Report on Power Quality Audit Conducted at:

A global & leading Tyre Company Ltd. China

Dates: 12th Oct 15 to 17th Oct 15.

Audit team:

SAS Powertech:

Mr. Narendra Duvedi. – Lead Auditor

- Electrical Engineering Graduate with Exposure to power electronics and more than 30 years experience.
- Bureau Of Energy Efficiency – Government Of India certified ENERGY AUDITOR
- BVQI certified Lead Auditor for ISO 50001.
- Chartered Engineer.

Mr. Rahul Deshpande. –

- Electrical Engineering Graduate with 15 years experience.
- Bureau Of Energy Efficiency – Government Of India certified ENERGY AUDITOR

Mr. Vijay Sonawane –

- Diploma Electrical Engineering with more than 10 years field experience.
- Measurement engineer.

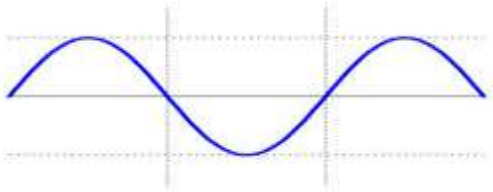
Goodyear:

Ms. Fiona, Mr. Frank and their team

INDEX		
Sr.	**Description**	**Page No**
1	A note on Power Quality	
2	Executive Summary	
3	Description Of electrical Infrastructure	
4	Methodology of Audit	
5	Analysis of historical data on Energy consumption	
6	Division of Electrical load between various sections	
7	Power Quality parameters at 10KV PCC	
8	Summary of data collected at Metering room substation	
9	Recommendations to achieve unity power factor at LT secondary of each transformer	
10	Detail transformer wise Loading and analysis of bus section and transformer wise reactive power requirement and current harmonics	
11	Exact recommendation of required retrofits and new equipment required for power factor improvement and harmonic mitigation.	
12	Report on different meetings conducted with maintenance teams.	

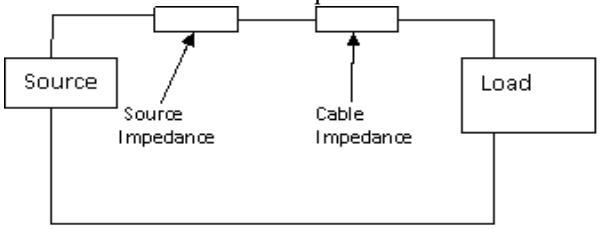
A note on electrical Power quality, it's importance, effects and remedies.

- Commercially available AC – alternating electric power is usually available in "Sinusoidal" form. The main specifications of this are "Value of Voltage", "Waveform" and "Frequency".



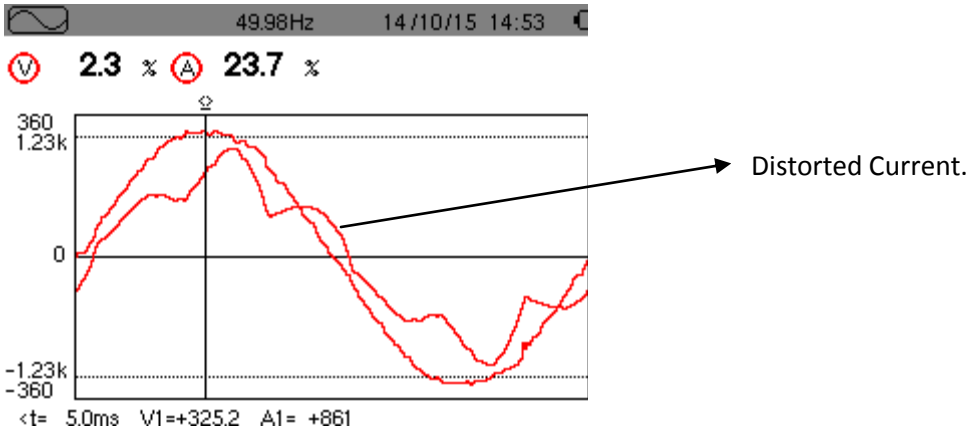
- In case of 50Hz frequency, each cycle takes 20msec to complete. Frequency variation can cause trouble to connected load and as such it should be as constant as possible. Iron losses in motors, transformers etc change with frequency. The Grid power frequency is usually maintained within +/- 1Hz.

- The electric distribution equivalent circuit is as follows

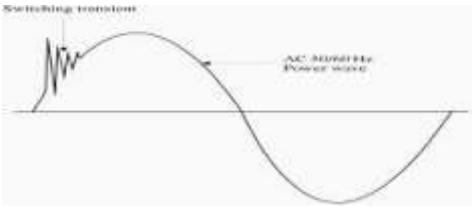


The waveform of voltage available across load may get affected and deviate from Sinewave due to various reasons like drawing non sinusoidal currents containing harmonic components, defects in generators (Alternators or UPS systems), higher source impedance, overloading, etc. If (Source+Cable) impedance is negligible in comparison with Load impedance under all conditions, the source is termed as "Infinite bus" and then the problems are less.
The distorted voltage waveform can affect equipment performance. Such distorted voltages and currents can result into overheating of cables, transformers etc and can also cause excessive voltage drops.

Example of distorted current – data collected at transformer 1101 at Leading globalChina.



- Voltage disturbances could be “sub - cycle” as shown bellow or “Sustained”. Sub - cycle disturbances are known as transients and sustained disturbances are known as “Sags” or “Swells”. A sub classification is also known as “Voltage dip”



- These power quality issues if present in available power supply can affect performance and reliability of critical loads like complex automation systems, communication devices and digitally controlled power electronic circuits and reflect into unwanted resetting digital circuits like PLCs, VFD controllers etc.

- In practise, the source, transmission level transformers, switchgear and part of cabling belongs to utility company and once the feeder enters the premises of consumer, the infrastructure belongs to consumer. If large amount of harmonic currents are demanded by load and are required to be supplied by utility company, the utility company equipment is also subjected to ill effects of these power quality disturbances. In view of limiting commercial impact of this demand raised by consumer, normally utility companies bind consumer into legal compliance requirements related to power quality. Such requirements usually are based on some international standards. One such standard related to harmonic compliance applicable at “Point of common coupling” or PCC is IEEE 519 1992.

- Voltage regulation and dynamic response (Value of Dip or Rise and Time required for correction) are noticeable parameters of small capacity power supplies like DG sets, UPS systems etc, which affect performance of critical loads if found beyond permissible limits. The applicable standard related to assess performance of UPS systems is IEC 62040 – 3

- In view of avoiding effects of power quality on setup, it is required that available quality of power should be matched with specific requirement of critical equipment for smooth and reliable operation. If this is not possible then a suitable power conditioning equipment like UPS / stabilizer / Series voltage correctors etc needs to be added in series after matching UPS output specifications with requirement of critical load.

Visible effects of power quality issues:-

- Equipment malfunction.
- Equipment failure, especially related to controlled rectifiers and front end components.
- Control Power supply failures and associated damages to subsequent circuits.
- Abnormal heating of electrical conductors, nuisance tripping.
- Insulation failures.
- Loosing Load and Motor alignment frequently due to harmonic torques developed in the motor.

Electrical compatibility and reliable equipment design.

