended for all the reasons explained above.
- It is advised that the plant may follow steps as recommended in above table.

MSEDCL Harmonic compliance limit calculations and checking the compliance as per recorded data.

We receive HT electrical supply through MSEDCL infrastructure such as substation transformers and cables / transmission lines etc. If consumer draws more harmonic currents, they have to flow through MSEDCL infrastructure and can damage them. Further the distribution losses beyond our metering kiosk till MSEDCL substation are not metered and are born by MSEDCL. In view of restricting this misuse by consumers, MSEDCL through their code document "Supply Code 2005" puts restriction on quantum of harmonics that can be drawn by a consumer. The compliance limits are defined in an international standard IEEE 519 1992, which MSEDCL has adopted vide supply code.

The prescribed method in this procedure directs consumer to calculate a ratio ISC/ IL, where
ISC is short circuit current of MSEDCL transformer which supplies HT voltage to consumer.
IL is Consumers average demand current during last 12 months. (For practical calculations this current is taken as maximum current during measurements. Generally, measurements are taken for 24 hours or for a full load cycle of process at consumers premises.) Then this ratio is referred in the standard table to know compliance limits.

The current harmonic index calculated for checking the compliance is defined as TDD – total demand distortion. TDD is defined as follows.

$$TDD = \frac{100\% \cdot \sqrt{(I_2^{\,2} + I_3^{\,2} + \ldots\ldots + I_n^{\,2})}}{I_{\max\ demand}}$$

Where I max = maximum current of fundamental frequency recorded.

I_2 ----I_n = Harmonic currents in above I max recorded.

In your case

MSEDCL MVA	50
% IMPEDANCE	13
MSEDCL SC MVA	384.6154
CONTRACT DEMAND IN KVA	1500
CONTRACT DEMAND IN MVA	1.5
Isc/IL	256.4103

Maximum harmonic current distortion in percentage of IL for voltages less than						
Individual harmonic order (odd harmonics)						
Isc/IL	<11h	11≤h<17	17≤h<23	23≤h<35	35≤h<49	TDD
<20	4	2	1.5	0.6	0.3	5
20<50	7	3.5	2.5	1	0.5	8
50<100	10	4.5	4	1.5	0.7	12
100<1000	12	5.5	5	2	1	15
>1000	15	7	6	3.5	1.4	20
Even harmonics are limited to 25% of odd harmonic limits above.						

The TDD compliance limit is 15%. The TDD calculations are shown on next page. **The TDD value is 38%, whereas compliance limit is 15%**. This is much beyond the compliance and need correction. This is measured on transformer secondary, the value may be 10% less on primary HT side due to transformer impedance. **MSEDCL will see this as non-compliant.**

Analysis of Current harmonic distortion				Recorded % VTHD at IF Max	
TimeStamp of IF Max		Current Amps	% Distortion		Volts
30-07-2018	IFmax in B	2737.6			
02:22:18:PM	Ih2	2.7376	0.1	Vh2	0
	Ih3	84.8656	3.1	Vh3	0.5
	Ih4	2.7376	0.1	Vh4	0
	Ih5	558.4704	20.4	Vh5	6.6
	Ih6	8.2128	0.3	Vh6	0.1
	Ih7	878.7696	32.1	Vh7	16.6
	Ih8	5.4752	0.2	Vh8	0
	Ih9	49.2768	1.8	Vh9	1.1
	Ih10	0	0	Vh10	0
	Ih11	41.064	1.5	Vh11	1.2
	Ih12	0	0	Vh12	0
	Ih13	5.4752	0.2	Vh13	0.5
	Ih14	0	0	Vh14	0
	Ih15	2.7376	0.1	Vh15	0.3
	Ih16	0	0	Vh16	0
	Ih17	5.4752	0.2	Vh17	0.2
	Ih18	0	0	Vh18	0
	Ih19	0	0	Vh19	0.1
	Ih20	0	0	Vh20	0
	Ih21	0	0	Vh21	0
	Ih22	0	0	Vh22	0
	Ih23	0	0	Vh23	0
	Ih24	0	0	Vh24	0
	Ih25	0	0	Vh25	0
	Ih26	0	0	Vh26	0
	Ih27	0	0	Vh27	0
	Ih28	0	0	Vh28	0
	Ih29	0	0	Vh29	0
	Ih30	0	0	Vh30	0
	Ih31	0	0	Vh31	0
	Ih32	0	0	Vh32	0
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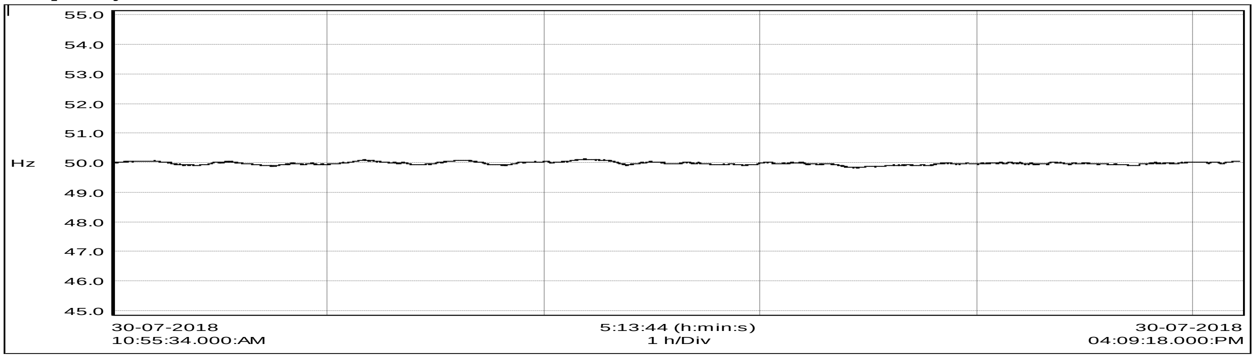
	Ih35	0	0	Vh35	0
	Ih36	0	0	Vh36	0
	Ih37	0	0	Vh37	0
	Ih38	0	0	Vh38	0
	Ih39	0	0	Vh39	0
	Ih40	0	0	Vh40	0
	Ih41	0	0	Vh41	0
	Ih42	0	0	Vh42	0
	Ih43	0	0	Vh43	0
	Ih44	0	0	Vh44	0
	Ih45	0	0	Vh45	0
	Ih46	0	0	Vh46	0
	Ih47	0	0	Vh47	0
	Ih48	0	0	Vh48	0
	Ih49	0	0	Vh49	0
	Ih50	0	0	Vh50	0
	Sum of sq(A)	1095621.69			
	Sqrt(A)	1046.719489			
	TDD	38.23493167			

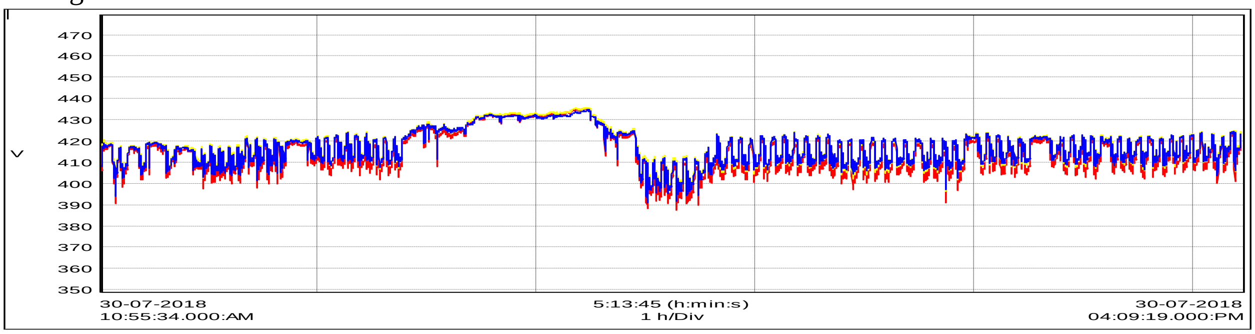
Recorded Data:

Main Incomer:

