Power Quality Audit Report

FOR

An American Tire Manufacturing Company

By

SAS Powertech Pvt Ltd.

101, Gera's Regent Manor, Survey No. 33, Area No. 39/570,
Behind Opulent Car Care Center Baner, Pune 411045

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Audit Period: November 2018

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Objective and the details of the equipment

Audit objectives:

1. Analysis of recorded power quality parameters at Transformers connected under T1 and T2.
2. Detailed Pie Charting of loading by major feeders.
3. Identifying sources of harmonics / PQ disturbances.
4. Analysis of reactive power compensation.
5. Recommendations for improvement in Power Quality and reactive power compensation to suit latest tariff modifications released by MSEDCL in connection with billing power factor and incentive.

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. Prasad Paraskar Mr. Nilesh Randhave
XXXXAAA Tires	**:**	Mr. aaaabbb Mr. ccccddd

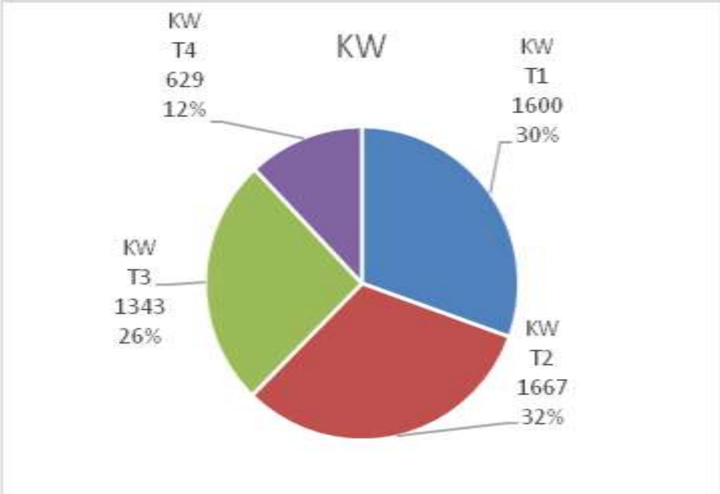
Certification:
Report Certified by:

Narendra R. Duvedi.

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

Executive Summary:

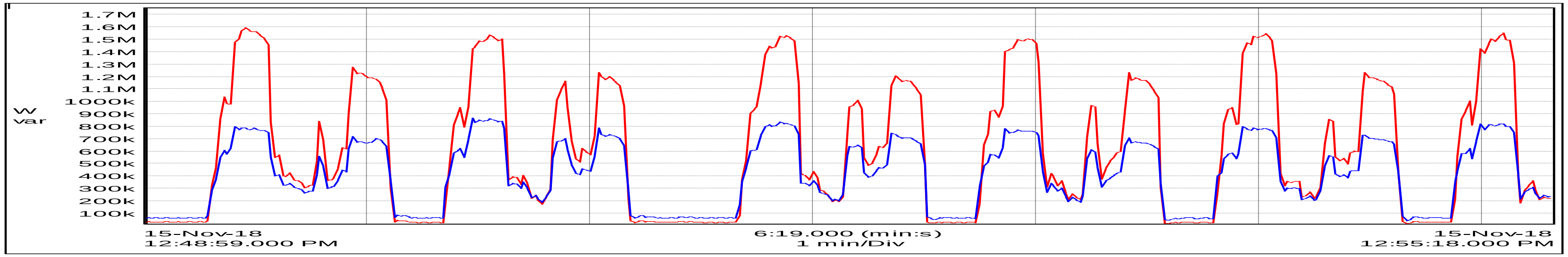
1. XXXXAAA Tyre is a tyre manufacturing company. Plant receives 132 kV supply from MSEDCL which is stepped down to 33 KV by main 10MVA transformer. There are two 10MVA transformers and one works as standby. The sub distribution is done with the help of four 33/6.9KV transformer of 5 MVA capacities. 6.9 KV is stepped down to working LT voltage of 600V and 433V using 16 transformers. Total peak plant load is almost 8 MVA and is fed by single 10MVA transformer. The average load is about 6000KW.



   As shown above Load on T1 and T2 is 62%. This and almost 50% load on T3 is nonlinear – comprises of DC and AC drives. So almost 75% plant load is nonlinear. On top of this load on T1 and T2 is fast fluctuating – being Banbury Mixer load.

2. At present all loads are LT loads and largest loads are 3 x 750KW Dc drives working with Banbury Mixers. The drives are more than 20 years OLD and are based on 6 pulse rectifiers. These rectifier configurations demand large 5^{th} and 7^{th} harmonic current. Other plant equipment like calendar machine also are equipped with DC / AC drives. The typical load cycles on mixers involve heavy load fluctuations within short time.

3. Following trend shows load fluctuations on Tr 10 which works under T1.



As shown the load fluctuates from 300KW to 1600KW every 50 Secs. The peak demand in every load cycle touches maximum transformer capacity in case of Tr10, 11 and 15.

4. Following table shows current and voltage distortion supported by major transformers.

TR ID	Vthd %	Ithd%	5th H Amps Max	7th H Amps Max
TR 10	14.6	140.6	400	75
TR11	5.4	22.5	260	60
TR 12	26	200	450	125
TR 5	6.9	24.9	600	25
TR 6	14.6	140.6	400	75
TR 8	5.4	22.5	260	60
TR 15	26	200	450	125
TR 13	12.4	32.1	110	23

The voltage distortion is a major matter of concern and is disturbing the power quality throughout the plant. This must be contributing in increasing distribution loss within plant electrical system. Most of these parameters are recorded with steady state loads. Starting inrush currents of large DC drives must be worsening the situation. This can cause damage to power electronics in the plant.

5. There are fixed capacitors and Detuned RTPFC panels installed in plant for Reactive power correction, which at present are not able to offer fast correction as required by load and most of the time result in over correction, causing resonance and associated voltage distortion. 5th harmonic current resonance is observed throughout the plant.

6. Unless this voltage distortion issue is resolved to reasonable level, the issues related to failures can not b resolved.

7. MSEDCL (Utility company) has since Sept 2018 started monitoring billing power factor with a different formula, which unable them to penalize consumer if excessive Lag or Lead reactive power is consumed by consumer. This is demanding keeping “KVARh Lag” and “KVARH Lead” figures to their possible minimum within billing cycle. MSEDCL is also ordered to start KVAH billing from 1st April 2020. In view of optimizing this and availing full 3.5% incentive, closure look at reactive compensation schemes is required. Present average monthly Energy charges (MSEDCL bill without all taxes) paid by Good year Aurangabad are INR 32.5 billion. The maximum incentive available on this is INR 1.13 billion. Even if power factor is maintained close to unity, and “KVARH Lead” > “KVARh Lag” at end of the month, this incentive will not be available. 1% incentive would mean INR 0.3 Billion. We have studied this situation and have advised some corrections to achieve this.

Recommended Execution Methodology and sequence:

1. Run load on TA and TB (Both 10MVA) – preferably with 4 to 5 MW on each transformer – to increase upstream source capacity and reduction in voltage distortion.

2. Take estimate for repair / retrofit of existing RTPFAC panels so that they deliver KVAR up to their rated capacity and in intelligent mode -for all transformers except those which support mixers. Ensure that they are 7% detuned / partially tuned for 5th harmonic filtration. Execute these modifications.

3. Take estimate for repair / retrofit of existing RTPFAC panels so that they deliver up to their rated capacity and in intelligent mode -T10, T11 and T15. Ensure they are capable of fast discharging with switching time less than 1 Sec. Execute these modifications.

4. Order and install additional RTPFC and AHF for all transformers except those which support mixers. Arrange HT feedback – wherever possible. Ensure that PF is controlled at last mile for all these transformers within expected limits for all loading conditions.

5. Survey PQ, harmonics levels, PF, Reactive power at all locations wherever this retrofitting is done.

6. Install AHF – 200A/600V in PF correction mode for Tr 10. Take trials with retrofitted RTPFC in fast discharge and fixed mode. Assess the results and repeat the procedure for Tr11 and Tr 15.

7. Take Max KW / KVAR recording at above 16 locations post implementation and update in ETAP SLD to run load flow analysis and decide about HT (6.9KV) detuned fixed correction required if any to fulfil PF maintenance requirements.

8. Configure EMS for getting PF, KWH, KVARH Lag, KVARH Lead and billing PF information on hourly basis at various levels of distribution. If such information can not be extracted from present EMS, budget and install suitable equipment so that power factor monitoring will be easy and automatic.

Audit Methodology: -

1. Record electrical load on Transformer 1, Transformer 2 & their sub-distribution using high end recording type power analysers to know important parameters like voltage, current, power, harmonic distortion etc.

2. Analyse power quality parameters using recorded data and recommend modifications for improvement in power quality.

3. Prepare detailed loading Pie chart using recorded power parameters.

4. Analyse reactive power compensation based on recorded parameters.

5. Identifying sources of harmonics and their individual contribution in Total Harmonic Distortion.

6. Recommend harmonic mitigation solutions and effective reactive power compensation to avail maximum incentive.

7. Present report based on above analysis.

Details of plant electrical system:

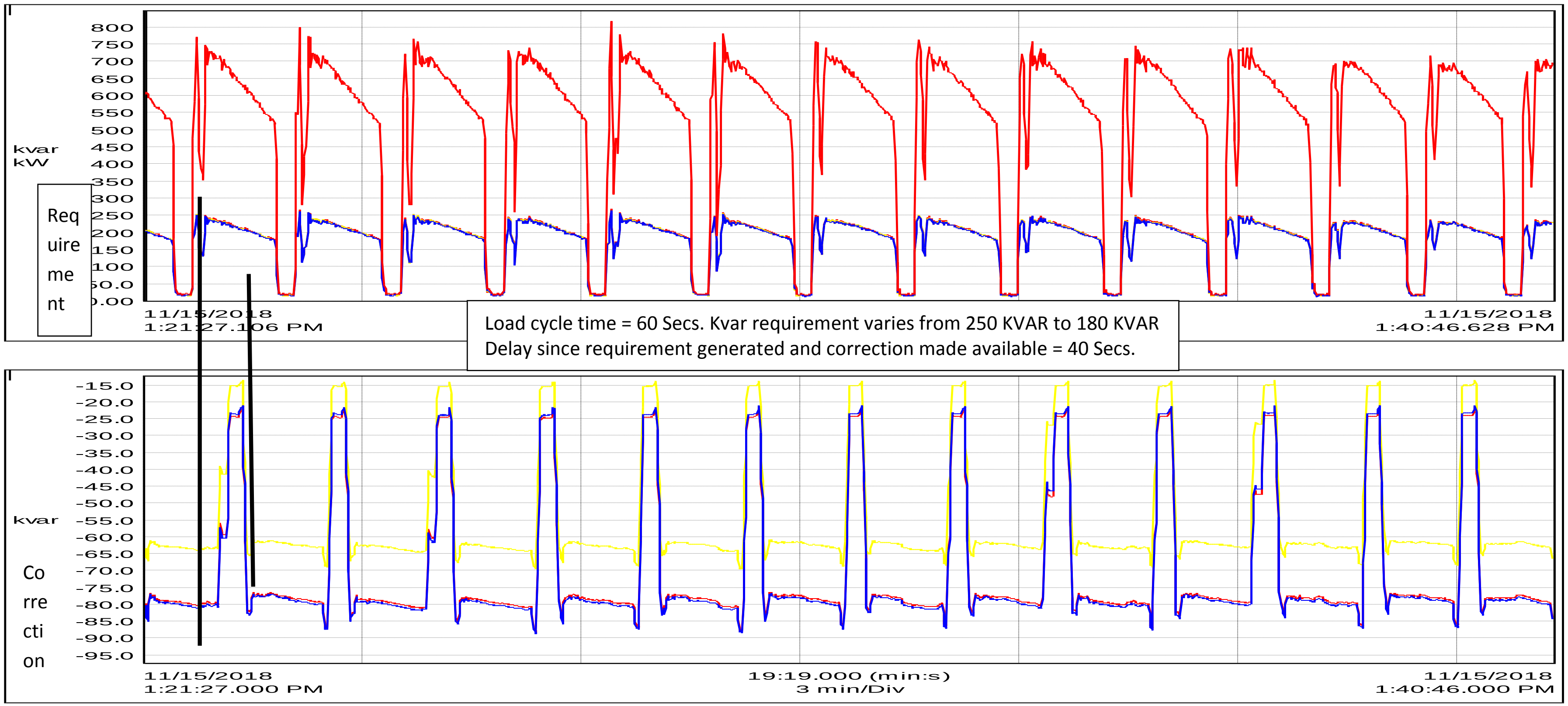
Plant receives three phase supply from MSEDCL with contract demand of 8000 KVA. Maximum demand during last 6 month is 7476 KVA and average plant load is 6000 KW. Plant transformer and APFC/RTPFC details are as shown below.