Although providing good quality of power is important, “Electrical Compatibility” is more critical. It is always advisable that the equipment manufacturer should decide detail power quality and workman ship compatibility requirements, exchange them among all stakeholders – namely

1) Critical equipment manufacturer,
2) End user,
3) UPS / SERVO STABILIZER / TRANSFORMER manufacturer
4) Contractors involved in executing the project.

Depending upon project value and seriousness of known issues related to power quality, a third party compliance / validation audit can be called for at the time of commissioning / execution and / or after about one month of operation. During such audits one can also decide periodicity of such inspection along with SOPs for predictive and preventive maintenance to get continual satisfactory performance from the equipment. During such audit, legal compliance as per requirements of utility company can also be checked.

Lastly one should also note that there could be design related issues with the equipment, which can affect reliable operation. Such issues may affect the performance despite of offering good quality power. It is very important to consider this while undertaking root cause analysis of failure of an equipment working on electrical power.

Acceptability of Power quality parameters have been decided in various international standards published by reputed world famous organizations like IEEE, IEC, NEMA etc. If equipment manufacturer commits that he can accept the power as per these standards, then the power quality can be checked as per these standards during the audit, otherwise the compliance has to be ensured against requirements of equipment manufacturer.

Executive Summary of findings and recommendations:

1) Leading globalDalian Tyre Manufacturing company Ltd Dalian China has a well designed, well implemented electrical infrastructure. The designer has used trusted conventional ways for making available reliable and trouble free electrical power to a modern automated tyre manufacturing facility.

2) 66 KV electric power supply available from utility fulfils all power quality requirements and the same is quite reliable also (Plant reports that there was no failure in available supply in last 4 years)

3) The voltage regulation is within +/- 2.5% and appears to be electronically corrected from utility side without introduction of voltage distortion. Subsequently number of tap changes on 31.5MVA main transformer are also very moderate. The power analysers were set to record sub cycle voltage disturbances, sags or swells for almost 72 hours on main 10KV bus. This was further repeated on Mixing section feeders which involve heavy loads. The analysers did not record even a single event during this time.

4) Plant has total running load of about 20MW peak, out of which 31% is consumed by Mixing section and another 31% by utilities. Both these loads are mostly non linear demanding harmonic currents.

5) The plant has adopted traditional passive harmonic mitigation techniques at load end which include
   a) All transformers not loaded for more than 50%,
   b) All large load centres have multi pulse transformers before rectifiers.
   c) All moderate non linear loads which mostly work in pairs have one DELTA – DELTA and DELTA – STAR transformers at front end.
   d) Line and Load reactors are installed where ever applicable.
   e) Detuned power factor correction at HT and LT level with intention to damp resonance where ever possible.

   These majors have avoided objectionable voltage distortion at all levels in distribution and also have confined current harmonics circulating between load and these passive filters.

6) At almost all LT level distribution centres, at present plant has used contactor based detuned passive power factor correction. These are close loop systems with typical feedback from one phase and use "Contactor based step switching". Most of the plant processes are batch type and as such the *KW load is continuously variable* and so the KVAR or reactive power demand. It is noticed that the present correction, with it's inherent delay (Contactor correction has delays in seconds, continuous operation damages the contactors also) cannot maintain the power factor closely at unity and always results in under or over correction. This reflects in aggravated local resonance and increased KVA demand. The same is passed on to 10KV HT side and most of the control room transformers. HT cables from control rooms to main HT distribution located on ground floor of main substation carry these extra currents.

7) In some of the 400KVAR power factor correction panels, this resonance is resulting into overheating of capacitors and reactors and your team has observed failures . During audit at utility section control room, abnormal heating smell was observed by auditors in one 400KVAR panel and was disconnected immediately.

8) This report gives details of unbalanced KVAR at all those bus sections which are recorded during the audit. If these are corrected at load end, using thyristor switched detuned filters, the 10KV level HT current can drop up to 200Amps and associated KVA demand also will drop. Active

harmonic filters may also be installed at selective load centres to get reduction in current harmonics. The detail report has necessary recommendations towards retrofitting existing detuned APFC panels with thyristor switches.

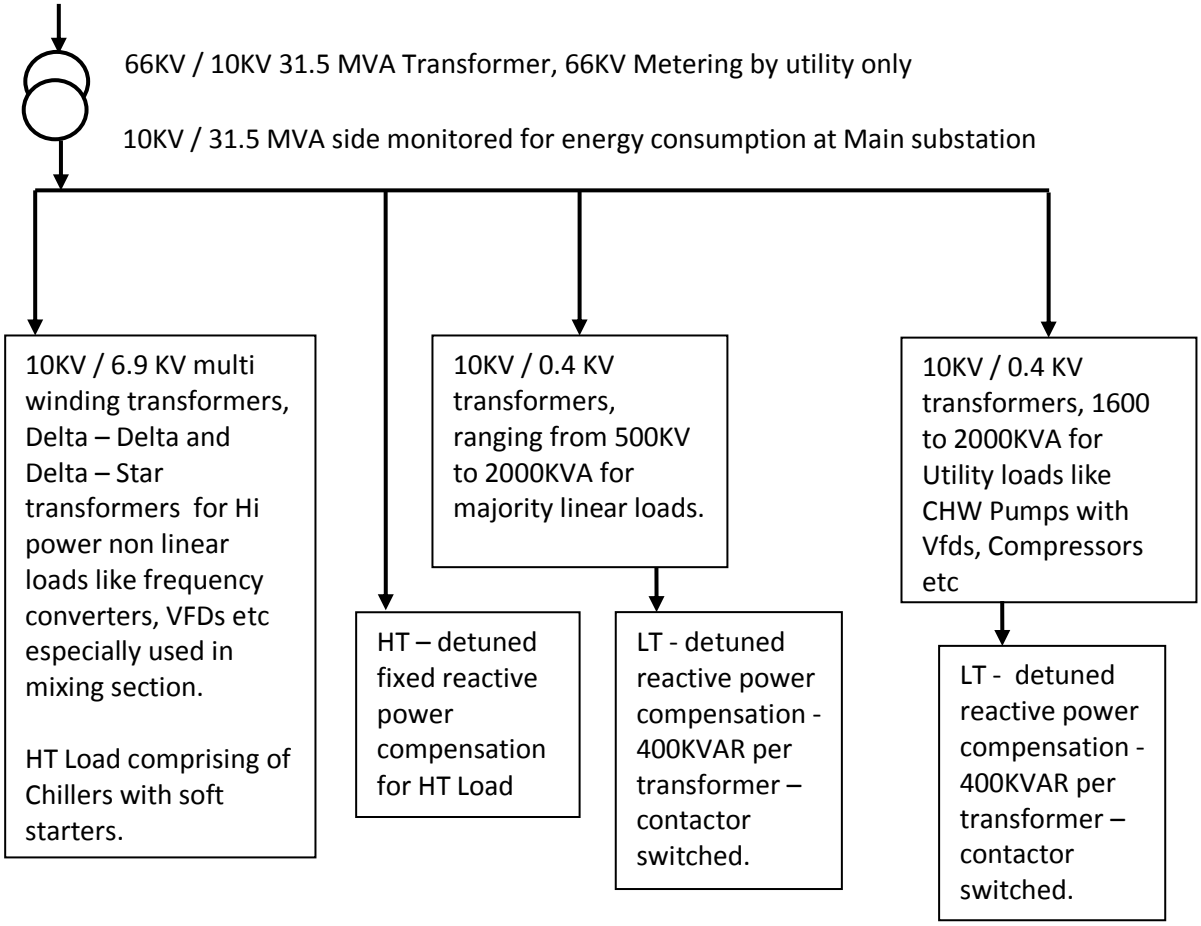
9) The plant has used Pile earthing which was done while erecting metallic columns of various plant buildings. With the help of drawings, the staff explained the earthing grids created bellow the ground. The effective loop earthing resistance was checked in each control room and the same was found to be much bellow 1 ohm. All internally run earth strips / cables are welded except for last mile bolted connection given to equipment. This has ensured a reliable earthing system with much longer life than any other conventional system. This system has ensured required safety from accidental electrical shock and has provided "Good earth" for all critical systems reducing possibility of malfunction due to electrical noise.