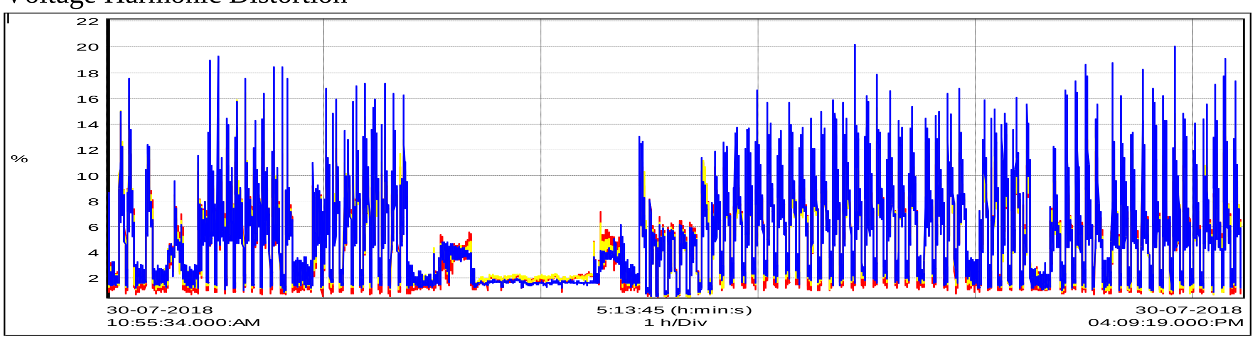
Frequency



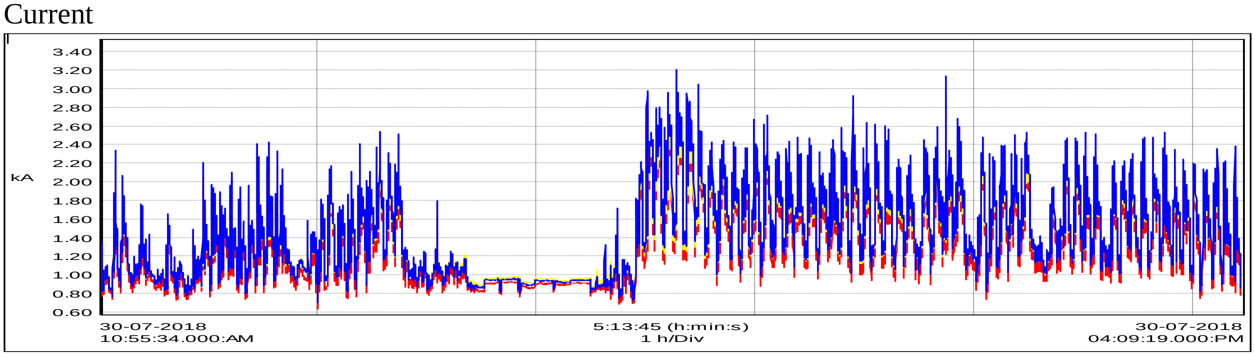
Voltage L-L



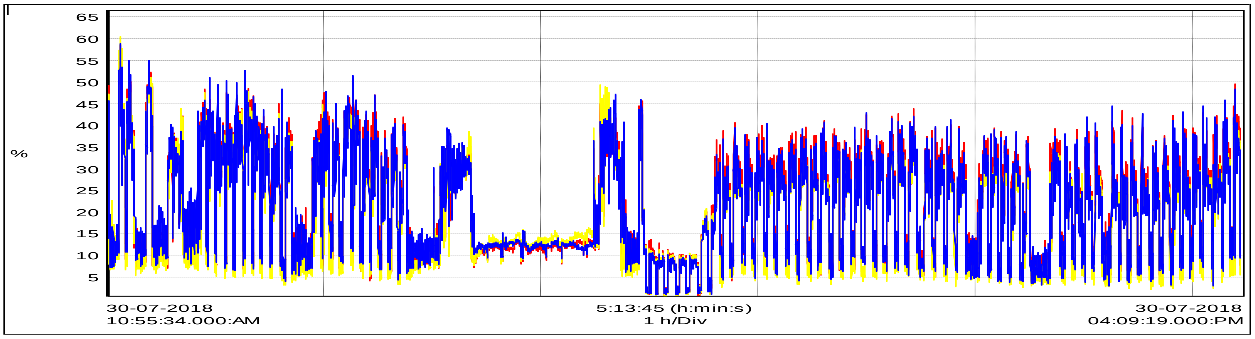
Voltage Harmonic Distortion



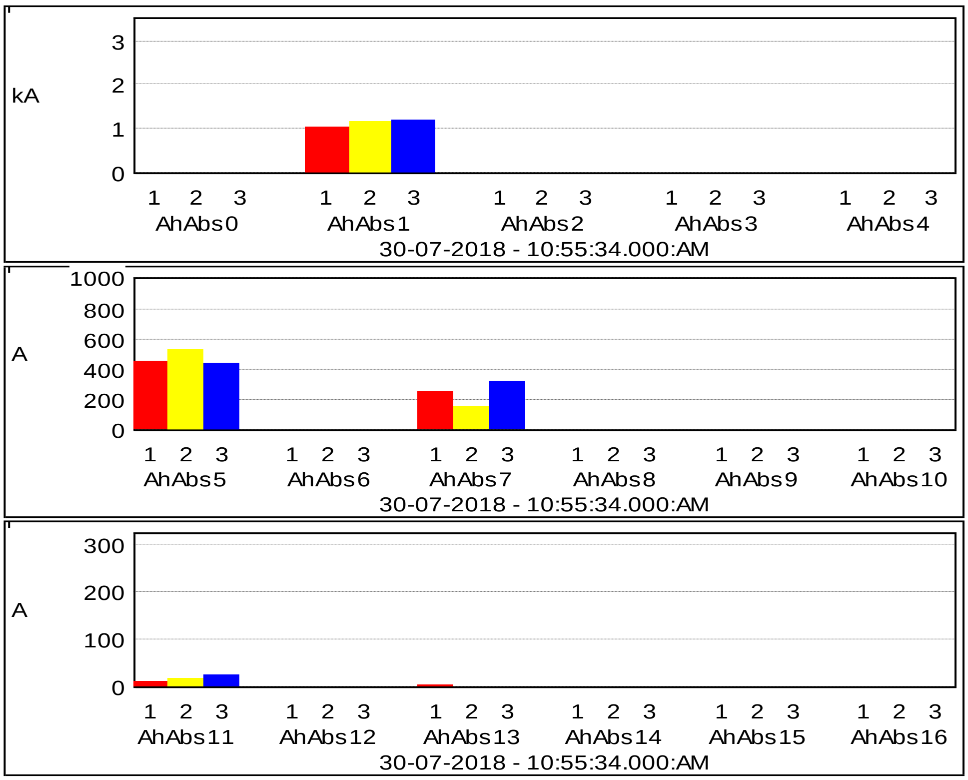
Current



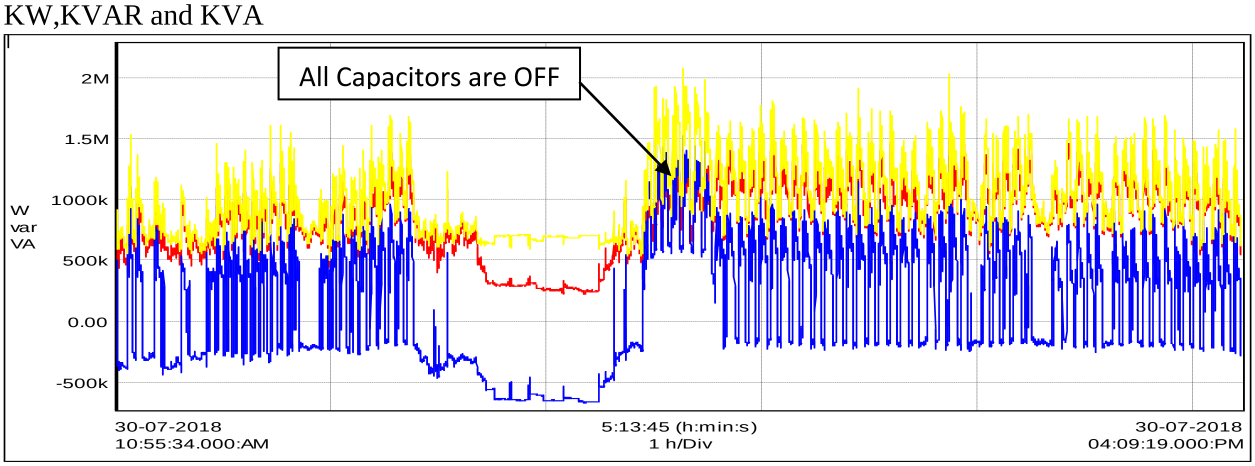
Current Harmonic Distortion



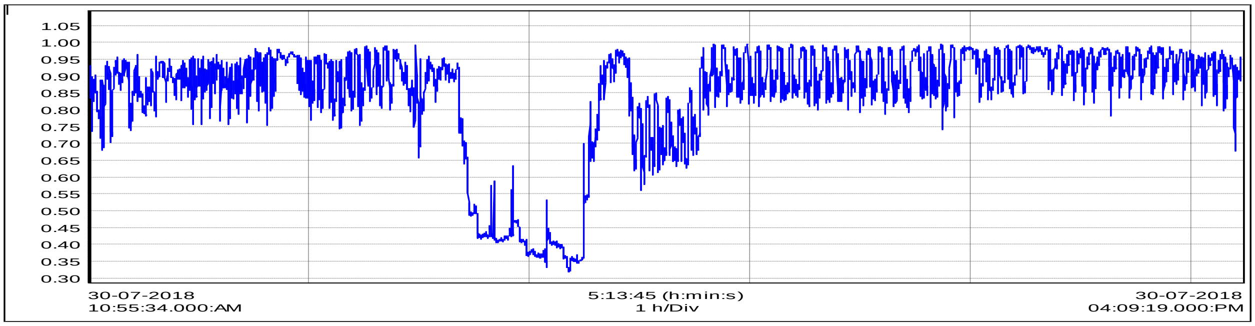
Individual Current Harmonics