Sr.No	Transformer	Rating	Voltage Ratio	Z %	APFC Details	
					Type	Rating (kVAR)
1	TR A/B	10MVA / 12.5MVA	132/33 KV	9.68%	-	-
2	TR 1	5MVA	33/6.9 KV	7.21%	-	-
3	TR 2	5MVA	33/6.9 KV	7.48%	-	-
4	TR 3	5MVA	33/6.9 KV	7.37%	-	-
5	TR 4	5MVA	33/6.9 KV	7.39%	-	-
6	TR 5	2MVA	6.6/0.433 KV	5.69%	FIXED+ RTPFC	1295KVAR @ 415V + 525 @525V
7	TR 6	2MVA	6.6/0.433 KV	5.85%	RTPFC	1000 @ 525 V
8	TR 7	2MVA	6.6/0.433 KV	5.61%	RTPFC	1500 @ 525
9	TR 8	2MVA	6.6/0.433 KV	0.057	RTPFC	1000 @ 525 V
					FIXED	300 @ 415
10	TR 9	2MVA	6.6/0.433 KV	5.62%	RTPFC	1000 @ 525 V
11	TR 10	2MVA	6.6/0.600 KV	5.31%	RTPFC	750 @ 750V
12	TR 11	2MVA	6.6/0.600 KV	5.31%	RTPFC	750 @ 750V
13	TR 12	500KVA	6.6/0.480 KV	4.83%	RTPFC	125 @ 525 V
14	TR 13	750KVA	6.6/0.480 KV	5.36%	RTPFC	250 @600V
15	TR 14	500KVA	6.6/0.480 KV	5.65%	RTPFC	50 @600V
16	TR 15	2MVA	6.6/0.600 KV	5.73%	RTPFC	2000 @ 750V
17	TR 16	2MVA	6.6/0.433 KV	9.72%	RTPFC	750 @ 525V
18	TR 17	500KVA	6.6/0.433 KV	3.92%	-	-
19	TR 18	500KVA	6.6/0.433 KV	3.92%	-	-
20	TR 19	2MVA	6.6/0.433 KV	5.69%	RTPFC	500 @525V
21	TR 20	500KVA	6.6/0.433 KV	3.76%	-	-

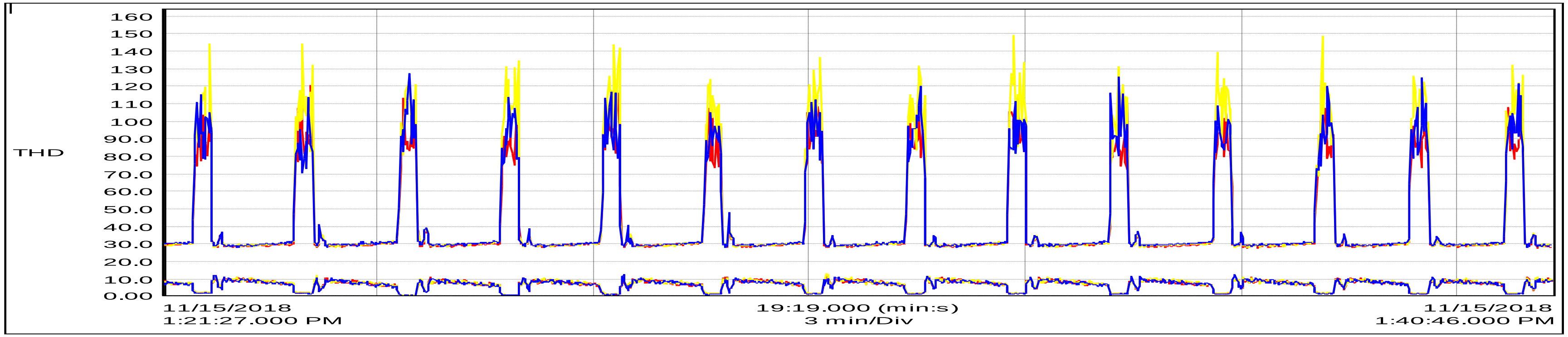
Salient Audit Findings and Recommendations

TR10 – Load 750KW Dc drive Bunbury Mixer.

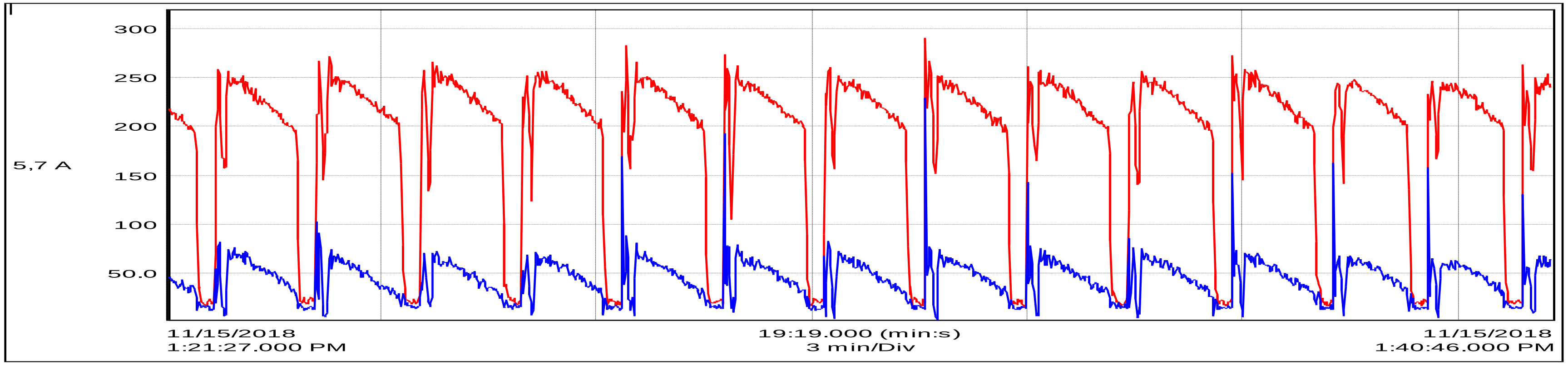
KW& KVAR



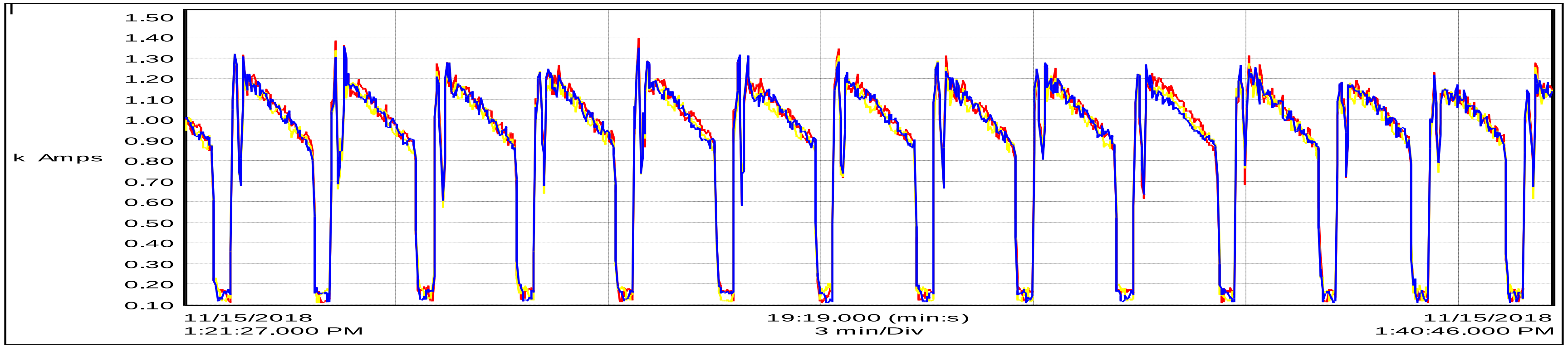
THDV, THDI %



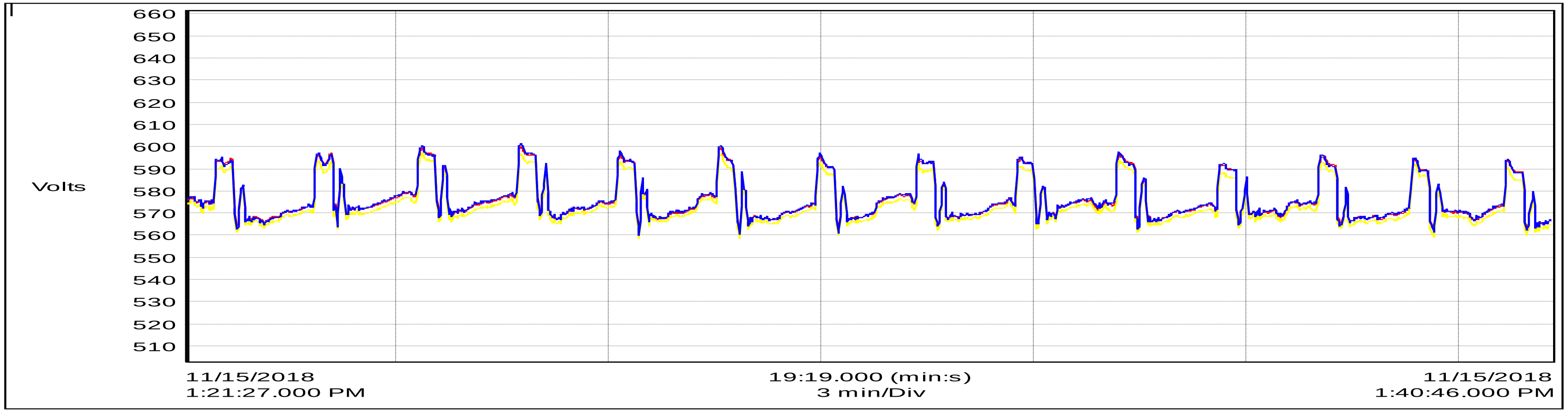
5th and 7th harmonic currents.



A RMS

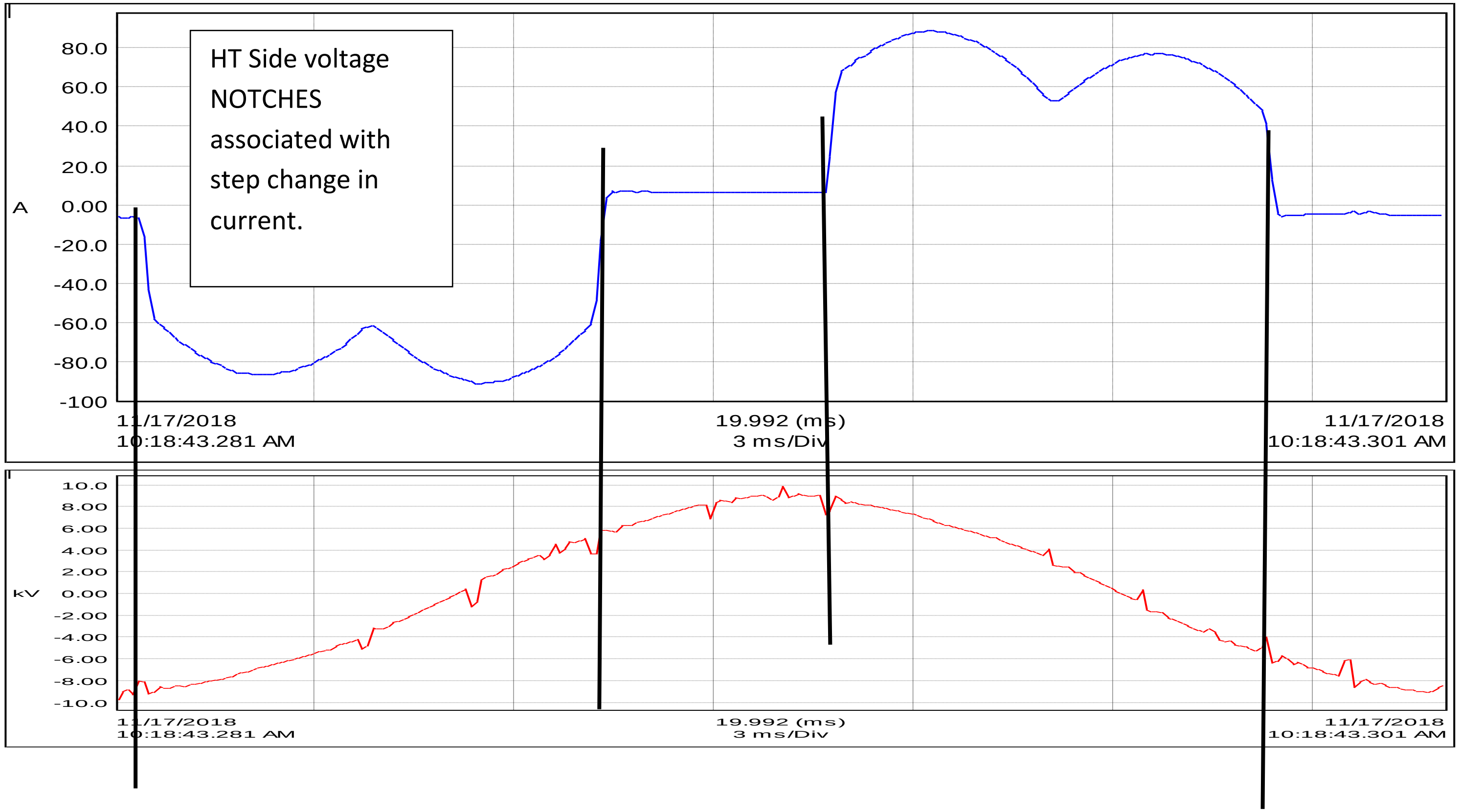


U RMS



- T 10 is 2 MVA 6.9KV/600Volts transformer.