10) We are compiling all recorded data and will submit the same to you separately with easy to use indexing. This can remain with you as power quality base line data and would be useful in future. The size of this data would be huge and we will submit the same in the form of a CD in due course of time.

---------- END OF SUMMARY----------

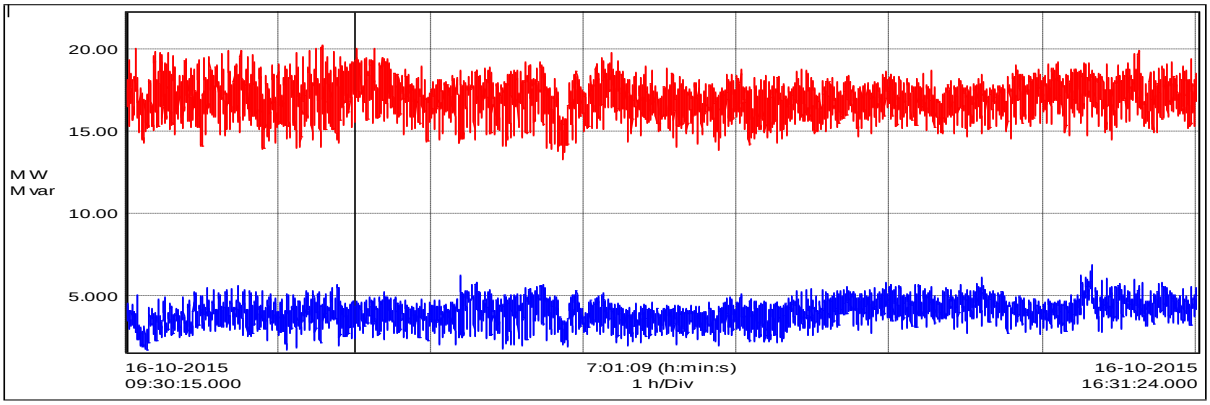
Description of electrical infrastructure at a Leading global Tyre Manufacturing Co Ltd. in China

66KV from 220KV substation



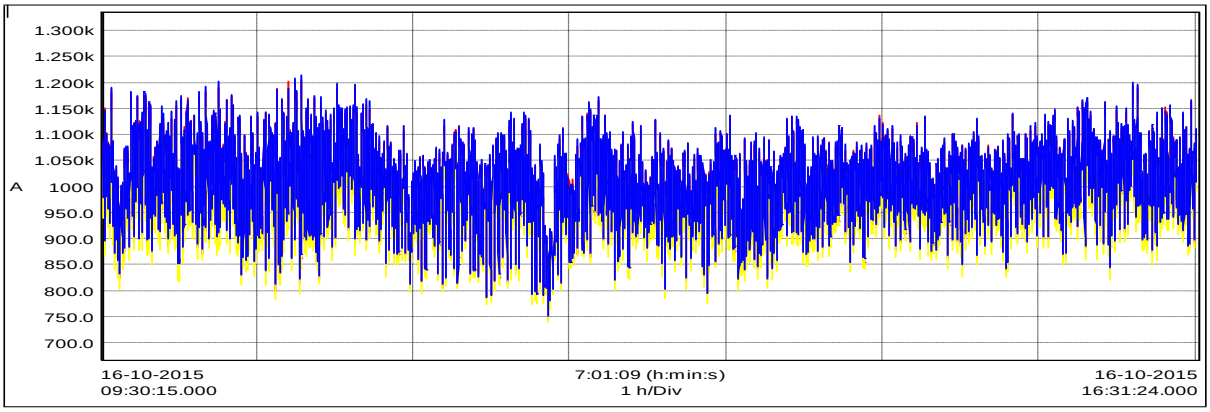
1) The plant runs on 66 KV input voltage available from Grid. The plant has 66Kv / 10KV 31.5MVA main transformer. The contract demand is also 31.5 MVA.
2) EHT supply side has GIS switchgear, whereas 10KV distribution is vacuum circuit breaker based. The plant has about 50 dry type transformers of various ratings and secondary voltages installed in various control rooms located as per plant requirement. LT voltage (380V typical) is further distributed to various loads through LT panels in control rooms.
3) Few HT loads receive required HT voltage as secondary voltage from respective transformers. These loads include HT motors for Mixers, Extruders, Chillers etc.
4) First floor of main substation houses bus protection and energy metering. This floor also has fixed HT detuned capacitors which help correcting HT load power factor.
5) Each control room has required HT distribution and transformer protection. Arrangement has been made to provide required HT redundant supply through different bus wherever process demands the same. LT distribution also has been equipped with "Tie Breakers" to provide alternate supply to critical processes.
6) LT side of each transformer is equipped with 400KVAR detuned APFC with contactor switching.
7) Electrical load continuously varies between 17MW to 20MW at most upstream level where as the same is variable at LT level as demanded by process. Plant runs for 24 x 7 all 30 days in any month.

HT – 10 KV PCC – KW loading pattern (7 hours)



KW plant load varies from 15MW to 20MW. This being a batch processing plant involving different processes, the load varies continuously within above range. This recording also shows that reactive power requirement also varies between 1MVAR and 5 MVAR.

HT – 10 KV PCC – Current pattern. (7 hours)



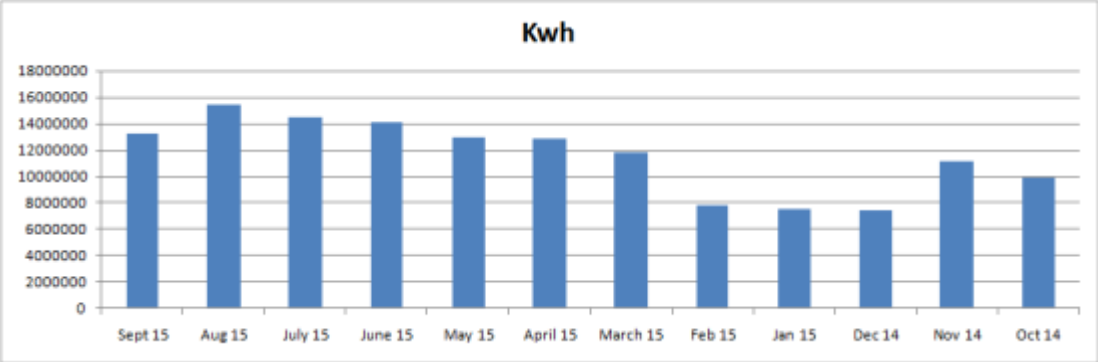
Methodology of Power quality audit conducted:

1) Introduction to power quality (PQ) parameters and their effects to Leading globalteam through an opening meeting and presentation.
2) Understand electrical energy flow within the plant.
3) Start Monitoring incoming side PQ parameters at most upstream level for longer duration.
4) Collect historical data on energy consumption at various points monitored by plant for one climatic cycle. Also collect 12 months Kwh consumption, preferably from energy bills.
5) Monitor PQ parameters at various downstream levels, at each level filter the data for maximum recorded disturbance and proceed with further downstream recording.
6) Conduct meetings with plant maintenance teams to understand nature of electrical failures / automation failures and their frequency. Try and relate these with PQ parameters available to their respective shops.
7) Monitor sub cycle level disturbances where ever required.
8) Undertake infrared thermography of problem areas to rule out / locate possibility of loose connections creating power quality issues.
9) Check earthing and grounding infrastructure at plant to insure adequacy.