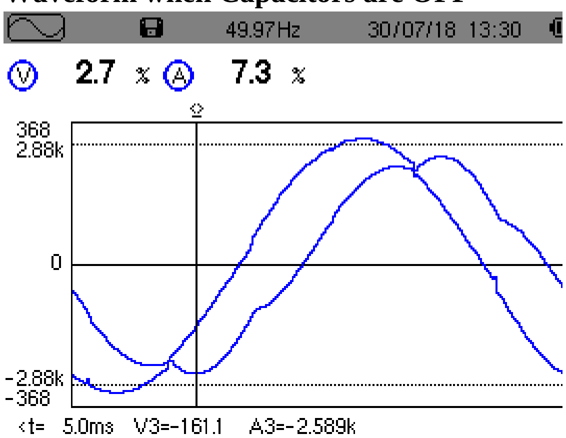
KW,KVAR and KVA



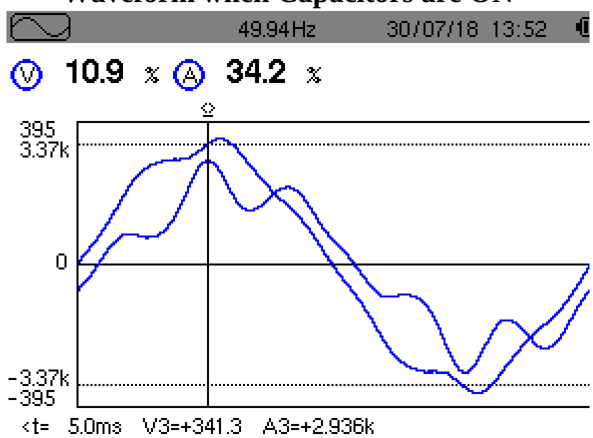
PF



Waveform when Capacitors are OFF

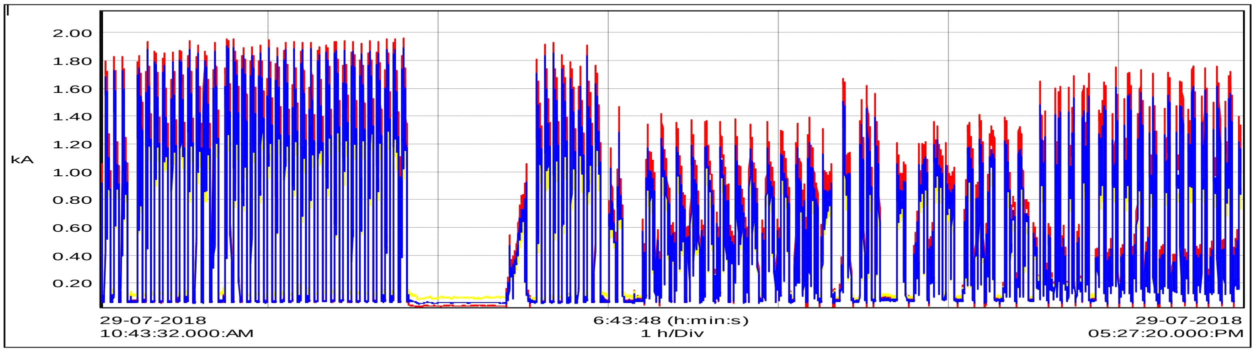


Waveform when Capacitors are ON

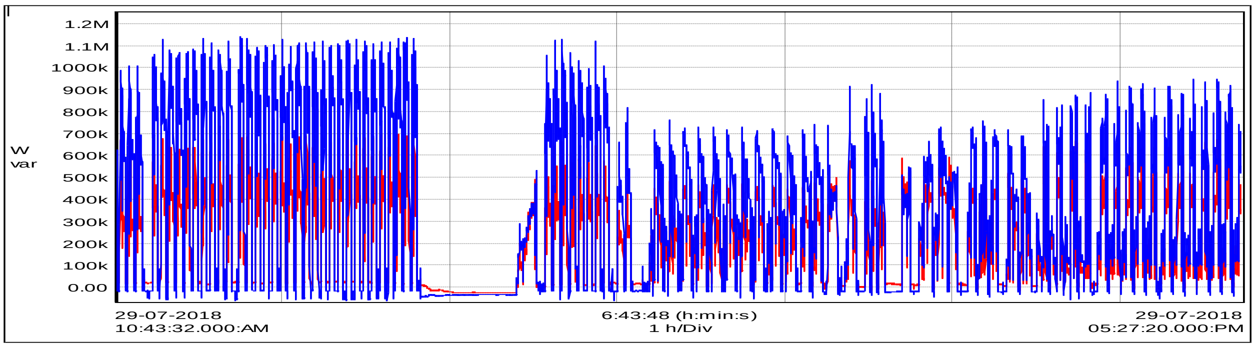


LBB 1

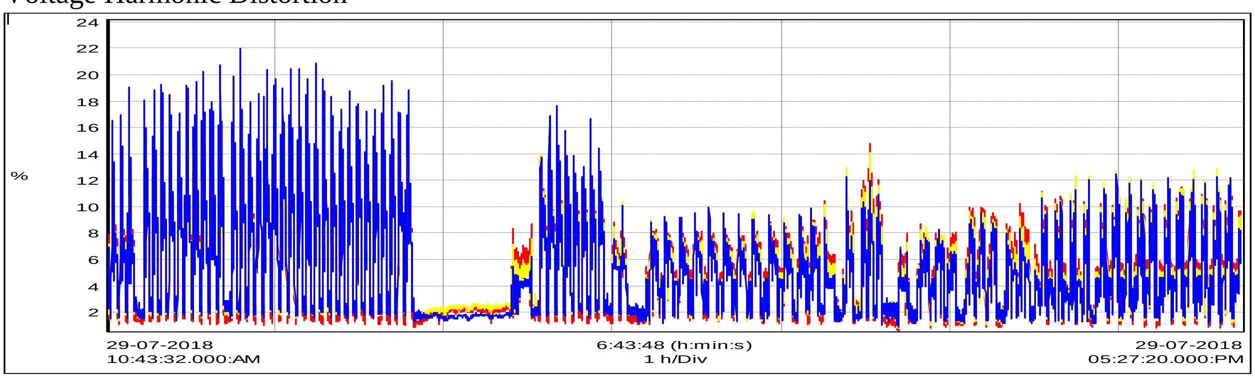
Current



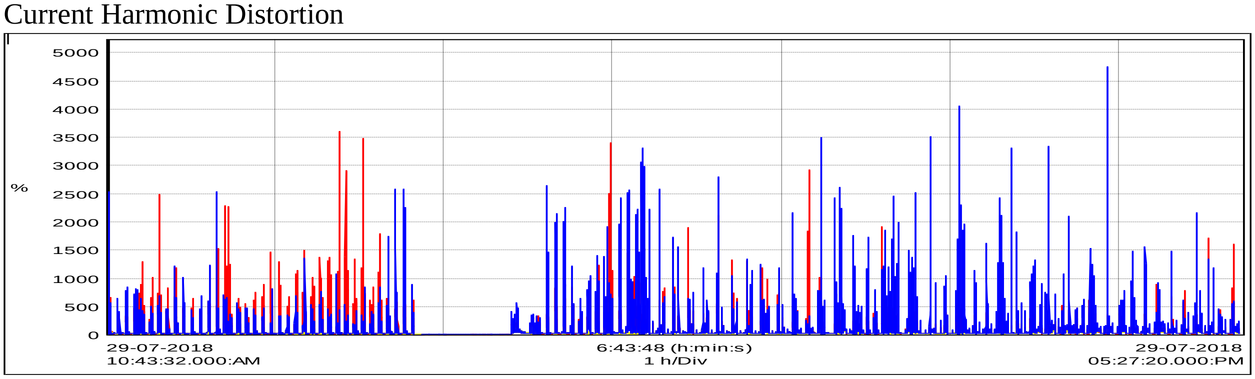
KW&KVAR