- 1300 Amp Peak current comprises of – 250Amps 5th Harmonic current and 75 Amps 7th Harmonic current. Whenever this current is drawn – voltage drops to 570Volts and voltage distortion is about 10 %.
- The peak KVA delivery expected from 2 MVA transformer is 1.732 x 1300 x 600 = 1350 KVA.



Present Reactive power correction:

Capacitor KVAR in STAR	Phase Voltage Rating	Parallel units	Total KVAR in STAR	Line Voltage Rating	Eq delta KVAR	Steps	Total Panel Capacity at 909 Volts	KVAR Capacity available at 600Volts	KVAR Rating at 750V
8.33	525	4	33.32	909.3	99.96	8	799.68	348.41	544.39

The available correction at present is 348 KVAR in 8 steps. The actual switching takes comparable time compared to load cycle time and the end result is the actual correction is not sufficient and not applied quickly when the same is needed.

Recommendations:

Long term: The DC drive should be replaced with 12 Pulse drives. (Assumption DC motor is in good working condition and well maintained). Then correct balance harmonics by AHF.

Short Term:

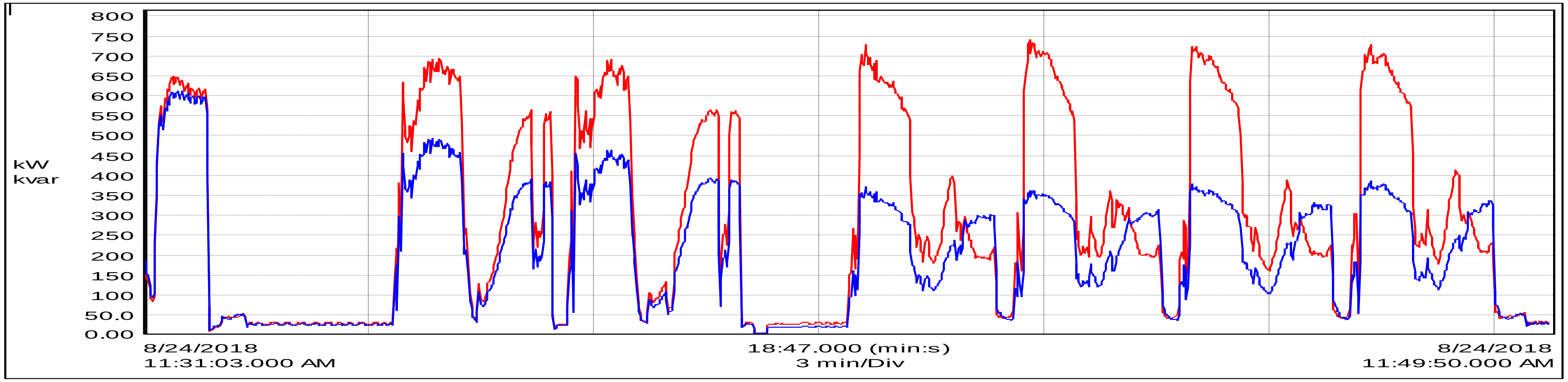
a) Retrofit 750KVAR / 750V RTPFC panel to give full correction of 348 KVAR and with speed. Use some part from this as fixed correction / fast acting current.

b) Install 600V / 200Amps active harmonic filter to provide fast Inductive or capacitive correction as required with target PF as 0.98. Any balance capacity in the filter may be used as harmonic filter.

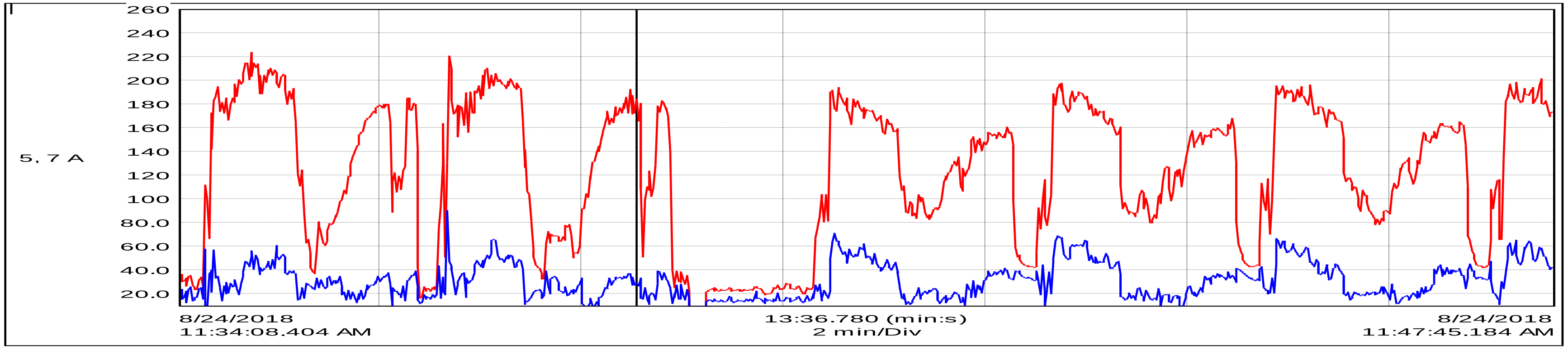
c) If the drive is replaced with 12 pulse rectifier based drive any time in future, use this 300 KVAR AHF for harmonic filtration.

TR 11 – Load 750KW Dc drive Bunbury Mixer.

KW & KVAR



5th & 7th current harmonic (Amp)



Recommendations:

The available correction at present is 348 KVAR in 8 steps. The actual switching takes comparable time compared to load cycle time and the end result is the actual correction is not sufficient and not applied quickly when the same is needed.

Recommendations:

Long term: The DC drive should be replaced with 12 Pulse drives. (Assumption DC motor is in good working condition and well maintained).

Short Term:

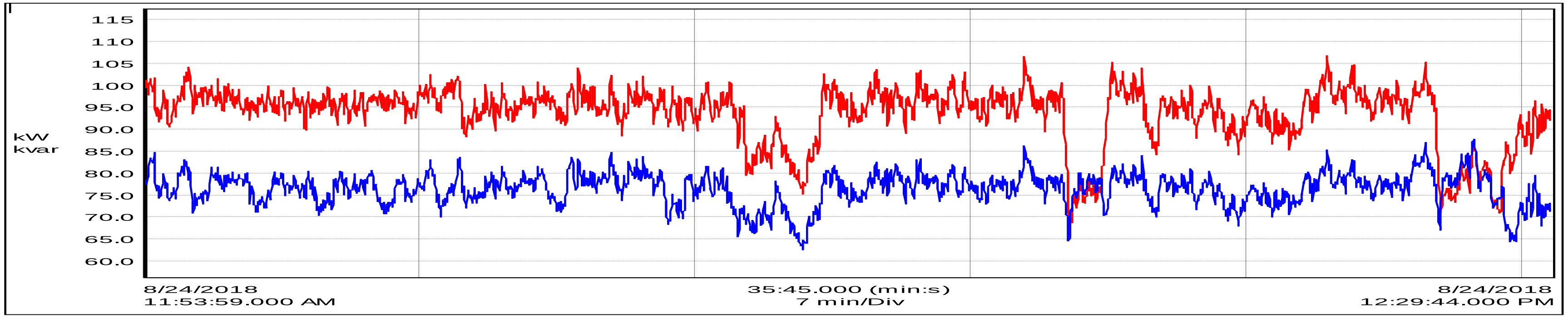
a) Retrofit 750KVAR / 750V RTPFC panel should be retrofitted to give full correction of 348 KVAR and also for fast correction. Use 250KVAR from this as fixed / fast correction.

b) Install 200Amps active harmonic filter to provide fast Inductive or capacitive correction as required with target PF as 0.98. Any balance capacity in the filter may be used as harmonic filter.

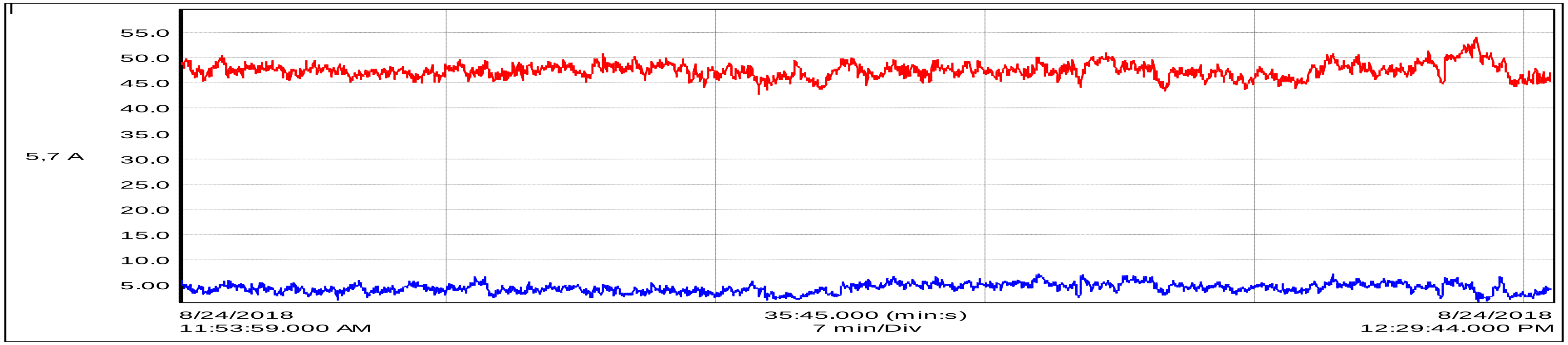
c) If the drive is replaced with 12 pulse rectifier based drive any time in future, use this 300 KVAR AHF for harmonic filtration

TR 12

KW& KVAR



5th and 7th current harmonic.(Amp)