10) Analyse all above collected data and prepare report based on above to locate issues related power quality and remedies to rectify the same if any.

Analysis of historical data collected at plant.

Monthly KWh consumption for last one year



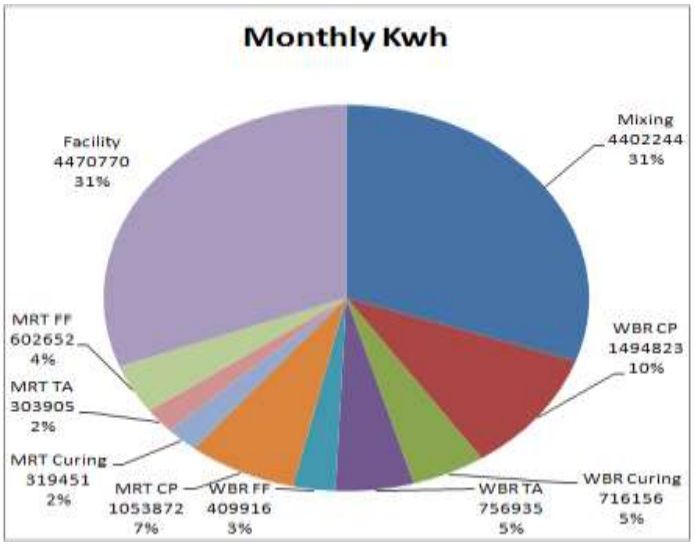
This bar graph shows that electrical consumption in Aug 2015 is maximum. This total consumption would be proportional to volume of production and will also depend on season. The utility consumption in plant ventilation will increase during summer, which would be peak during August. Considering average monthly consumption to be 13 million Kwh, average KW load would be around 18MW. It can be seen from above graphs that the audit was conducted with peak load varying between 15 to 20MW.

Actual data on Aug and Sept 15 shows that increase in consumption of utility or facility section in Aug 15 is 30% taking Sept 15 as base. However total plant consumption shows 16% increase. We have compared this to explain the fact that during audit, total average MW load has touched the maximum value (20MW) which it would have touched in Aug 15.

Division of load between various sections based on Sept 15 data as per computerised energy monitoring system available in control room.

Sr.	Transformer Name/ Section Name	Monthly Kwh	KW
1	Mixing	4402244	6114.23
2	WBR CP	1494823	2076.14
3	WBR Curing	716156	994.66
4	WBR TA	756935	1051.30
5	WBR FF	409916	569.33
6	MRT CP	1053872	1463.71
7	MRT Curing	319451	443.68
8	MRT TA	303905	422.09
9	MRT FF	602652	837.02
10	Facility	4470770	6209.40
		14530724	20181.56

All these sections are fed through various 10KV BUS sections and associated standby arrangement.



This division shows that 62% energy is spent for "Mixing section" and "Facility" section. These two sections have equal contribution and also account for most of the non linear load.

1) We monitored "Main 10KV secondary feeder" for more than 24 hours using high - end power analysers. 24 hours recording was done to monitor min, max, avg, rms power quality parameters and energy parameters.

2) We also monitored sub - cycle thresholds and alarms to understand transient behaviour of this "main 10KV secondary feeder" and locate any disturbance generated either internally or externally.

3) Each 10KV bus sub section associated with 1A,2A,3A,4A and 1B, 2B,3B, 4B was monitored and recorded for 15 to 20 mins. The historical data on monthly consumption of these bus sections was taken from plant EMS and compared with actual load while recording.

4) From above data the bus sections drawing current with harmonic distortion >10% and having under compensated or over compensated reactive power were selected for downstream study.

5) The control rooms connected to these selected bus – sections were then studied in detail by measuring and recording individual transformer LT side in these control rooms.

6) When downstream data was recorded, one power analyser was continuously connected to "Main 10KV secondary feeder" and it was ensured that plant is optimally loaded. Transformer wise monthly KWH data was collected from plant energy monitoring system (EMS) and KW load was calculated prior to reaching the load station. In most of the cases the load during recording was either same or more than the historical data.

7) We conducted 4 meetings with different sectional maintenance heads and their teams to understand maintenance related recurring or unexplainable issues if any and to assess whether they are due to power quality problems.

8) We have gone through relevant sections of "National Electricity Code" and "Contract between Good year and Electricity Supply Company" to know contractual and statutory obligations and compliance requirements related to Electrical Power Quality as applicable to Good Year. We will submit our comments related to this separately as we require translation to English to understand the same better. We also request you to let us know "Fault Level" available at 66KV. The document mentions that the incoming 66KV line originates from a nearby 220KV substation installed by utility company, but the transformer capacity and % impedance is not known.

Power Quality Parameters at 10 KV PCC

Load profile and Power Quality Parameters for 7 hours of normal working at 10 KV PCC				
Parameter with Unit	**Unit**	**Average**	**Minumum**	**Maximum**
Load profile				
Active Load	MW	17.024	13.286	20.272
Reactive Power Demand	Mvar	4.033	1.723	6.957
Apperant Demand	MVA	17.508	13.449	20.742
Line current RMS A 1	Amps	1002	747	1206
Line current RMS A 2	Amps	978	741	1168
Line current RMS A 3	Amps	1006	751	1214
Current total harmonic distortion A1	%	2.017	1.3	5.2
Current total harmonic distortion A2	%	2.243	1.5	4.5
Current total harmonic distortion A3	%	2.128	1.4	5.2
Current Imbalance I unb	%	1.732	0.6	2.6
K Factor Line 1		1.039	1.01	1.13
K Factor Line 2		1.038	1.01	1.1
K Factor Line 3		1.04	1.01	1.13
Power factor 1		0.969	0.92	0.992
Power factor 2		0.978	0.935	0.996
Power factor 3		0.97	0.922	0.993
Power factor mean		0.973	0.926	0.994
Power Quality Parameters while supporting above laod				
Parameter with Unit	**Unit**	**Average**	**Minumum**	**Maximum**
Frequency Hz		50.031	49.93	50.09
Line to Line Voltage U 1	KV RMS	10.15	9.93	10.51
Line to Line Voltage U 2	KV RMS	10.162	9.95	10.52
Line to Line Voltage U 3	KV RMS	10.163	9.95	10.51
Voltage total harmonic Distortion U1	THDV %	1.526	0.8	2.7
Voltage total harmonic Distortion U2	THDV %	1.499	0.7	2.6
Voltage total harmonic Distortion U3	THDV %	1.556	0.8	2.7
Voltage imbalance V unb	%	0.114	0	0.4
Fliker Pst U1		0.547	0.43	0.94
Fliker Pst U2		0.552	0.46	0.7
Fliker Pst U3		0.553	0.43	1.04
Voltage transient occurance recording. Transient threshold set at +/- 33% of Line to Neutral voltage.			Transients recorded in 48 hours	NIL
Voltage Alarm recording. Threshold set at +/- 5% of 10 KV			Alarms recorded in 48 hours	NIL

Comments and Remarks

1) 66KV side measurements were not possible as entire metering on this side is sealed by utility company. Hence all the measurements are carried on 10KV side and further downstream LT side.