Voltage Harmonic Distortion

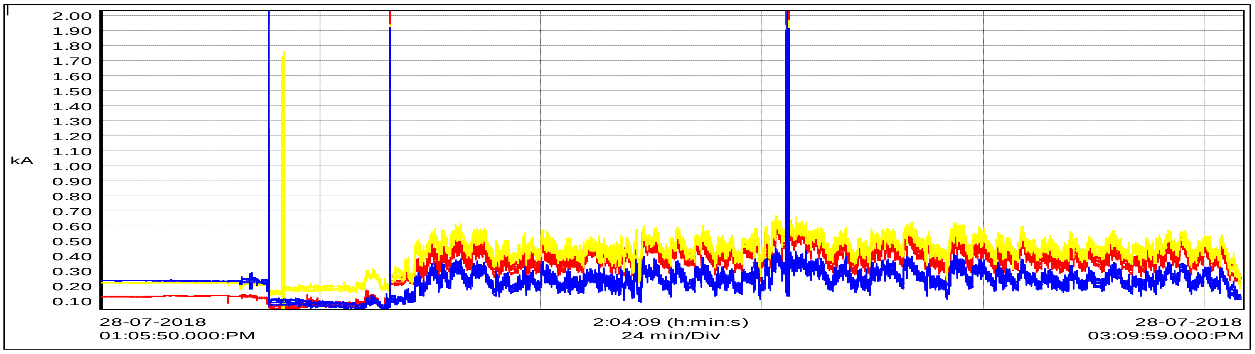


Current Harmonic Distortion

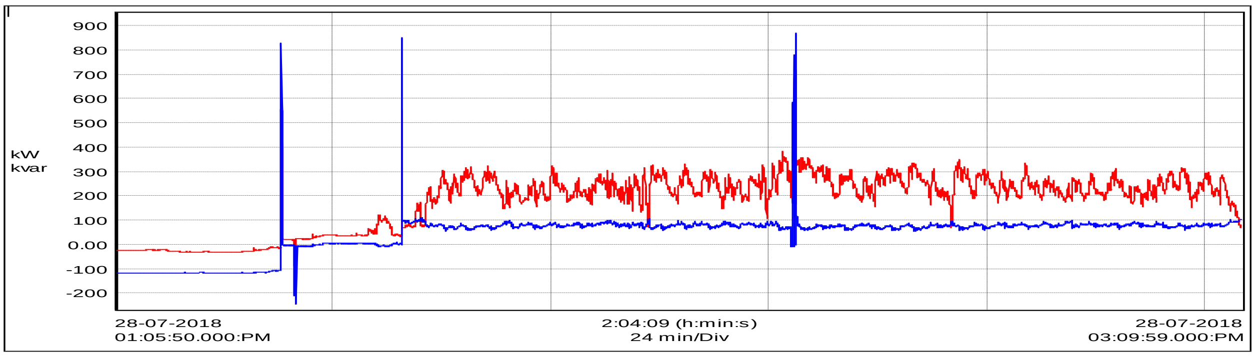


Mixing Mill LBB-1

Current



KW and KVAR



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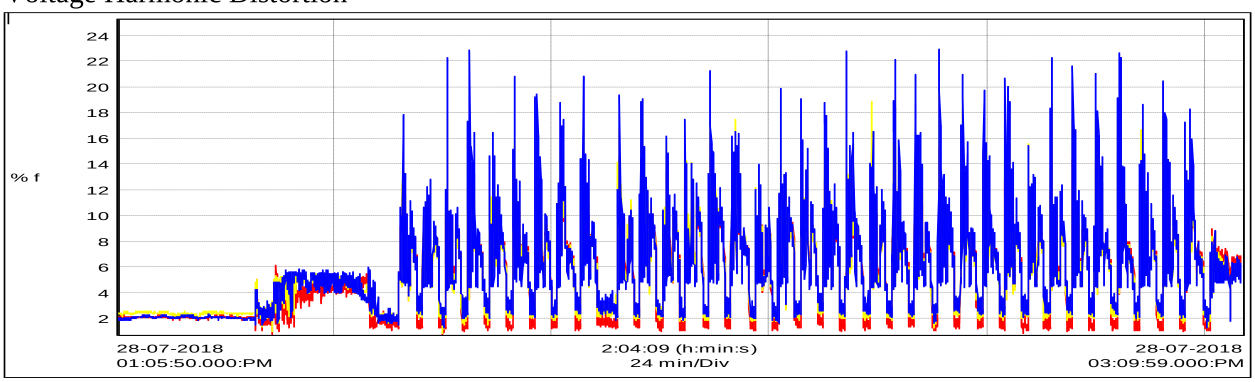
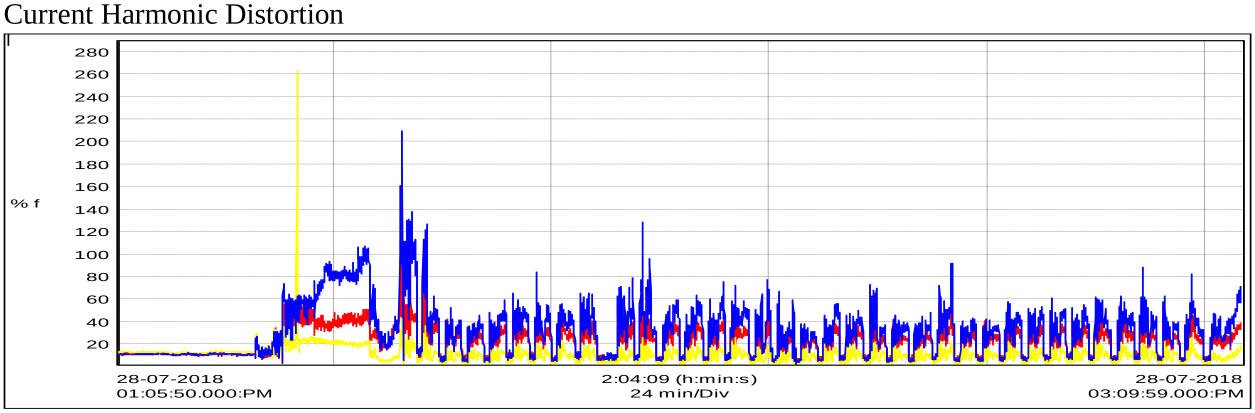
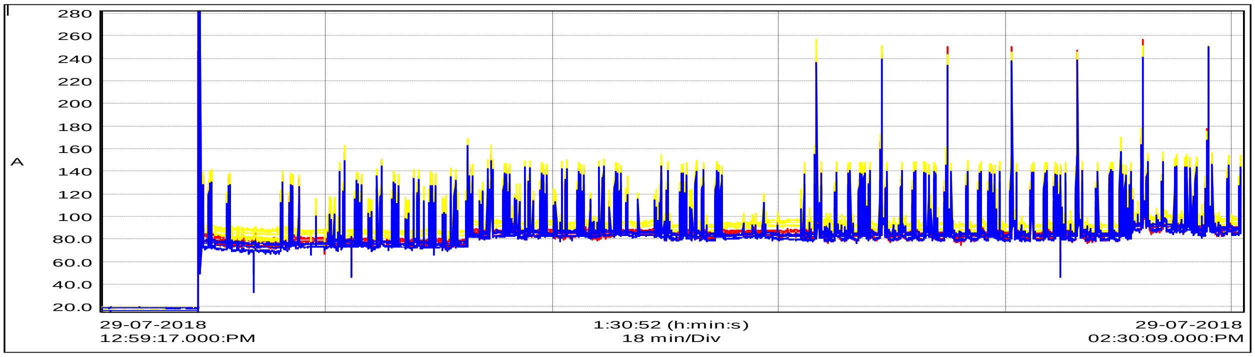