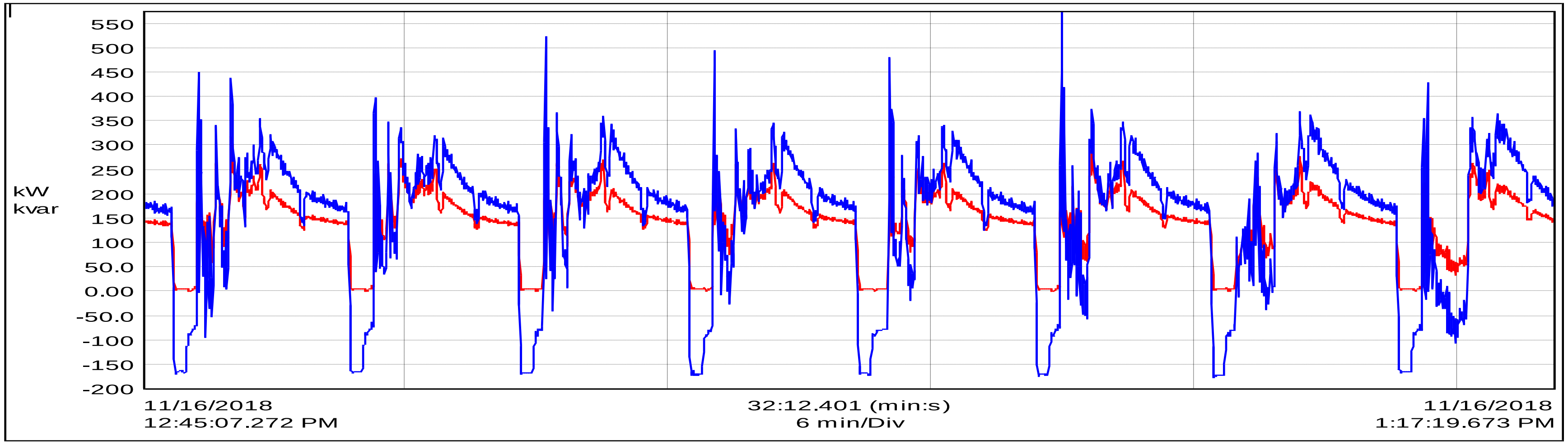


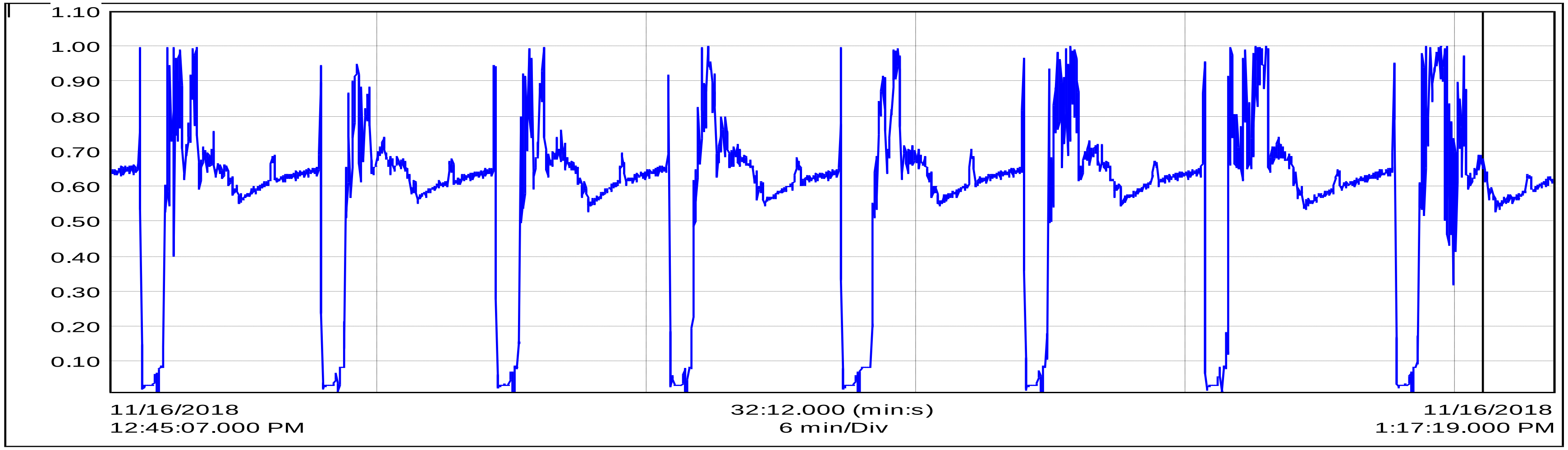
Recommendations:

a) Retrofit 125KVAR for fast correction, improve power factor.

b) Install 100 Amps active harmonic filter to reduce harmonic distortion and improve power quality.

TR 15 – Load 750KW Dc drive Bunbury Mixer.





The available correction at present is 2000 KVAR. The actual switching takes comparable time compared to load cycle time and the end result is the actual correction is not sufficient and not applied quickly when the same is needed.

Recommendations:

Long term: The DC drive should be replaced with 12 Pulse drives. (Assumption DC motor is in good working condition and well maintained).

Short Term:

- **a)** Retrofit 2000KVAR / 750V RTPFC panel should be retrofitted to give full and fast correction of 348 KVAR. Use 250KVAR from this as fixed correction.
- **b)** Install 200Amps active harmonic filter to provide fast Inductive or capacitive correction as required with target PF as 0.98. Any balance capacity in the filter may be used as harmonic filter.
- **c)** If the drive is replaced with 12 pulse rectifier based drive any time in future, use this 300 KVAR AHF for harmonic filtration.

Recorded Power Quality Parameters on all transformers:

	Rating MVA	Max KVA delivered	Average KW	MAX KW	Average KVAR	Max KVAR	Vthd %	Ithd%	5th H Amps Max	7th H Amps Max
Tr B	10	8475	5644	7500	800	1500	2.8	9.7	-	-
Tr 1 HT	5	3321	1600	2500	-643	500	9.8	24.2	20	4
Tr 10 LT	2	2070	474	750	449	250	15.4	145.8	250	75
Tr 11 LT	2	1839	292	750	208	500	9.4	166.2	250	70
Tr 12 LT	0.5	177	94	105	76.5	85	8.1	40.3	55	5
Tr 5 LT	2	1412	1000	1200	115	200	6.9	24.9	600	25
Tr 2 HT	5	4078	1667	2500	242	1500	8.8	31.2	55	3.5
Tr 6 LT	2	781	396	700	91.5	600	14.6	140.6	400	75
Tr 8 LT	2	1553	1041	1200	240	200	5.4	22.5	260	60
Tr 15 LT	2	2063	301	700	141	1400	26	200	450	125
Tr 3 HT	5	2618	1343	2000	110	800	1.7	7.9	14	2
Tr 7	2	1388	825	950	250	150	3.6	11.1	80	30
Tr 9	2	1794	813	1000	395	300	4.3	15.1	120	60
Tr 13	0.75	356	250	250	249	186	12.4	32.1	110	23
Tr 14	0.5	203	50	50	184	192	10.1	34	69	8.5
Tr 4 HT	5	945	629	750	-270	-200	2.5	2.5	10	5
Tr 16	2	105	50	60	-10.5	15	2	60	60	35
Tr 17	0.5	167	48	80	20	22	5.2	174	150	150
Tr 18	0.5	113	44	81	10	19	5.1	145	62	34
Tr 19	2	430	110	195	-75	130	2.9	20	35	20
Tr 20	0.5	148	25.8	90	6.3	27	4.1	59	61	30
			5813.8	8161						

- The detailed assessment of power quality parameter shows voltage and current distortion of higher side.
- Such voltage distortion may causes severe effect on the performance of major electrical equipment mostly electrical drive.

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Reactive Power Correction Recommendation:

Sr	Transformer	Requirement			Available detuned capacity KVAR @600V	Proposed detuned Capacity KVAR @ 600V	Proposed AHF Capacity KVAR (300A AHF used in PF correction mode.)	Correction Range Available KVAR
		Min KVAR	Max KVAR	KW				
Mixer Transformers LT 600V								
1	TR 10	300	800	1600	350		200	150 - 550
2	TR 11	0	600	300	350		200	150 - 550
3	TR 15	-150	300	250	350		200	150 - 550
Other Transformers LT 433V								
Sr	Transformer	Requirement			Available detuned capacity KVAR @415V	Proposed detuned Capacity KVAR @ 415V	AHF for Harmonic filtration	
		Min KVAR	Max KVAR	KW				
4	Tr5 – 2 MVA		615	1200	525	300	300A	RTPFC servicing
5	Tr 12 – 0.5 MVA		85	105	80	100	100A	RTPFC servicing
6	Tr6 – 2 MVA		600	700	625	0	300A	RTPFC servicing
7	Tr8-2 MVA		650	1200	625	100	150A	RTPFC servicing
8	Tr7-2MVA		840	950	937		100A	RTPFC servicing
9	Tr9-2MVA		750	1000	625	200	150A	RTPFC servicing
10	Tr13-0.750MVA		186	257	156	250	100A	RTPFC servicing

Tr14, Tr16, Tr17, Tr18 & Tr20 were marginally loaded during audit.

We have not proposed any modification here. The same may be proposed after knowing prospective / maximum expected load on these transformers.

11	Tr19-2MVA		135	195	468		100A	RTPFC servicing

Tr ID	Type	Voltage Ratio	Rating	Load on TB Existing	TB Reactive Power compensated	Load on TA+TB, Reactive power compensated	Load on TA+TB HT Compensated
TR A	Transf. 2W	132 / 33 kV	10000 kVA			2.6	2.6
Tr1	Transf. 2W	33 / 6.9 kV	5000 kVA	7.56	5.93	5.86	5.84
Tr2	Transf. 2W	33 / 6.9 kV	5000 kVA	5.78	5.24	5.22	5.11
Tr3	Transf. 2W	33 / 6.9 kV	5000 kVA	9.29	6.83	6.79	6.6
Tr5	Transf. 2W	6.9 / 0.433 kV	2000 kVA	5.59	5.28	5.22	5.2
Tr6	Transf. 2W	6.9 / 0.433 kV	2000 kVA	0.84	0.773	0.77	0.762
Tr7	Transf. 2W	6.9 / 0.433 kV	2000 kVA	12.65	11.04	11	10.86
Tr8	Transf. 2W	6.9 / 0.433 kV	2000 kVA	5.72	5.23	5.21	5.15
Tr9	Transf. 2W	6.9 / 0.433 kV	2000 kVA	4.11	3.15	3.13	3.09
Tr10	Transf. 2W	6.9 / 0.6 kV	2000 kVA	2.37	1.18	1.17	1.16
Tr11	Transf. 2W	6.9 / 0.6 kV	2000 kVA	0.707	0.448	0.443	0.441
Tr12	Transf. 2W	6.9 / 0.48 kV	500 kVA	0.699	0.403	0.398	0.397
Tr13	Transf. 2W	6.9 / 0.48 kV	750 kVA	2.69	1.27	1.26	1.25
Tr14	Transf. 2W	6.9 / 0.48 kV	500 kVA	2.54	2.43	2.42	2.39
Tr15	Transf. 2W	6.9 / 0.6 kV	2000 kVA	0.551	0.536	0.534	0.528
Tr16	Transf. 2W	6.9 / 0.433 kV	2000 kVA	0.0349	0.0342	0.034	0.0338
Tr17	Transf. 2W	6.9 / 0.433 kV	500 kVA	0.253	0.247	0.246	0.244
Tr18	Transf. 2W	6.9 / 0.433 kV	500 kVA	0.327	0.32	0.319	0.316
Tr19	Transf. 2W	6.9 / 0.433 kV	2000 kVA	0.122	0.119	0.119	0.118
Tr20	Transf. 2W	6.9 / 0.433 kV	500 kVA	0.456	0.446	0.444	0.441
Tr31	Transf. 2W	33 / 6.9 kV	5000 kVA	0.408	0.399	0.398	0.369
TRB	Transf. 2W	132 / 33 kV	10000 kVA	29.31	24.02	11.5	11.16
Total Loss				**92.01**	**75.33**	**65.09**	**64.06**

Notes

Column 5 above shows Transformer loss with existing situation and at Average KW consumption.

The calculations above do not cosider effect of harmonics. Actual loss may be 25% more

Cable lossess are not considered above as cable lengths are not known at present. They may be 10% of above.

Thus actual loss may be around 125KW at present - which translates to around Rs.22500 per day.

Column 6 shows reduction in Loss with reactive power effectively compensated at all last mile transformers.

Column 7 shows lossess with Reacive power compensated and load is divided between TA and TB.