2) It can be seen that there is reactive power requirement on continuous basis and the average is around 4MVAR. (Highlighted as above). This can be reduced to some extent if individual transformers in control rooms can be maintained at unity power factor on continuous basis.

3) This will result into some reduction in demand and also in fixed charges payable to utility company against the demand which at present are 33RMB / KVA.
4) As highlighted in table of Power quality parameters, maximum voltage harmonic distortion is slightly on higher side at 2.7%. This will reduce if all downstream transformers reduce supplying reactive power. This excess supply is result of 400KVAR correction given to each control room transformer, which is contactor controlled. The change in reactive power requirements as a result of heavily fluctuating load is much faster compared to rate of change offered by contactor switching.

5) We are in the process of understanding power factor incentive available from the utility documents given to us. In case you know the procedure to calculate the same, kindly let us know. This will be helpful in calculating payback for the investments required if any for maintaining the overall power factor at unity. (Just to give you an Idea, in Indian conditions for a typical bill of 6700000 RMB per month, the incentive would be 400000 RMB)

6) As per EMS data, around 30% load appears to be HT load. The power factor for this will have to be corrected at HT level. The investment here will have to be justified only against incentives if any.

7) Maintaining unity power factor by controlling reactive compensation and harmonic distortion goes hand in hand and in turn can affect power quality, if executed using a wrong method.

Data Collected at Metering room substation									
Sr. No.	Department	Control Room No	KWH	KW	Actual KW	Vthd %	Ithd%	Pf	KVAR
1	Mixing	3B-1	705360	980	1600	1.5	12	0.64+	-640
2		3B-2	833860	1158	1800	1.4	10.5	0.94+	-234
3		3B-3	1026160	1425	1800	1.2	10.2	0.87+	-295
4		3A-1	782320	1087	1962	2.1	25.6	0.93	1024
5		3A-2	991440	1377	0				
			4339140	**6027**	**7162**				
6	WBR (FF/TA/CURING)	1A-5	140560	195	194	2	32.4	0.94	68
7		1B-5	261520	363	204	1.2	22	0.73+	-173
8		1A-3	352400	489	481	2.7	5.8	0.94	240
9		1B-3	371920	517	655	1.1	11.7	0.64+	-590
10		1A-4	364720	507	543	2.4	10.6	0.99	194
		1B 4	0	0	550	1.2	10	0.96	158
11		1B-2	304880	423	266	1.2	6.7	0.64+	-305
12		1A-2	265760	369	460	1.9	8.4	0.99	94
13		1B-1	134640	187	126	1.9	7	0.82	96
14		1A-1	748240	1039	1199	2	16.6	0.97	278
			2944640	**4090**	**4678**				
15	CP/MRT TA,(CUR,FF	2A-2	392000	544	507	2	12.2	0.99	155
16		2B-2	0	0	471	1.3	10	0.64+	-542
17		2A-3	60160	84	119	2	7.3	0.95	44
18		2B-3	234880	326	344	1.6	19	0.65+	-363
19		2A-4	293120	407	504	2.1	10.4	0.99	188
20		2B-4	308000	428	168	1.5	11	0.28+	-694
21		2A-5	208400	289	289	2.1	23.7	0.91	133
22		2B-5	124960	174	0				
			1621520	**2252**	**2402**				
23	FAC	4A-2	187840	261	310	2.2	2.1	0.78	247
		4B-2	171520	238	0				
24		4A-1	1538000	2136	2619	2.1	3.5	0.96	807
25		4B-1	1043760	1450	1080	1.9	12	0.73+	-998

1) Although overall power factor at "Main 10KV secondary" at main substation HT distribution is maintained close to unity with the help of HT reactive power compensation, as shown above at each bus section and at downstream control rooms HT distribution, the power factor at 10KV is not maintained at unity.

2) As can be seen from last column of above table, the reactive power requirement is substantial and for few bus sections, there is requirement whereas for others one can see over compensation.

3) If this reactive power requirement is brought down close to zero, current handled by transformers in control rooms and HT cables running up to 10KV HT distribution will reduce.

4) This action will also bring down resonance between transformer impedance and present reactive power compensation, where ever exists. This will contribute in reducing harmonic currents handled by transformers in control rooms and HT cables running up to 10KV HT distribution.

5) Both these points will contribute in reducing distribution loss to some extent.

Data Collected at Metering room substation											
Sr. No.	Department	Control Room No	KWH	KW	Actual KW	Vthd %	Ithd%	Pf	KVAR	I actual	I @ unity PF
1	Mixing	3B-1	705360	980	1600	1.5	12	0.64	-640	144.34	92.38
2		3B-2	833860	1158	1800	1.4	10.5	0.94	-234	110.56	103.93
3		3B-3	1026160	1425	1800	1.2	10.2	0.87	-295	119.46	103.93
4		3A-1	782320	1087	1962	2.1	25.6	0.93	1024	121.81	113.28
5		3A-2	991440	1377	0						
			4339140	**6027**	**7162**						
6	WBR (FF/TA/CURING)	1A-5	140560	195	194	2	32.4	0.94	68	11.92	11.20
7		1B-5	261520	363	204	1.2	22	0.73	-173	16.13	11.78
8		1A-3	352400	489	481	2.7	5.8	0.94	240	29.54	27.77
9		1B-3	371920	517	655	1.1	11.7	0.64	-590	59.09	37.82
10		1A-4	364720	507	543	2.4	10.6	0.99	194	31.67	31.35
		1B 4	0	0	550	1.2	10	0.957	158	33.18	31.76
11		1B-2	304880	423	266	1.2	6.7	0.64	-305	24.00	15.36
12		1A-2	265760	369	460	1.9	8.4	0.99	94	26.83	26.56
13		1B-1	134640	187	126	1.9	7	0.818	96	8.89	7.27
14		1A-1	748240	1039	1199	2	16.6	0.97	278	71.37	69.23
			2944640	**4090**	**4678**						
15	CP/MRT TA,(CUR,FF	2A-2	392000	544	507	2	12.2	0.99	155	29.57	29.27
16		2B-2	0	0	471	1.3	10	0.64	-542	42.49	27.19
17		2A-3	60160	84	119	2	7.3	0.95	44	7.23	6.87
18		2B-3	234880	326	344	1.6	19	0.65	-363	30.56	19.86
19		2A-4	293120	407	504	2.1	10.4	0.99	188	29.39	29.10
20		2B-4	308000	428	168	1.5	11	0.28	-694	34.64	9.70
21		2A-5	208400	289	289	2.1	23.7	0.91	133	18.34	16.69
22		2B-5	124960	174	0						
			1621520	**2252**	**2402**						
23	FAC	4A-2	187840	261	310	2.2	2.1	0.78	247	22.95	17.90
		4B-2	171520	238	0						
24		4A-1	1538000	2136	2619	2.1	3.5	0.96	807	157.51	151.21
25		4B-1	1043760	1450	1080	1.9	12	0.73	-998	85.42	62.36
										1266.88	**1053.75**

- Last three columns of above table show effect of maintaining individual bus section power factor at unity. Total HT current can drop by almost 20%.