Current Harmonic Distortion



LBB – 1 Accessories

Current



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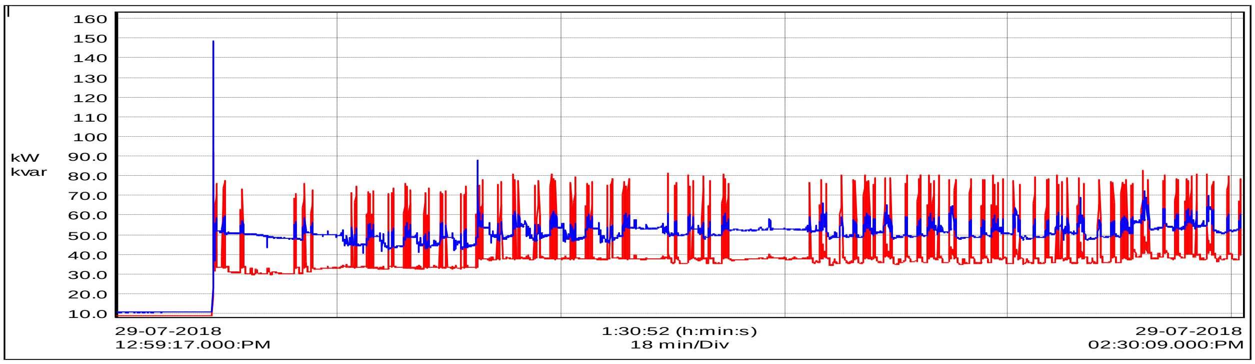

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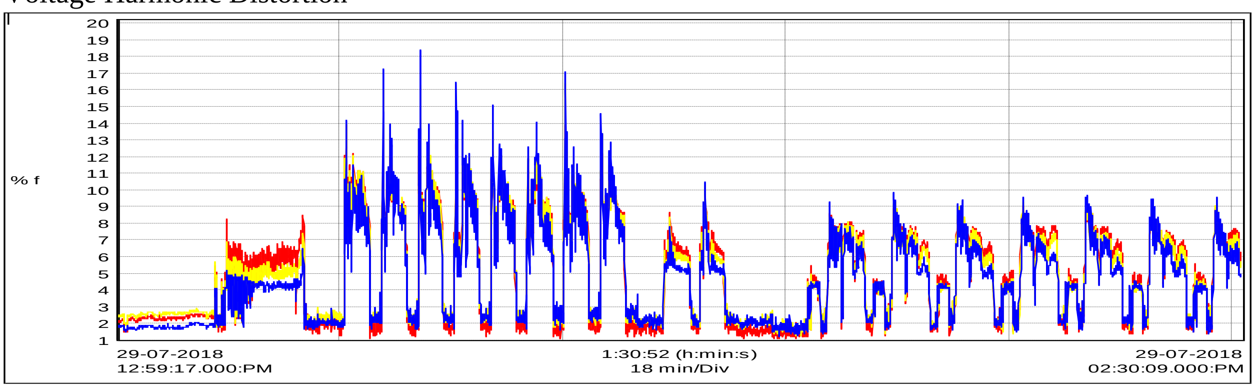

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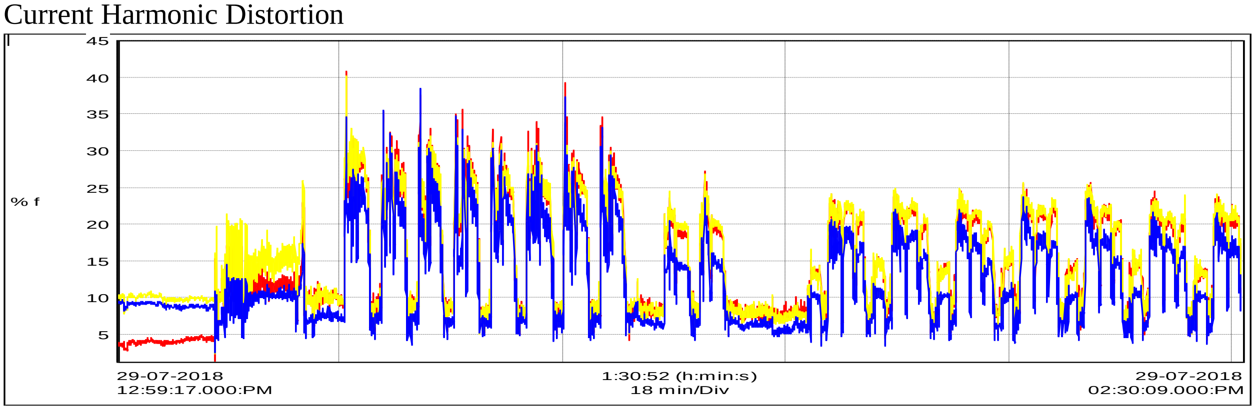
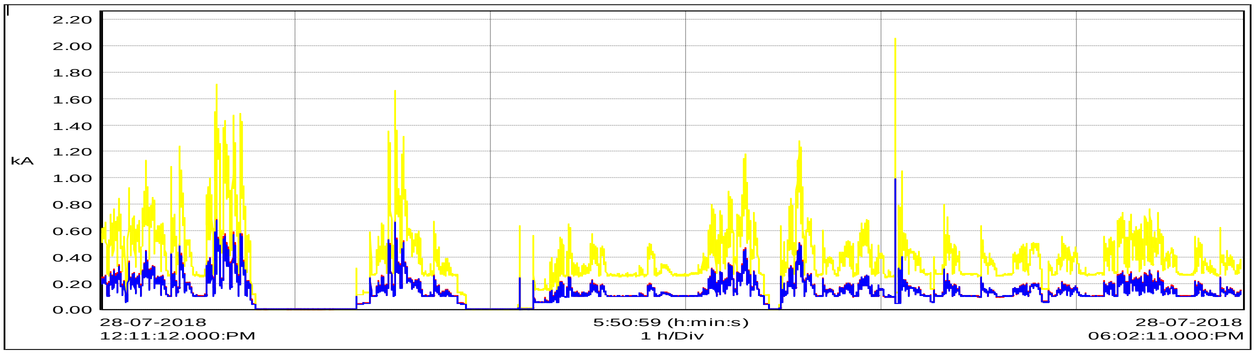


LBB-2

Current



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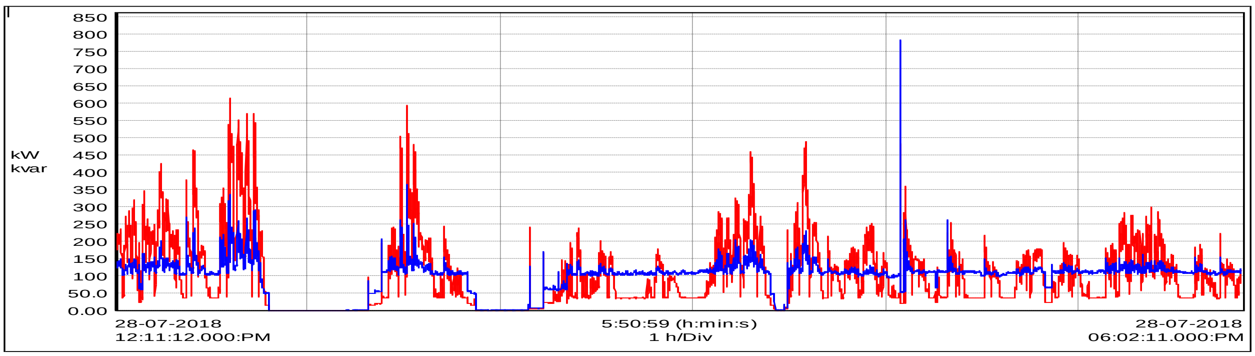