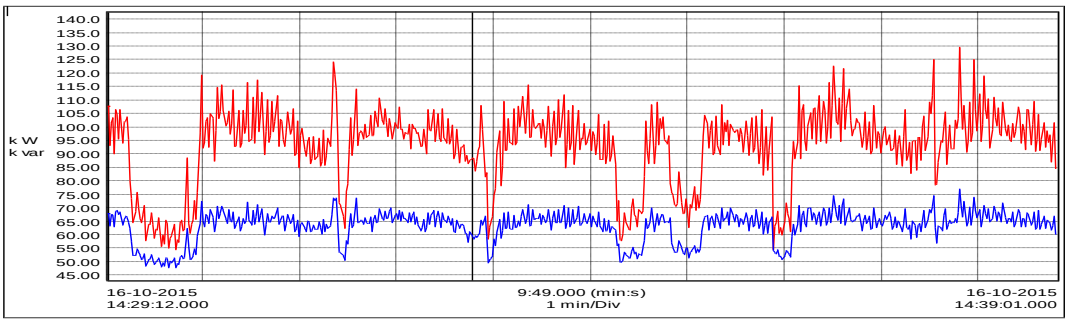
- Almost all loads are periodic in nature and change continuously. Present reactive power compensation applied to the LT side of control room transformers is of "Contactor Switched detuned capacitor type". Each panel consists of 400KVAR contactor switched detuned capacitors. Due to fast changing load, these panels cannot track reactive power requirement as contactors require time in seconds to switch and offer the correction. End result is reactive power at each transformer is either under or over corrected. Resulting into increased line current and increased current harmonics.

- This increased line current and current harmonics are handled by transformers and HT cables up to main substation.

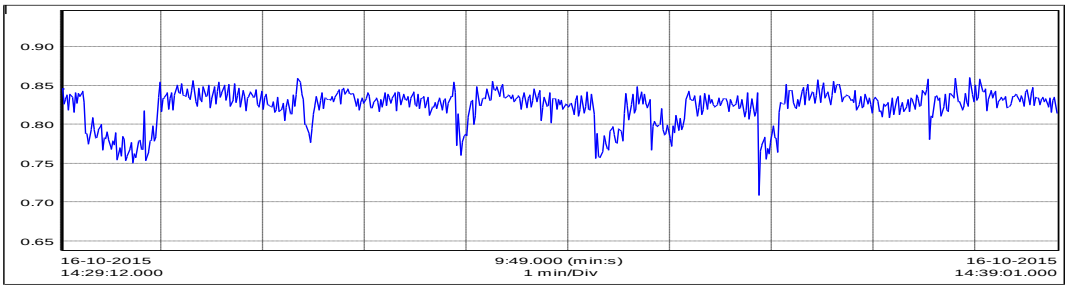
- If thyristor switched fast acting correction is used at LT side of these transformers, there will be reduction in KVA requirement, which will contribute in reduction of charges paid for demand.

Typical Transformer Loading for transformers installed in various control rooms.

KW/ KVAR



Power Factor



There are about 50 such transformers with 10KV/0.4KV voltage ratio with most of them having rating of 1600KVA. Each of these transformers at present is equipped with 400KVAR detuned capacitors which are contactor switched.

We recommend following to achieve close to unity power factor at each transformer secondary.

1) 400 KVAR reactive power compensation panel should be checked thoroughly for current feedback from LT incomer, healthiness of PF controller and other associated switchgear and repaired wherever necessary.

2) The contactors in these panels should be replaced by thyristor switches so that, fast acting correction can be offered resulting into improved average power factor. This retrofitting is possible in present panels.

3) One step may be replaced by 25 KVAR so that final step size can also reduce keeping over correction under control. (Note here that if all 50 panels settle offering 50 KVAR extra, total over correction would be 2500KVAR.)

Detail transformerwise load from EMS

SR	Bus	Tr Name CR No	Voltage Ratio	KVA	Monthly Kwh	KW	KVAR Range	
		Mixing						
1	3B1	Tr101/CR1	10/0.4kV	1600	340457	472.86	-425.00	-175.00
2	3B1	Tr102/CR1	10/6.9kV	2880	309636	430.05		
3	3A1	Tr201/CR2	10/0.4kV	1600	242830	337.26		
4	3A2	Tr202/CR2	10/6.9kV	2880	563997	783.33		
5	3B2	Tr301/CR3	10/0.4kV	1600	280001	388.89	50.00	250.00
6	3B2	Tr302/CR3	10/6.9kV	2880	574475	797.88		
7	3A2	Tr401/CR4	10/0.4kV	1600	315491	438.18	0.00	350.00
8	3A2	Tr402/CR4	10/6.9kV	2880	713087	990.40		
9	3B3	Tr501/CR5	10/0.4kV	1600	363952	505.49	40.00	55.00
10	3B3	Tr502/CR5	10/6kV	2000	348688	484.29		
11	3B3	Tr503/CR5	10/6kV	2000	349630	485.60		
					4402244	**6114.23**		
		WBR CP						
12	1A1	Tr1101/CR11	10/0.4kV	1600	284528	395.18	110.00	140.00
13	1A1	Tr1201/CR12	10/0.4kV	1600	244368	339.40	40.00	180.00
14	1A1	Tr1203/CR12	10/0.48kV	750	120667	167.59		
15	1A1	Tr1204/CR12	10/0.48kV	750	121070	168.15		
16	1B1	Tr1301/CR13	10/0.4kV	1600	116446	161.73		
17	1B1	Tr1302/CR13	10/0.48kV	500	10572	14.68		
18	1B1	Tr1303/CR13	10/0.48kV	500	10819	15.03		
19	1A2	Tr1401/CR14	10/0.4kV	1600	225976	313.86	0.00	350.00
20	1A2	Tr1402/CR14	10/0.48kV	750	47411	65.85		
21		Tr1403/CR14			0	0.00		
22	1B2	Tr1501/CR15	10/0.4kV	1600	238718	331.55	100.00	300.00
23	1B2	Tr1502/CR15	10/0.48kV	750	32798	45.55		
24	1B2	Tr1503/CR15	10/0.48kV	750	41450	57.57		
					1494823	**2076.14**		
		WBR Curing						
25	1B3	Tr1601/CR16	10/0.4kV	1600	379159	526.61	100.00	200.00
26	1A3	Tr1602/CR16	10/0.4kV	1600	336997	468.05	200.00	300.00
					716156	**994.66**		
		WBR TA						
27	1B3	Tr1603/CR16	10/0.4kV	1600	184776	256.63	90.00	115.00
28	1A3	Tr1604/ CR16	10/0.4kV	1600	22152	30.77		
29	1B4	Tr1701/CR17	10/0.4kV	1600	175222	243.36	100.00	350.00
30	1A4	Tr1702/ CR17	10/0.4kV	1600	374785	520.53	50.00	200.00
					756935	**1051.30**		
		WBR FF						
31	1B5	Tr1801/CR18	10/0.4kV	1600	266917	370.72	100.00	200.00
32	1A5	Tr1802/CR18	10/0.4kV	1600	142999	198.61	0.00	80.00

Detail transformerwise load from EMS

SR	Bus	Tr Name CR No	Voltage Ratio	KVA	Monthly Kwh	KW	KVAR Range	
		MRT CP						
33	2A2	Tr2101/CR21	10/0.4kV	1600	316206	439.18	-150.00	-400.00
34	2A2	Tr2102/CR21	10/0.48kV	750	0	0.00		
35	2A2	Tr2103/CR21	10/0.48kV	750	18064	25.09		-220.00
36	2B2	Tr2201/CR22	10/0.4kV	1600	349822	485.86		
37	2B2	Tr2202/CR22	10/0.48kV	750	29412	40.85		
38	2B2	Tr2203/CR22	10/0.48kV	750	41032	56.99		
39	2B3	Tr2301/CR23	10/0.4kV	1600	239836	333.11	-240.00	-120.00
40	2B3	Tr2302/CR23	10/0.4kV	1600	59500	82.64	-20.00	160.00
41	2B3	Tr2303/CR23			0	0.00		
					1053872	**1463.71**		
		MRT Curing						
42	2B4	Tr2401/CR24	10/0.4kV	1600	157627	218.93	-300.00	-150.00
43	2A4	Tr2402/CR24	10/0.4kV	1600	161824	224.76	0.00	300.00
					319451	**443.68**		
		MRT TA						
44	2B4	Tr2403/CR24	10/0.4kV	1600	168194	233.60	-180.00	-100.00
45	2A4	Tr2404/CR24	10/0.4kV	1600	135711	188.49	-50.00	150.00
					303905	**422.09**		
		MRT FF						
46	2B5	Tr2501/CR25	10/0.4kV	1600	189187	262.76	125.00	300.00
47	2A5	Tr2502/CR25	10/0.4kV	1600	211135	293.24	120.00	220.00
48		Tr2505/CR25			202330	281.01		
					602652	**837.02**		
		Facility						
49	4B1	Tr3001/CR30 HV2	10/0.4kV	1600	334623	464.75		
50	4A1	Tr3002/CR30 HV 7	10/0.4kV	1600	369046	512.56	175.00	375.00
51	4B1	Tr3003/CR30 HV 3	10/0.4kV	1600	272738	378.80	-100.00	40.00
52	4A1	Tr3004/CR30 HV 8	10/0.4kV	1600	307982	427.75	30.00	125.00
53	4B1	Tr3005/CR30 HV 4	10/0.4kV	1600	71948	99.93	135.00	145.00
54	4A1	Tr3006/CR30 HV 9	10/0.4kV	1600	202542	281.31		
					1558879	**2165.11**		
		Other utility load HT						
55		Canteen 72			18121	25.17		
56	4B2	32HV 2 - Chiller 1			55041	76.45		
57	4B2	32HV 3 - Chiller 3			60268	83.71		
58	4B2	32HV 4 - Chiller 5			0	0.00		
59	4A2	32 HV 5 - Chiller 2			8052	11.18		
60	4A2	32HV 6 - Chiller 4			123647	171.73		
61	4A2	32HV 7 - Spare			0	0.00		
62		30HV 10 - HV Comp			712622	989.75		
63		30HV 5 - Nitrogen			375261	521.20		
					1353012	**1879.18**		
					12971845	**18016**		

Comments:

1) Above table shows that various transformers located in control rooms are not loaded beyond 50%.

2) It was observed that each of them has 200KVAR+200KVAR detuned filter with 50KVAr steps which are contactor switched. These panels are supposed to work in automatic mode with a Power factor controller receiving current feedback from transformer main LT incomer.

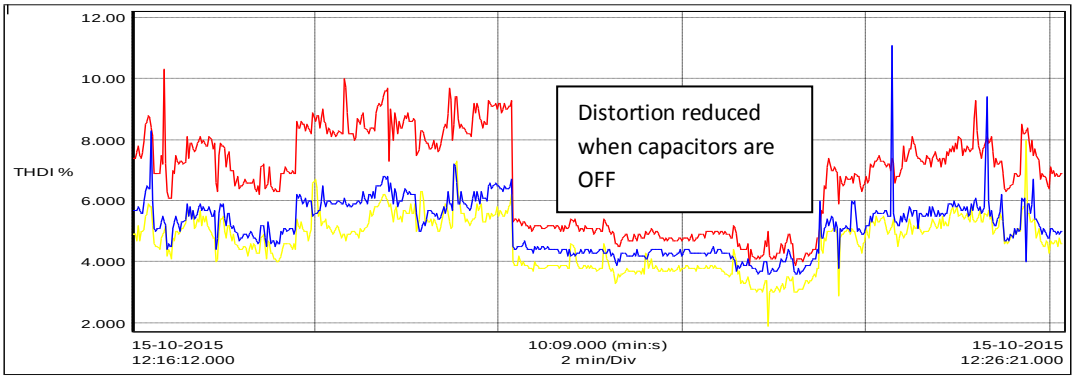
3) If these automatic panels are working properly to suit the reactive power requirement, the net KVAR should be within +/- 50 KVAR.

4) In above table up to KW column the load is calculated from Sept 2015 data available from plant EMS.

5) Sample transformers were surveyed from those Bus sections where either KVAR imbalance or high current harmonic level was found during PQ parameter recording was done for various 10KV bus sections.

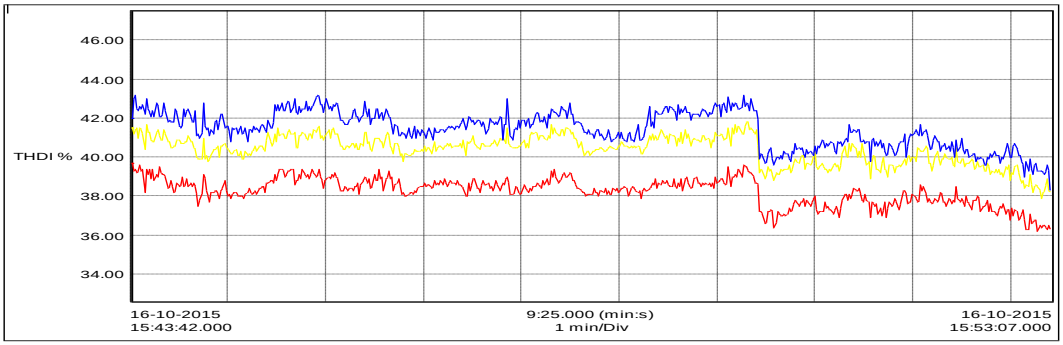
6) As can be seen from last two columns of above table, these panels do not function as required. The main reason for this is they are contactor switched and the load requirement is continuously varying in most of the cases.

7) The end result is the reactive power remains either over or under compensated resulting into generating net reactive power requirement at upstream level while also creating unwanted resonance at few of the feeders.