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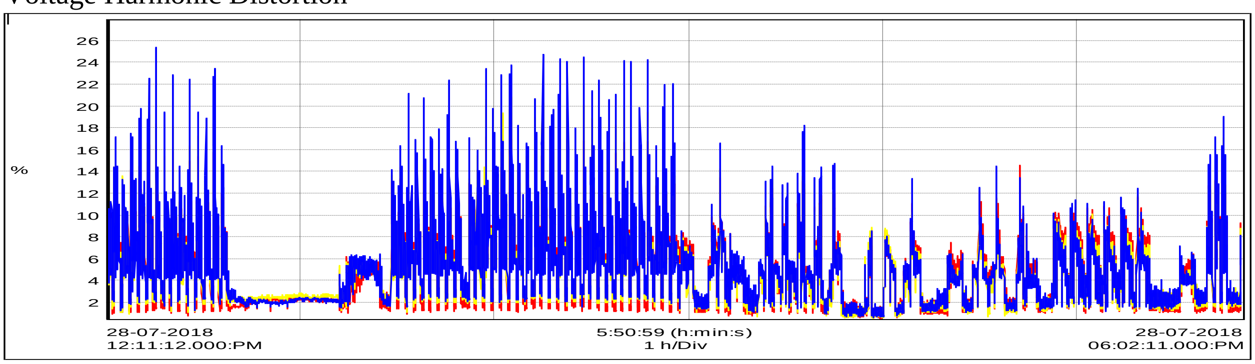
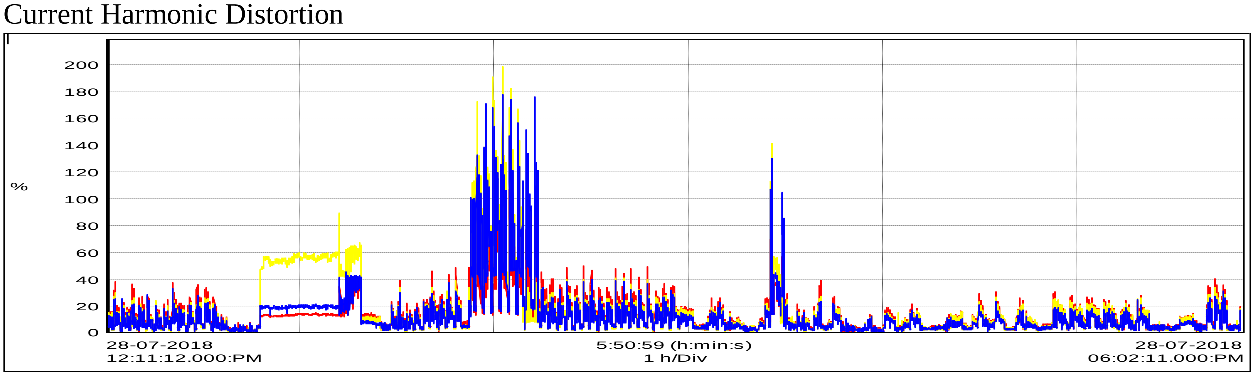
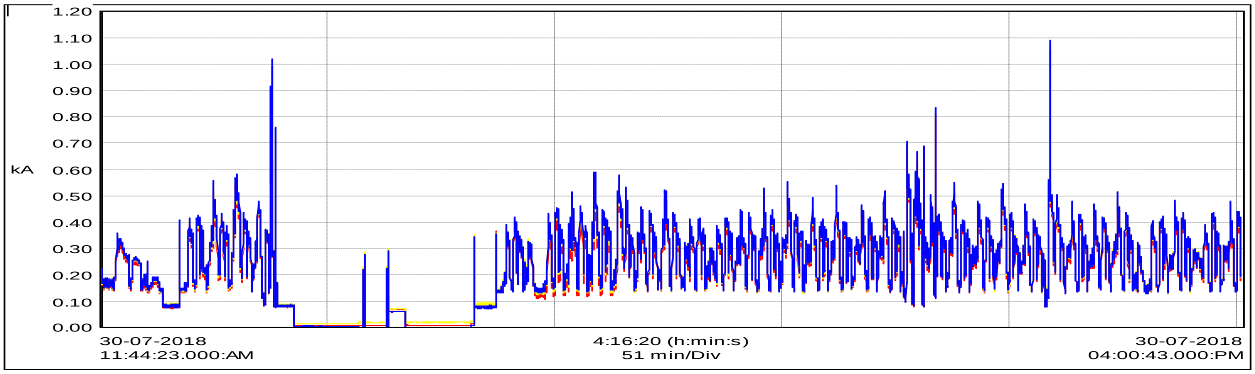


Current Harmonic Distortion



LBB-3

Current



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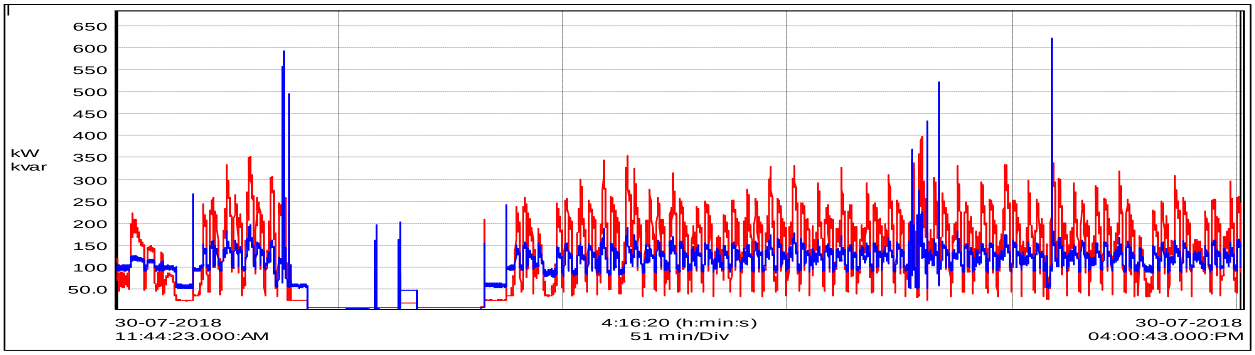

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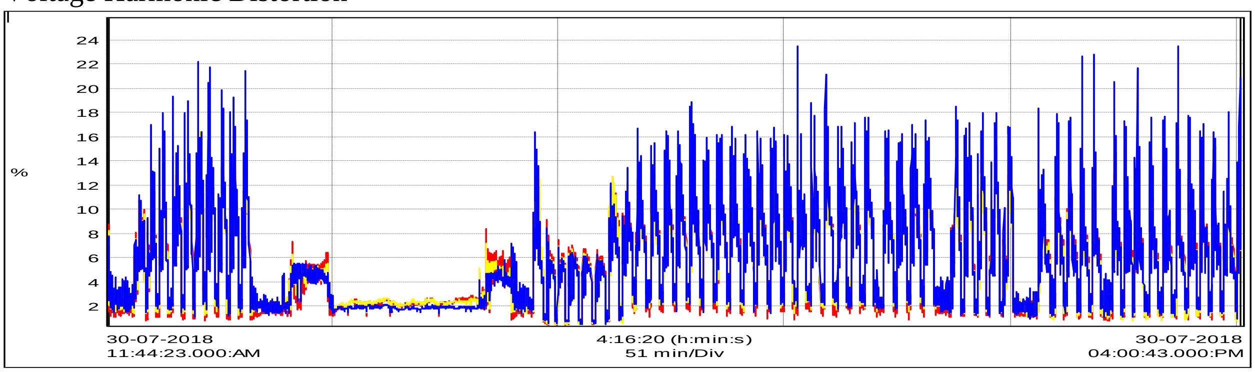
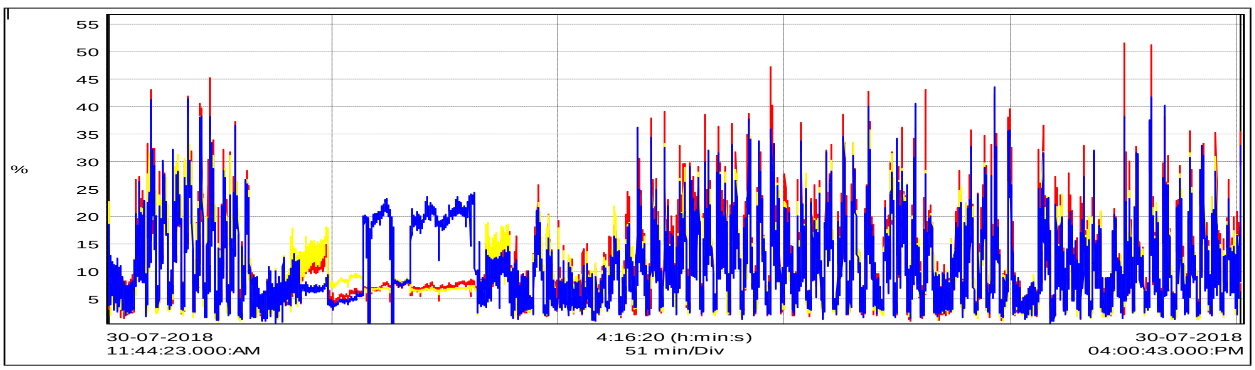
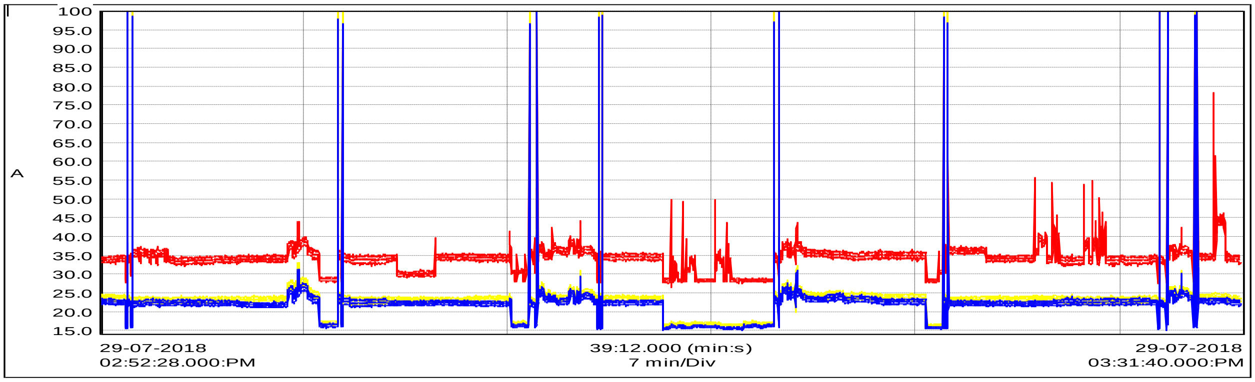