Above graph is generated based on data collected at Tr. 2402. As shown excess correction generates current harmonics upto 10%, where as load generated harmonics are only 4%.

8) There are few feeders (Tr 3003) Like this where load generated current harmonics are on higher side 43%. Such feeders will need active harmonic filters for mitigating these harmonics in addition to thyristor switched APFC



9) Following table shows bus - sections which are experiencing higher current harmonics, partly due to load demand and partly due to excess KVAR correction

.

Data Collected at Metering room substation									
Sr. No.	Department	Control Room No	KWH	KW	Actual KW	Vthd %	Ithd%	Pf	KVAR
1	Mixing	3B-1	705360	980	1600	1.5	12	0.64	-640
2		3B-2	833860	1158	1800	1.4	10.5	0.94	-234
3		3B-3	1026160	1425	1800	1.2	10.2	0.87	-295
4		3A-1	782320	1087	1962	2.1	25.6	0.93	1024
6	WBR (FF/TA/CURING)	1A-5	140560	195	194	2	32.4	0.94	68
7		1B-5	261520	363	204	1.2	22	0.73	-173
9		1B-3	371920	517	655	1.1	11.7	0.64	-590
		1B 4	0	0	550	1.2	10	0.957	158
14		1A-1	748240	1039	1199	2	16.6	0.97	278
15	CP/MRT TA,(CUR,FF	2A-2	392000	544	507	2	12.2	0.99	155
16		2B-2	0	0	471	1.3	10	0.64	-542
18		2B-3	234880	326	344	1.6	19	0.65	-363
20		2B-4	308000	428	168	1.5	11	0.28	-694
21		2A-5	208400	289	289	2.1	23.7	0.91	133
25		4B-1	1043760	1450	1080	1.9	12	0.73	-998

10KV / 0.4KV transformers connected to these bus sections will need active harmonic filters in addition to converting contactor switched panels to thyristor switched panels.

10) Out of above following Transformers will need Thyristor switched detuned APFC

List of Transformers need Thyristor switched detuned APFC							
SR	Tr Name CR No	Voltage Ratio	KVA	SR	Tr Name CR No	Voltage Ratio	KVA
	Mixing				**WBR FF**		
1	Tr101/CR1	10/0.4kV	1600	24	Tr1801/CR18	10/0.4kV	1600
2	Tr201/CR2	10/0.4kV	1600	25	Tr1802/CR18	10/0.4kV	1600
3	Tr301/CR3	10/0.4kV	1600		**MRT CP**		
4	Tr401/CR4	10/0.4kV	1600	26	Tr2101/CR21	10/0.4kV	1600
5	Tr501/CR5	10/0.4kV	1600	27	Tr2102/CR21	10/0.48kV	750
	WBR CP			28	Tr2103/CR21	10/0.48kV	750
6	Tr1101/CR11	10/0.4kV	1600	29	Tr2201/CR22	10/0.4kV	1600
7	Tr1201/CR12	10/0.4kV	1600	30	Tr2202/CR22	10/0.48kV	750
8	Tr1203/CR12	10/0.48kV	750	31	Tr2203/CR22	10/0.48kV	750
9	Tr1204/CR12	10/0.48kV	750	32	Tr2301/CR23	10/0.4kV	1600
10	Tr1301/CR13	10/0.4kV	1600	33	Tr2302/CR23	10/0.4kV	1600
11	Tr1302/CR13	10/0.48kV	500		**MRT Curing**		
12	Tr1303/CR13	10/0.48kV	500	34	Tr2401/CR24	10/0.4kV	1600
13	Tr1401/CR14	10/0.4kV	1600	35	Tr2402/CR24	10/0.4kV	1600
14	Tr1402/CR14	10/0.48kV	750		**MRT TA**		
15	Tr1501/CR15	10/0.4kV	1600	36	Tr2403/CR24	10/0.4kV	1600
16	Tr1502/CR15	10/0.48kV	750	37	Tr2404/CR24	10/0.4kV	1600
17	Tr1503/CR15	10/0.48kV	750		**MRT FF**		
	WBR Curing			38	Tr2501/CR25	10/0.4kV	1600
18	Tr1601/CR16	10/0.4kV	1600	39	Tr2502/CR25	10/0.4kV	1600
19	Tr1602/CR16	10/0.4kV	1600		**Facility**		
	WBR TA			40	Tr3001/CR30 HV1	10/0.4kV	1600
20	Tr1603/CR16	10/0.4kV	1600	41	Tr3002/CR30 HV	10/0.4kV	1600
21	Tr1604/ CR16	10/0.4kV	1600	42	Tr3003/CR30 HV	10/0.4kV	1600
22	Tr1701/CR17	10/0.4kV	1600	43	Tr3004/CR30 HV	10/0.4kV	1600
23	Tr1702/ CR17	10/0.4kV	1600	44	Tr3005/CR30 HV	10/0.4kV	1600
				45	Tr3006/CR30 HV	10/0.4kV	1600

This can be achieved by replacing contactors with thyristor switches in these panels. Each panel will need 8 thyristor switches and SMPS power supply of adequate rating. Along with this one step of 50KVAR will have to be replaced by 25 KVAR in these panels. Present power factor controllers and current feedback cabling will need through inspection and repairs / replacement as required to ensure that retrofitted system delivers required results.

11) Following transformers would need 100Amps active harmonic filters, which will work in parallel with above detuned APFC panels to control load generated current harmonics.

Sr. No.	Bus Sections	Transformers	Total
4	3A-1	TR 201	1
6	1A-5	TR 1802	1
7	1B-5	TR 1801	1
14	1A-1	TR 1201, 03, 04	3
21	2A-5	TR 2501	1
			7

12) Addition of equipment in reactive power compensation as shown in point 10 and 11 above, would ensure that reactive power compensation from LT load remains close to required limit keeping power factor unity at each transformer secondary. This will be accomplished without amplifying current harmonics.

Report on meetings conducted with different maintenance teams.

Auditors conducted 4 meetings with maintenance teams of different sections to co relate breakdowns, any other issues experienced by them with power quality.

Following are auditors observations related to this.

a) Number of failures encountered (as reported to auditors) is very less – bellow 5 or 6 during last 4 year of operation.
b) All major subsystems used for production and automation are under AMC with respective vendors and they are responsible for uptime, repairs and even root cause analysis of any failure.
c) Auditors explained these teams that at each load centre, under normal working conditions, the capacity of electrical power made available is almost two times actual requirement with decent voltage regulation. So any power supply glitches experienced would be mostly related to increased contact resistance resulting from loose connections. Electrical loose contacts can develop due to external vibrations, electrical vibrations due to various electromagnetic effects, aging of electrical contacts, springs etc.
d) Auditors recommended that ON LOAD infrared thermography of critical electrical panels would help in locating such loose connections on "Predictive basis" and if corrected in planned manner, can avoid subsequent failure. In view of effective utilization of this technique "Pre and Post Thermography" is recommended. The "Tags" found should be corrected before "post" procedure.
e) As regards specific issues raised by mixing section, (One drive failure, SMPS input side transformer overheating and one extruder transformer overheating) a specific measurement survey and site inspection was conducted to ensure that these problems were not due to power quality issues.

_____ END OF REPORT_____