Current Harmonic Distortion

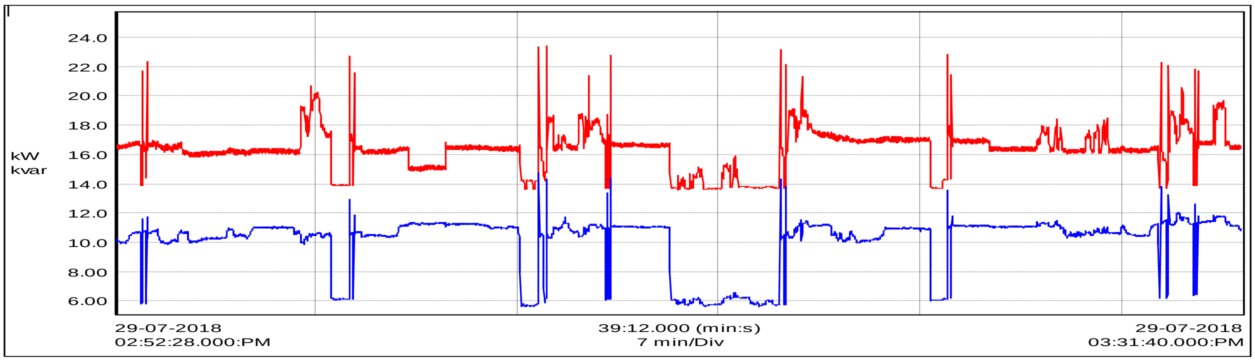


Pump House

Current



KW and KVAR



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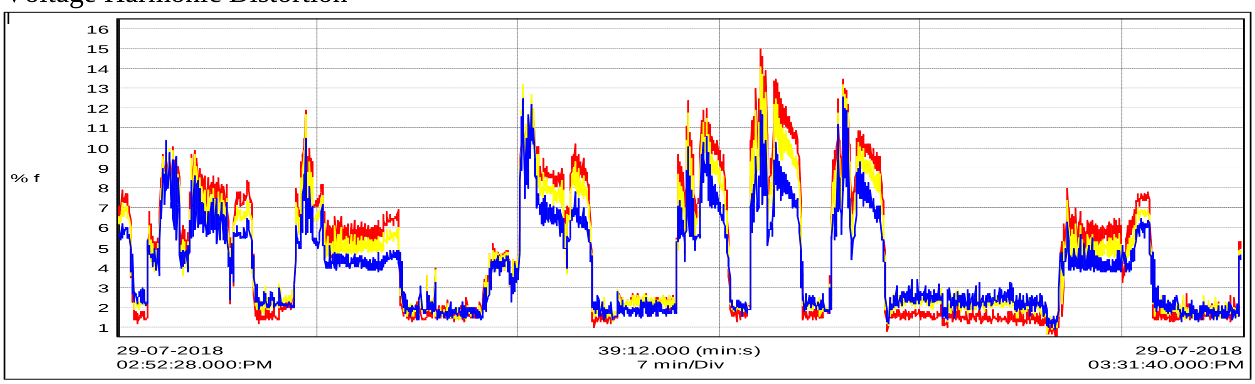

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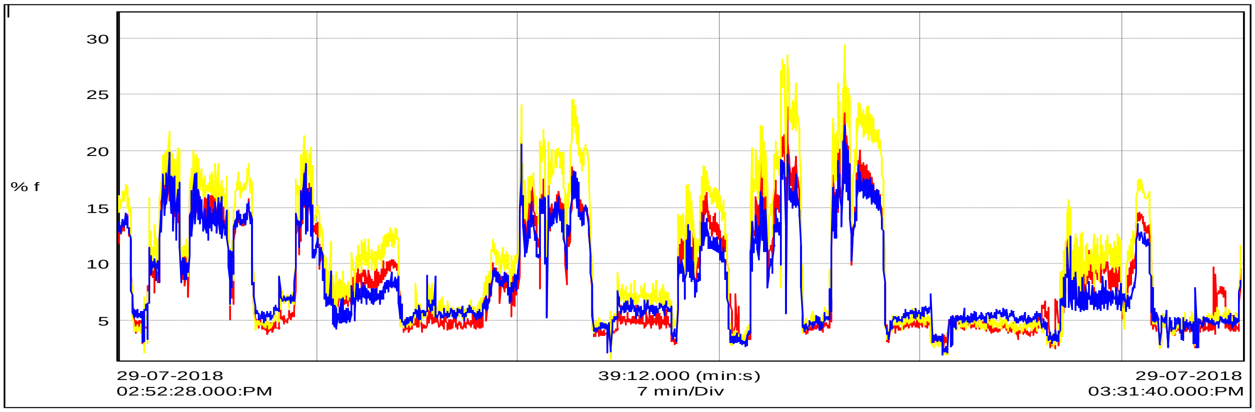
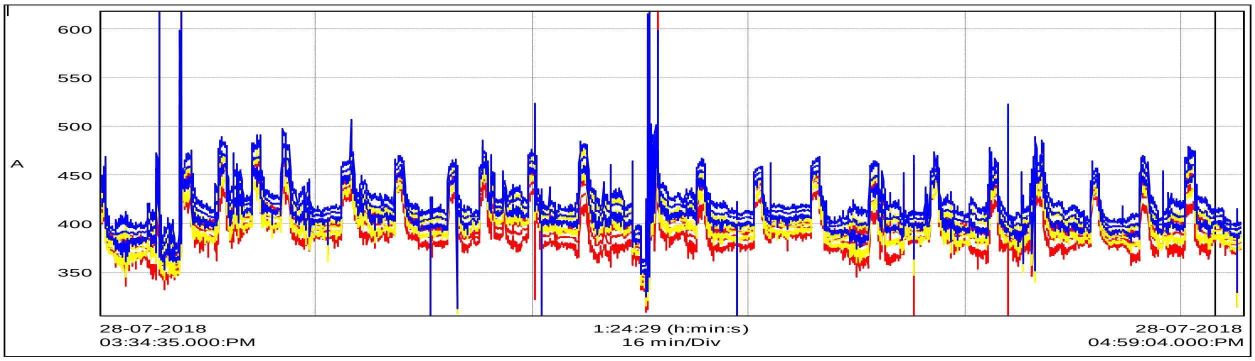
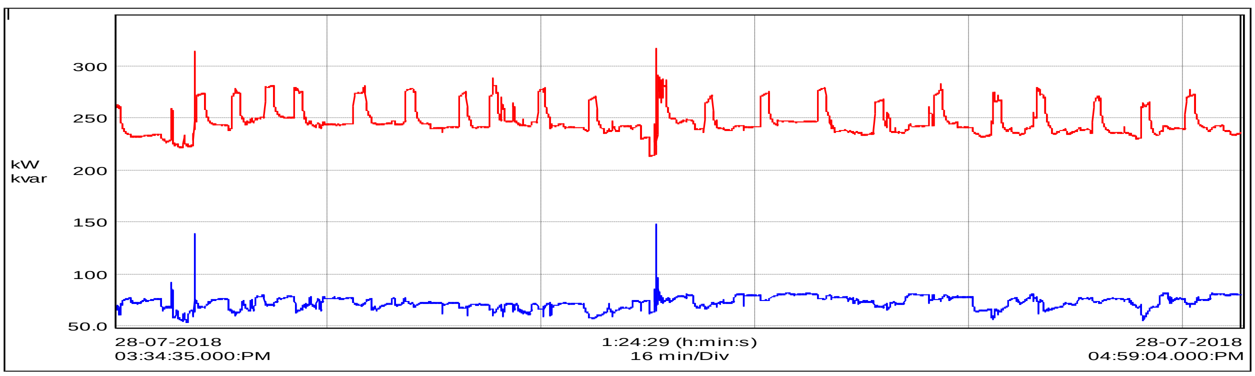


Utility

Current



KW and KVAR



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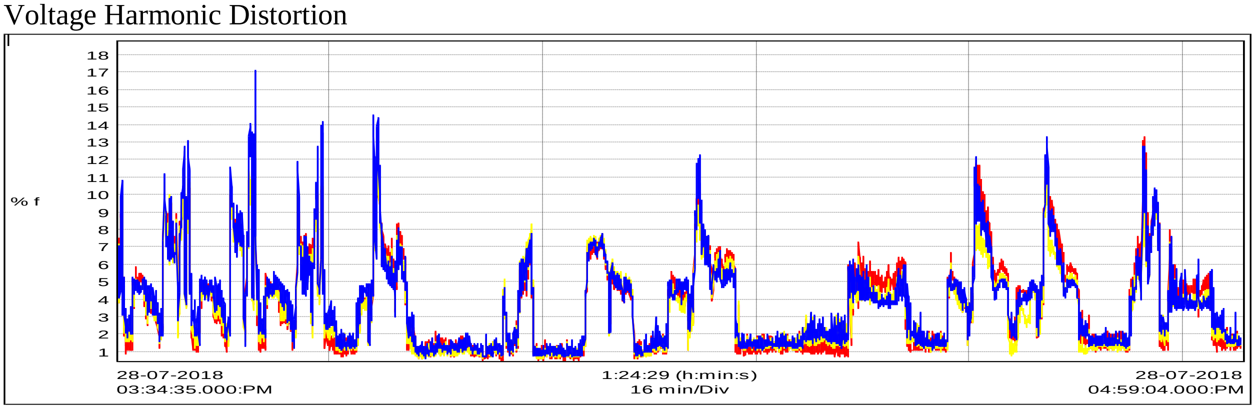
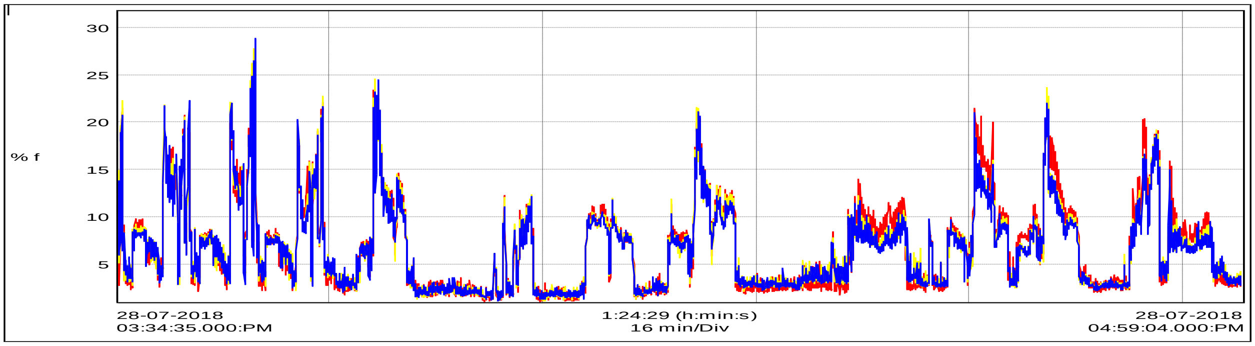


Current Harmonic Distortion


30
25
20
% f
15
10
5
28-07-2018
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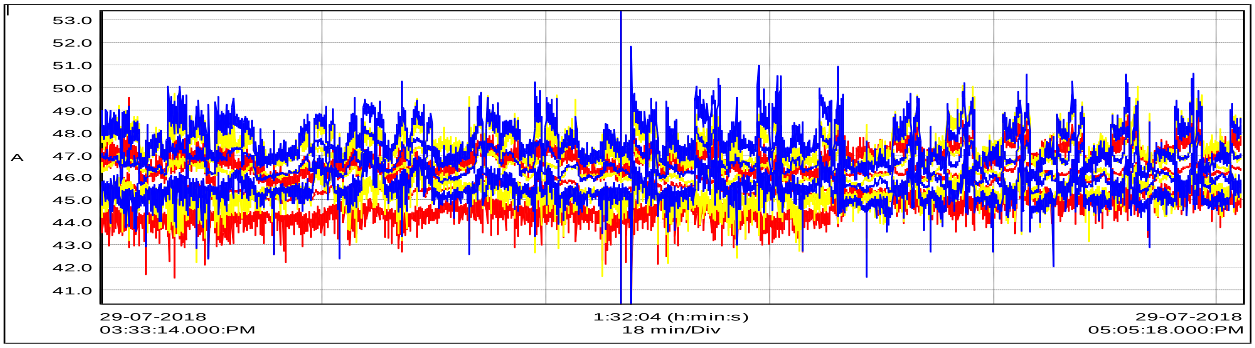
Lab Mill

Current



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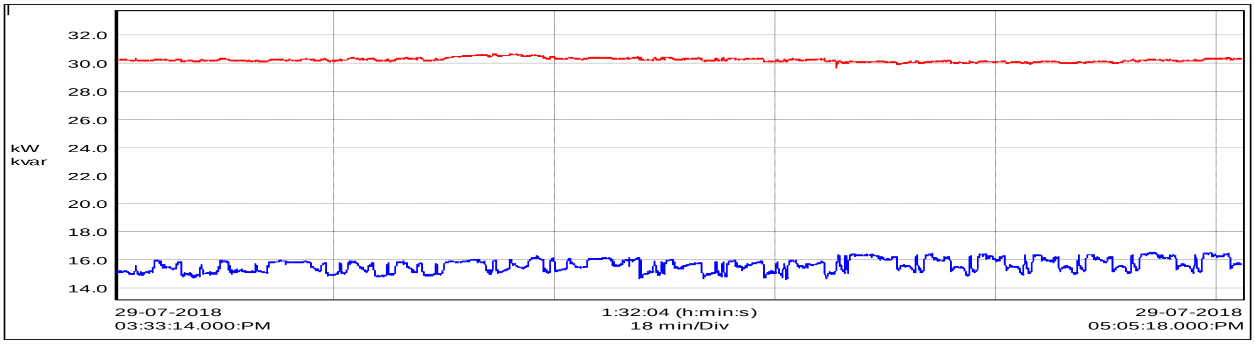

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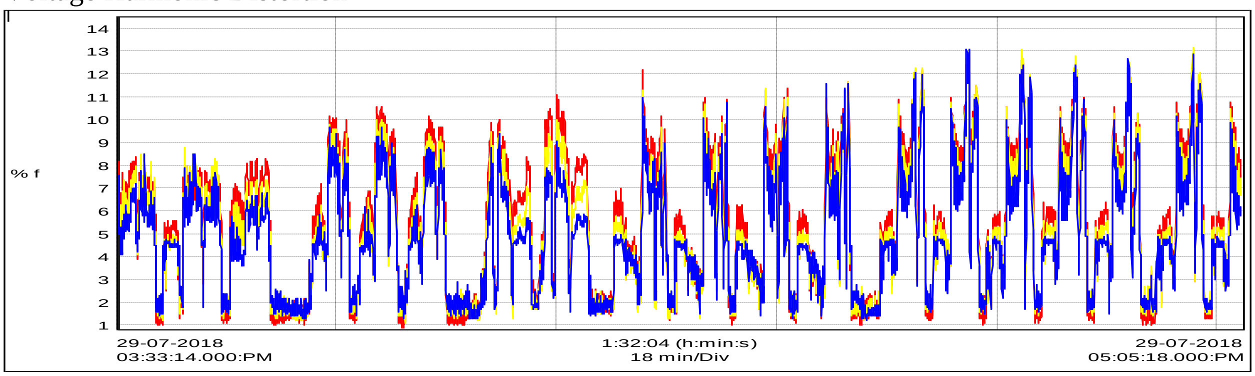

Current Harmonic Distortion