Column 8 shows lossess with HT correction added. This does not bring in noticable reduction in loss,

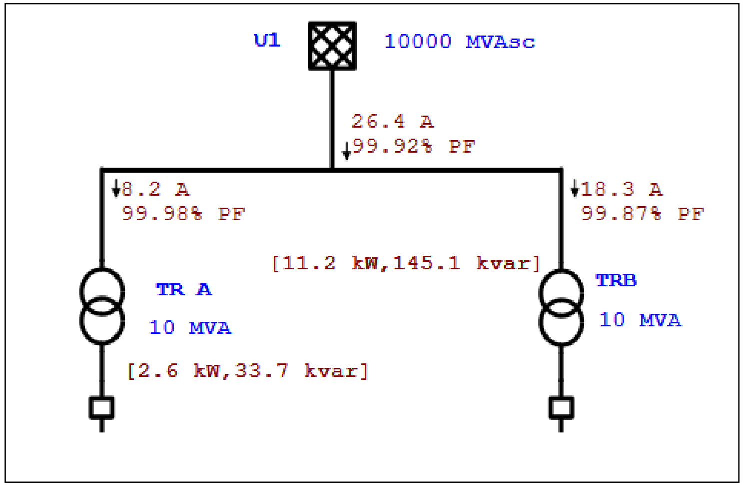
HT correction with fast acting RTPFC at all down stream levels will ensure EHT PF at 100% and will offer 3.5% Incentive

After implementing harmonic mitigation and power factor improvement distribution loss will reduce by 28KW

The projected annual saving in energy cost due to above will be - 28KW x 20 Hrs X 325 days x Rs.9 = Rs.1638000.00

Addition to incentive without much manual intervention will be 1% of energy charges in your bill - amounting to Rs. 300000 per month or Rs.3600000

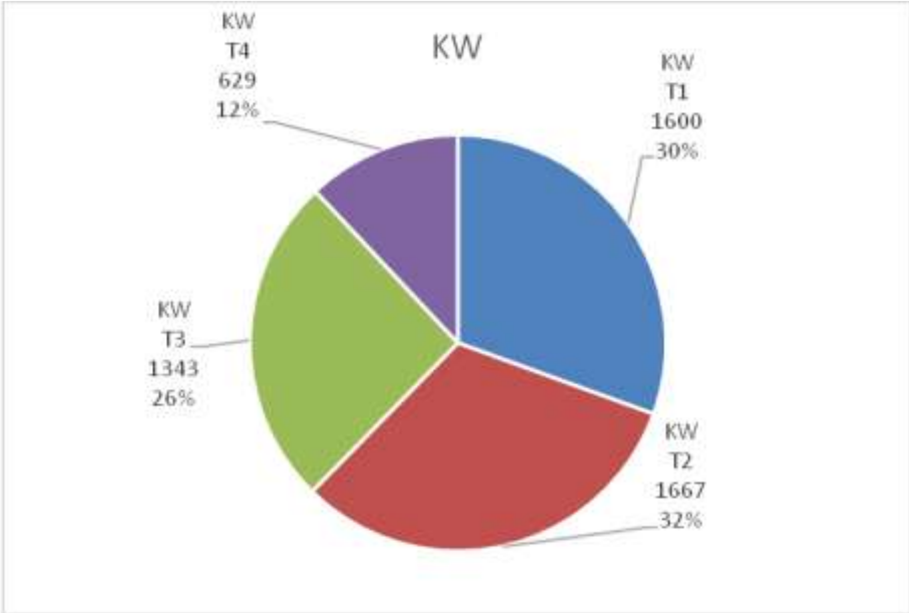
Transformer losses in present situation and with proposed solution:



This diagram shows that if total suggested solution is implemented, the EHT transformer level – MSEDCL metering level power factor will be maintained at 0.999 without over correction.

Loading Pie Chart for main MV plant Transformers

Tr ID	Rating MVA	Max KVA delivered	Max KW	Average KW
TB	**10**	**8475**	**7500**	**5644**
Tr 1 HT	**5**	3321	2500	**1600**
Tr 10 LT	2	2070	750	474
Tr 11 LT	2	1839	750	292
Tr 12 LT	0.5	177	105	94
Tr 5 LT	2	1412	1200	1000
Tr 2 HT	**5**	**4078**	2500	**1667**
Tr 6 LT	2	781	700	396
Tr 8 LT	2	1553	1200	1041
Tr 15 LT	2	2063	700	301
Tr 3 HT	**5**	**2618**	2000	**1343**
Tr 7	2	1388	950	825
Tr 9	2	1794	1000	813
Tr 13	0.75	356	250	250
Tr 14	0.5	203	50	50
Tr 4 HT	**5**	**945**	750	**629**
Tr 16	2	105	60	42.9
Tr 17	0.5	167	80	48
Tr 18	0.5	113	81	44
Tr 19	2	430	195	110
Tr 20	0.5	148	90	25.8
		14599	**8161**	**5806.7**



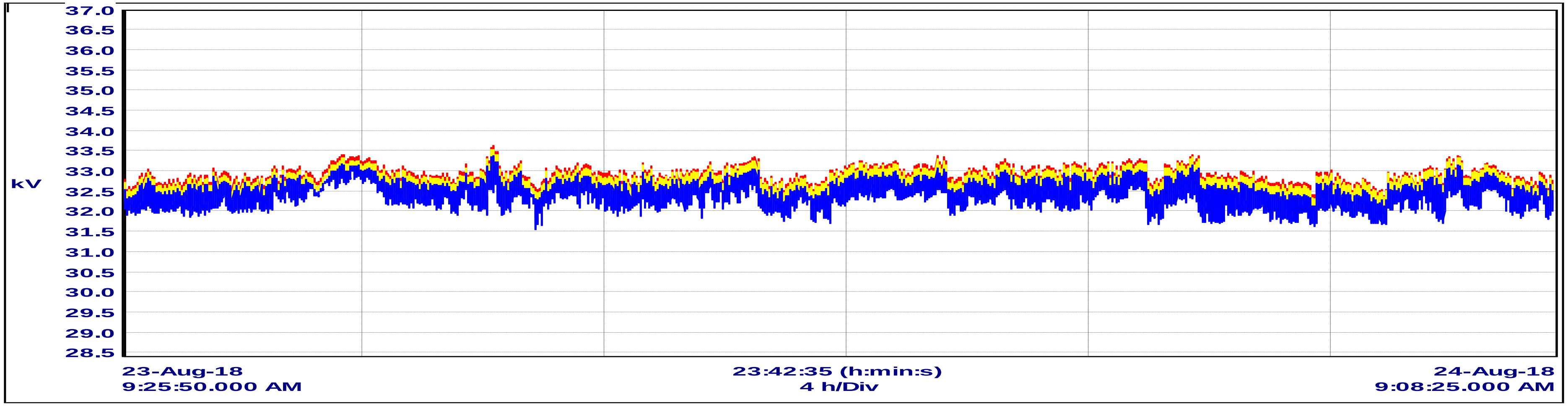
- Last MSEDCL bill has recorded MD as 7446 KVA The MD matches more or less with Peak consumption of 7926KW
- Last MSEDCL KWH are 4111440 (Running load = 4111440/(24 * 30) = 5710KW This matches with AVG KW = 5806

Recorded Data

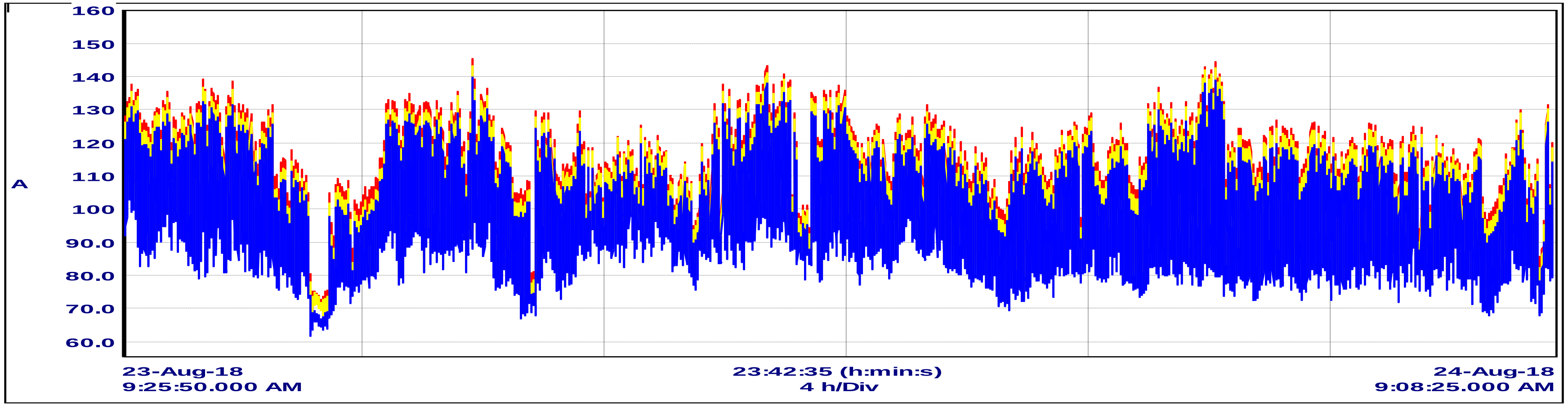
Recorded Data:

TR-B:

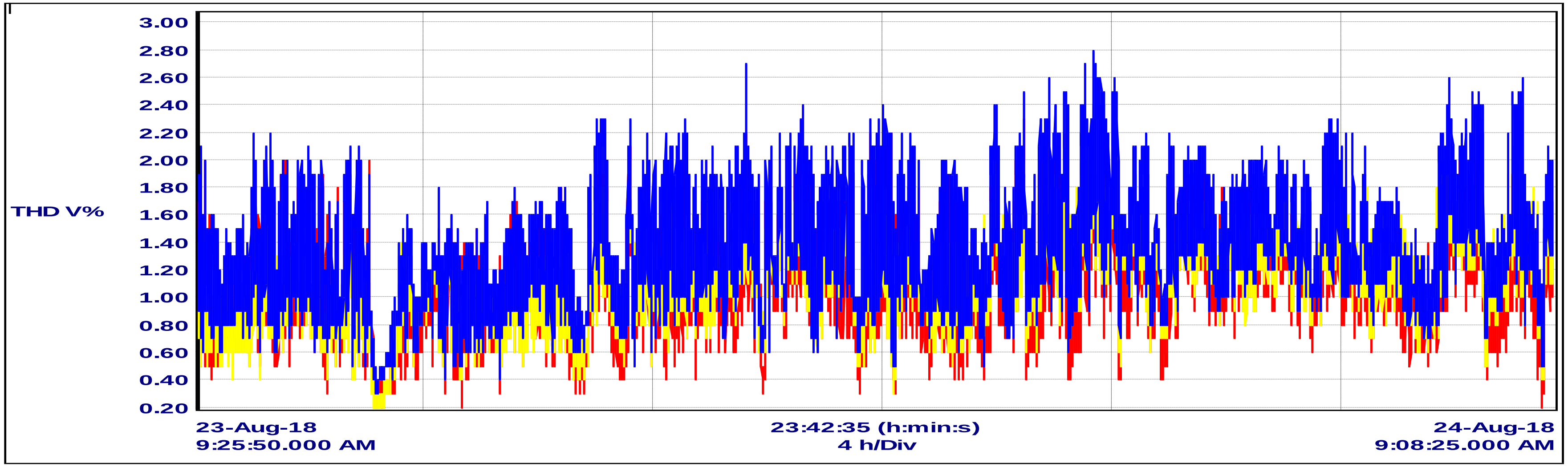
Voltage L-L



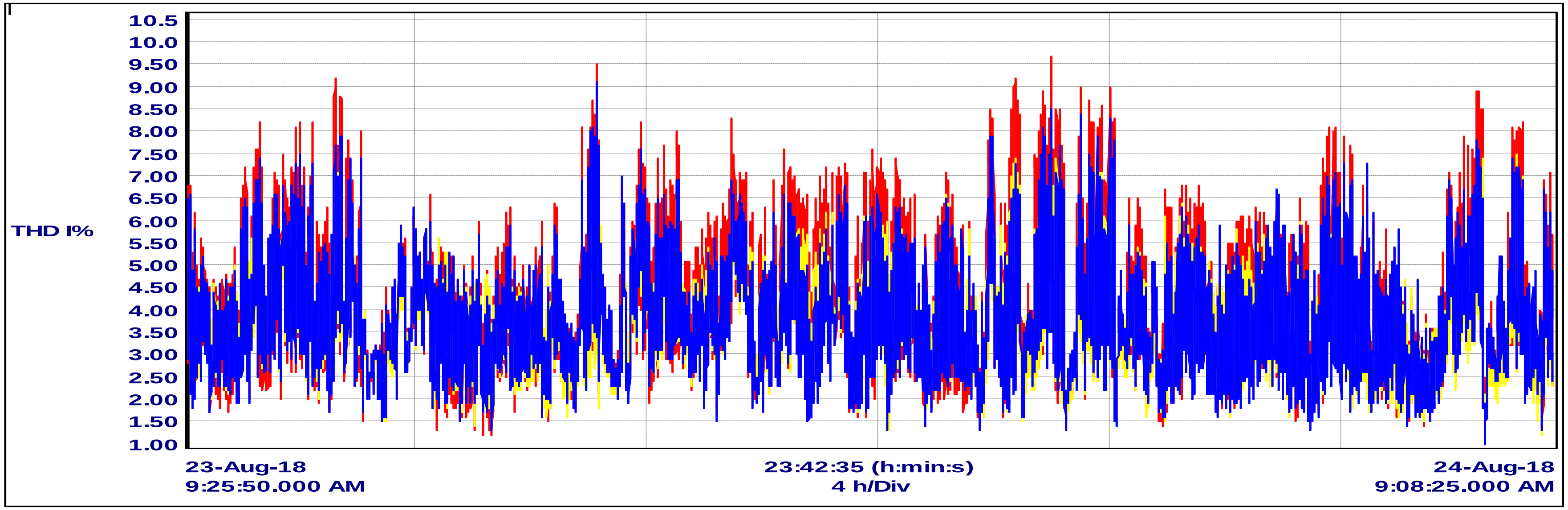
Current



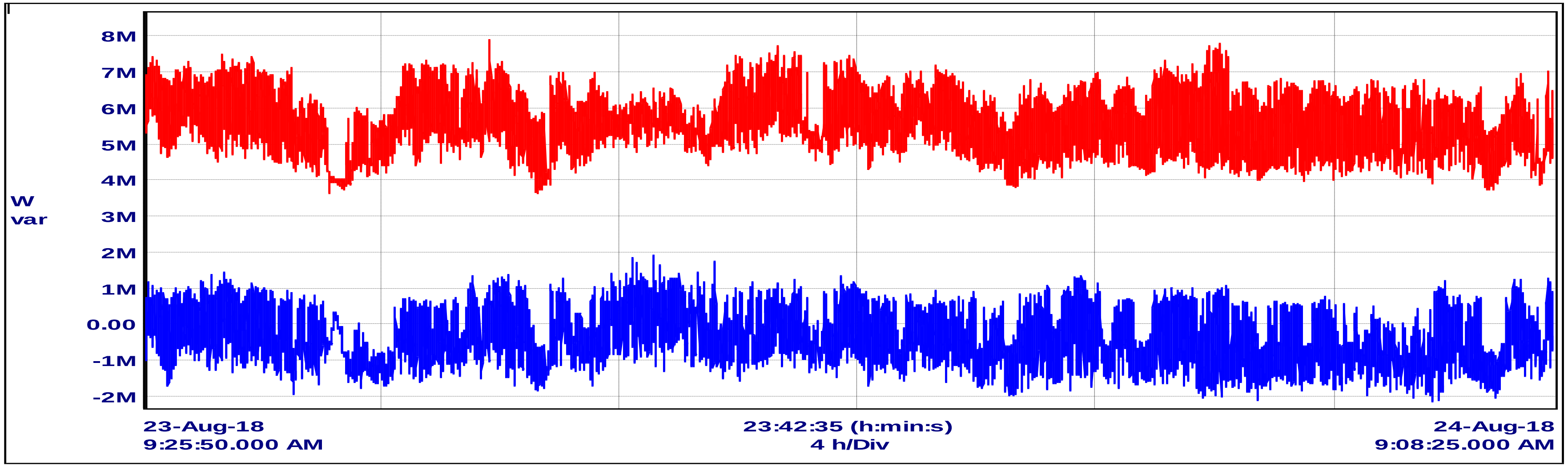
Voltage Harmonic Distortion



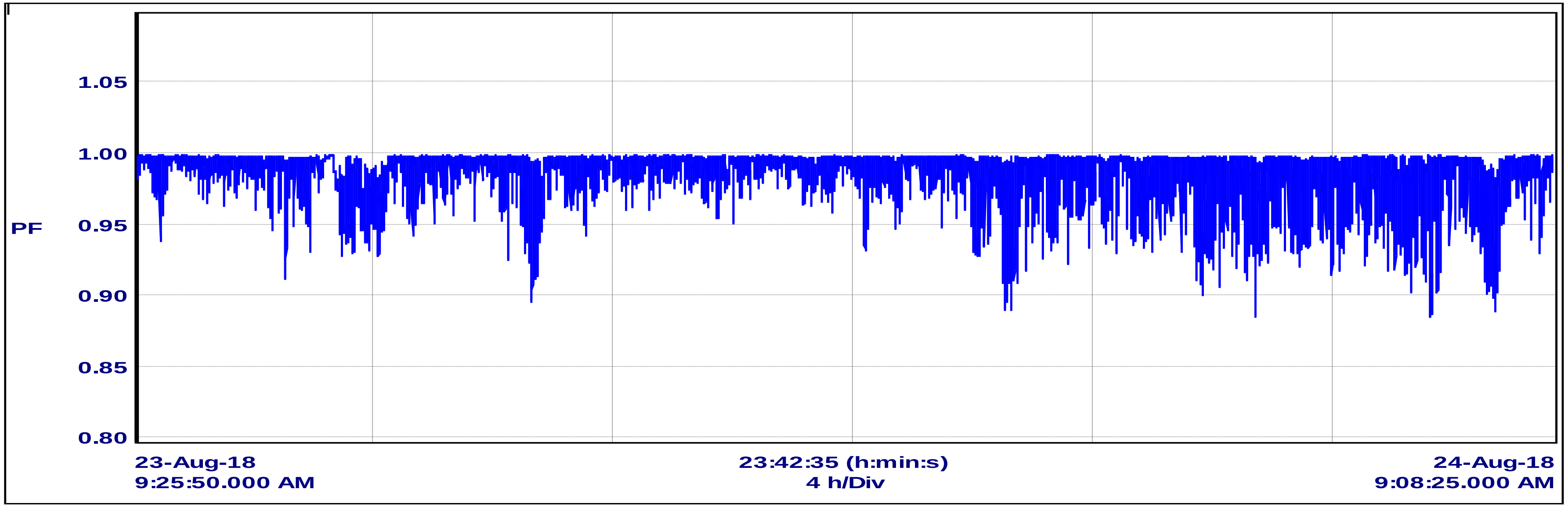
Current Harmonic Distortion



KW, KVAR

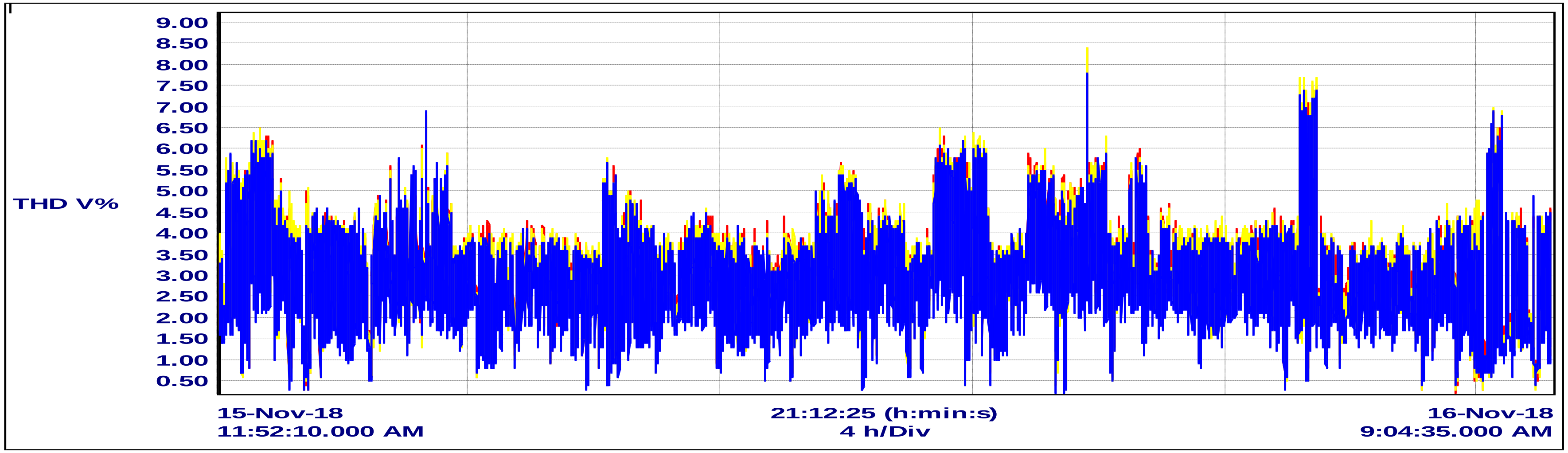

8M
7M
6M
5M
4M
3M
2M
1M
0.00
-1M
-2M
W
var
23-Aug-18
9:25:50.000 AM
23:42:35 (h:min:s)
4 h/Div
24-Aug-18
9:08:25.000 AM

PF

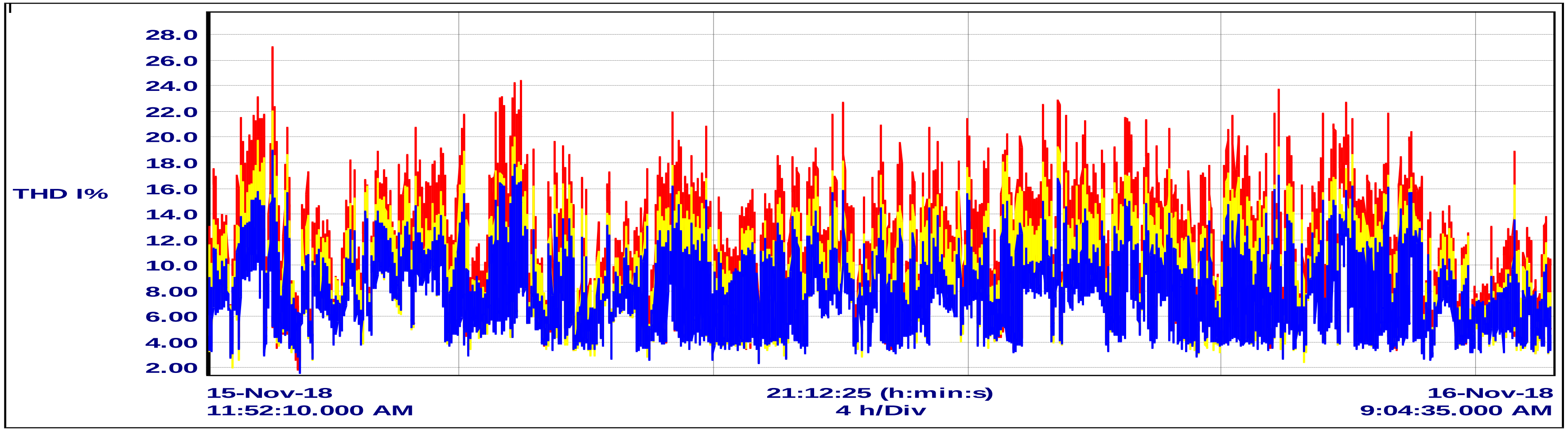

1.05
1.00
0.95
0.90
0.85
0.80
PF
23-Aug-18
9:25:50.000 AM
23:42:35 (h:min:s)
4 h/Div
24-Aug-18
9:08:25.000 AM

TR-1:

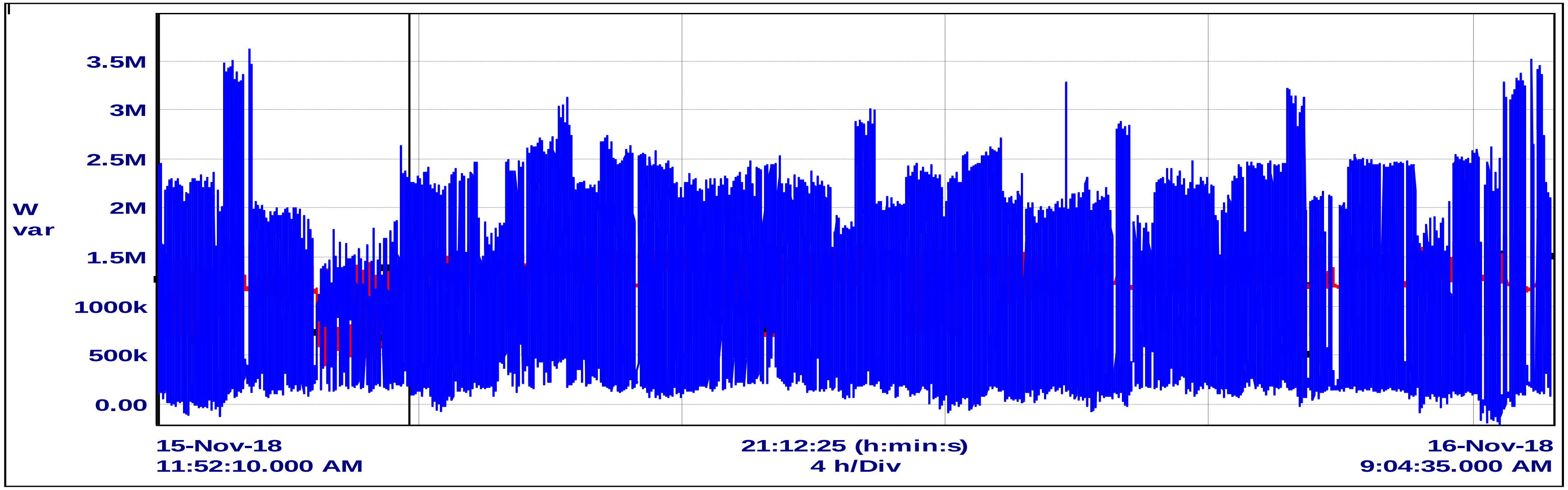
Voltage Harmonic Distortion



Current Harmonic Distortion

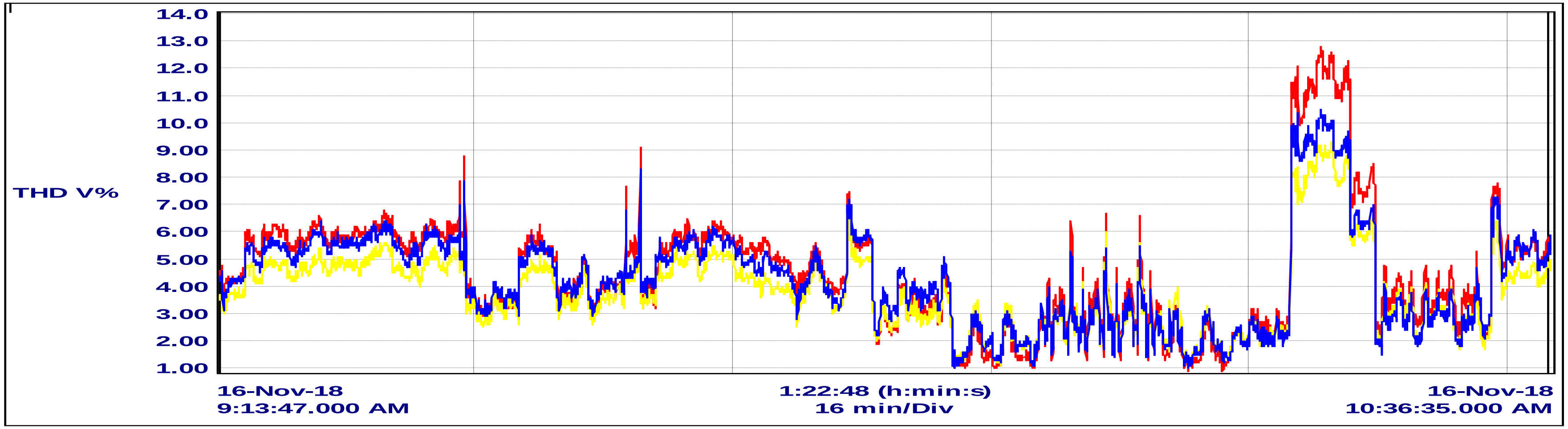


KW, KVAR

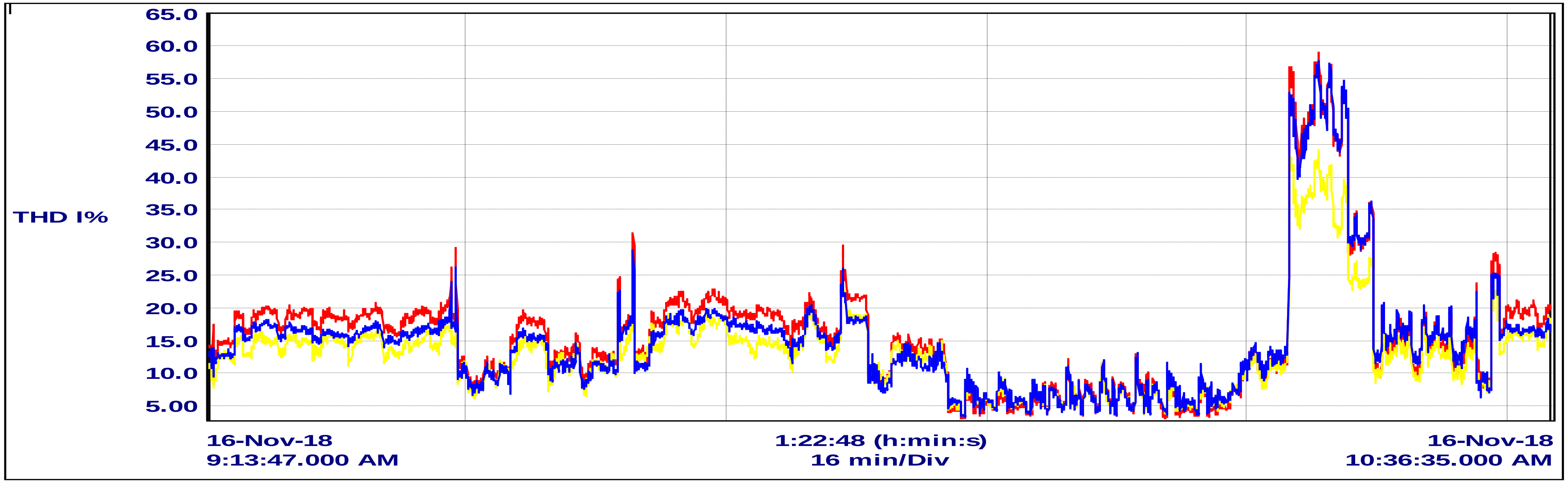


TR-5 LT:

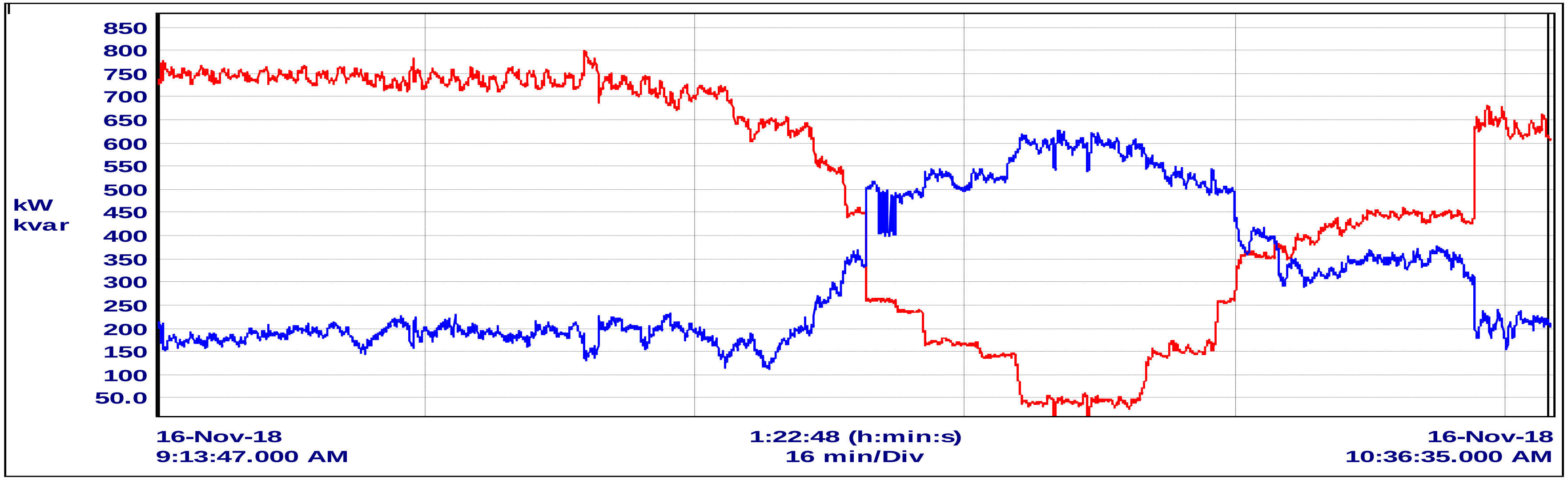
Voltage Harmonic Distortion



Current Harmonic Distortion

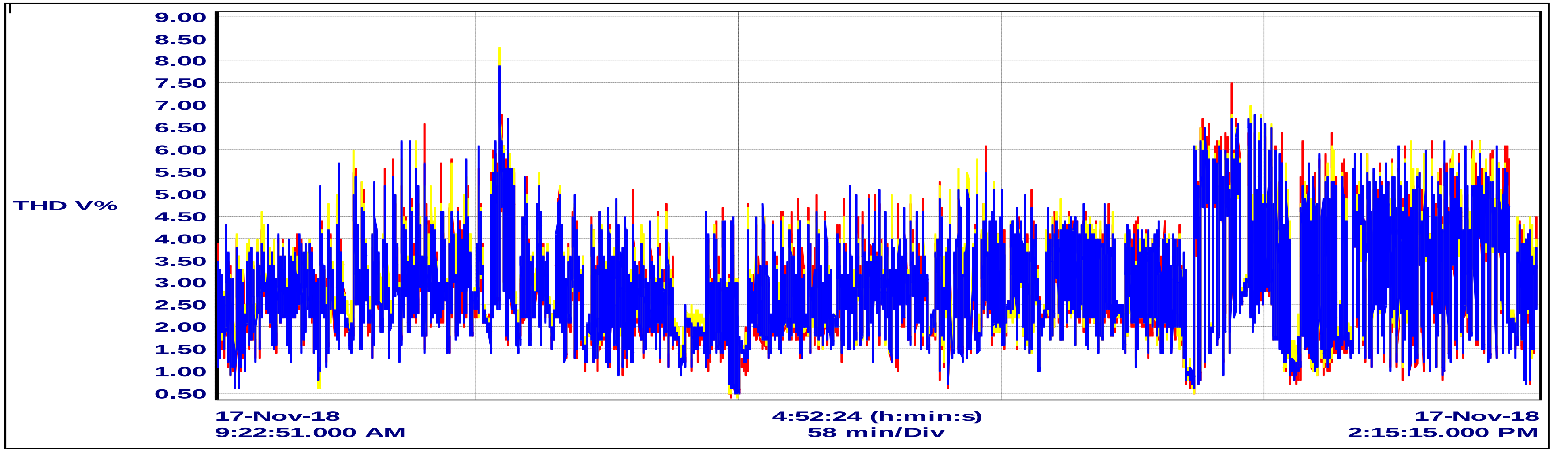


KW, KVAR

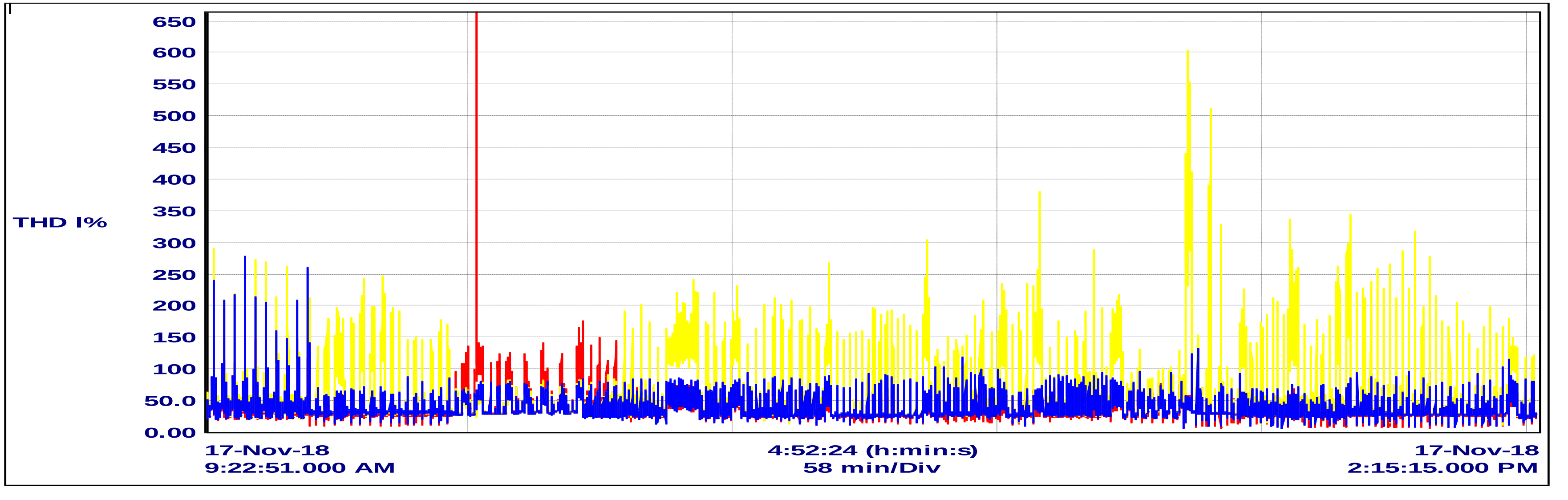


TR-10 HT:

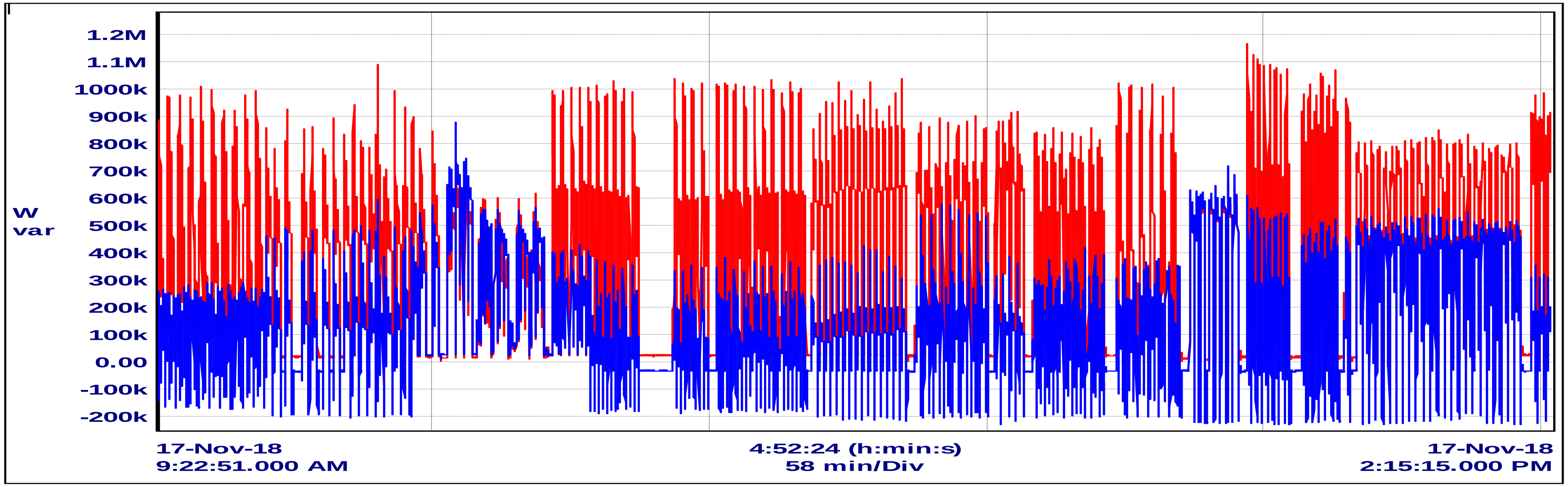
Voltage Harmonic Distortion



Current Harmonic Distortion

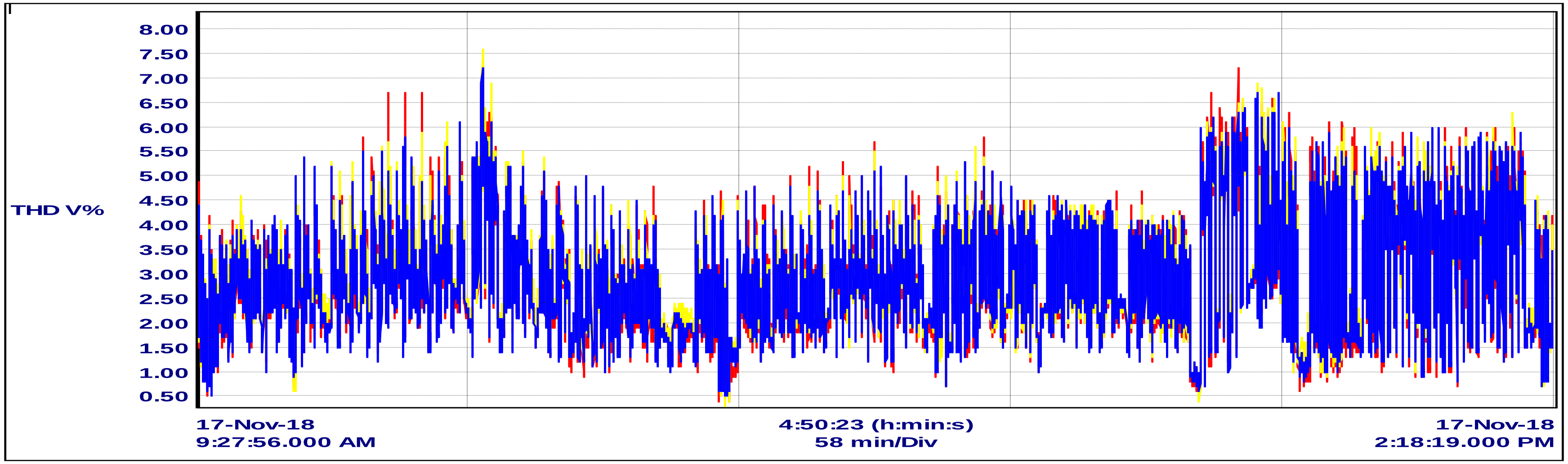


KW, KVAR

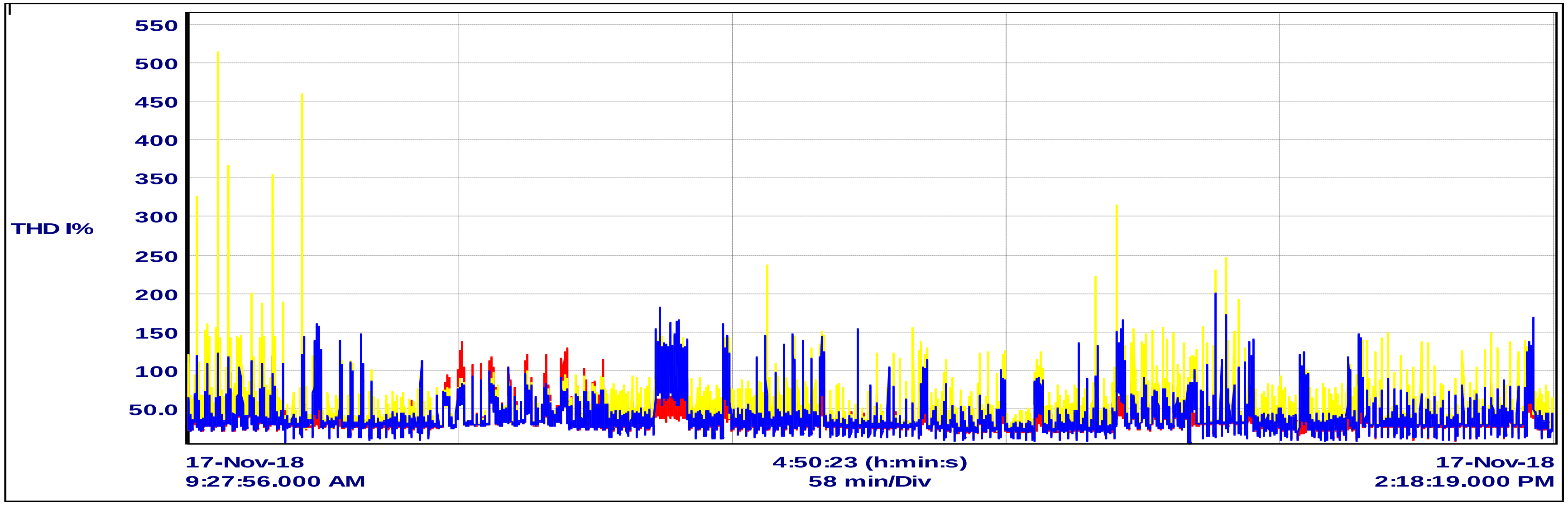


TR-11 HT:

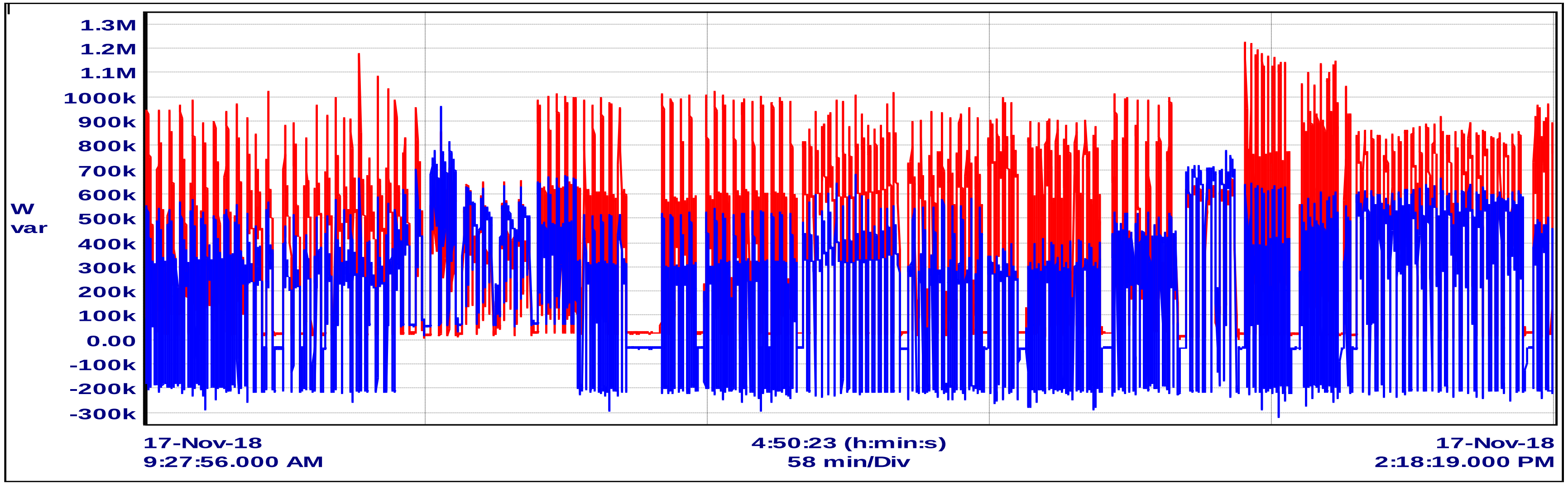
Voltage Harmonic Distortion



Current Harmonic Distortion

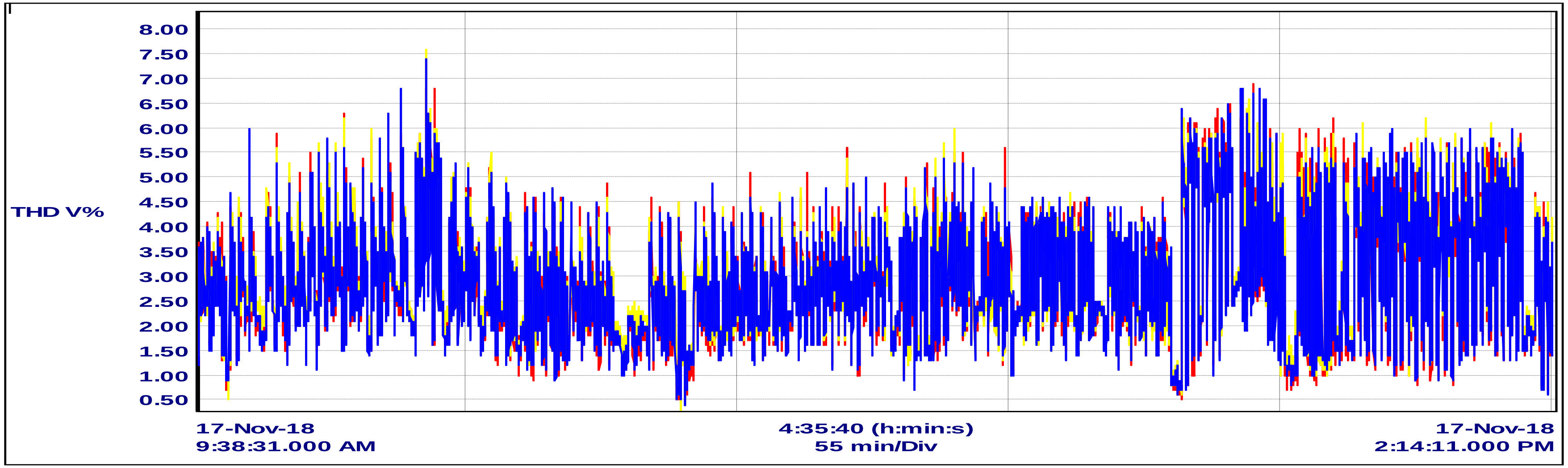


KW, KVAR

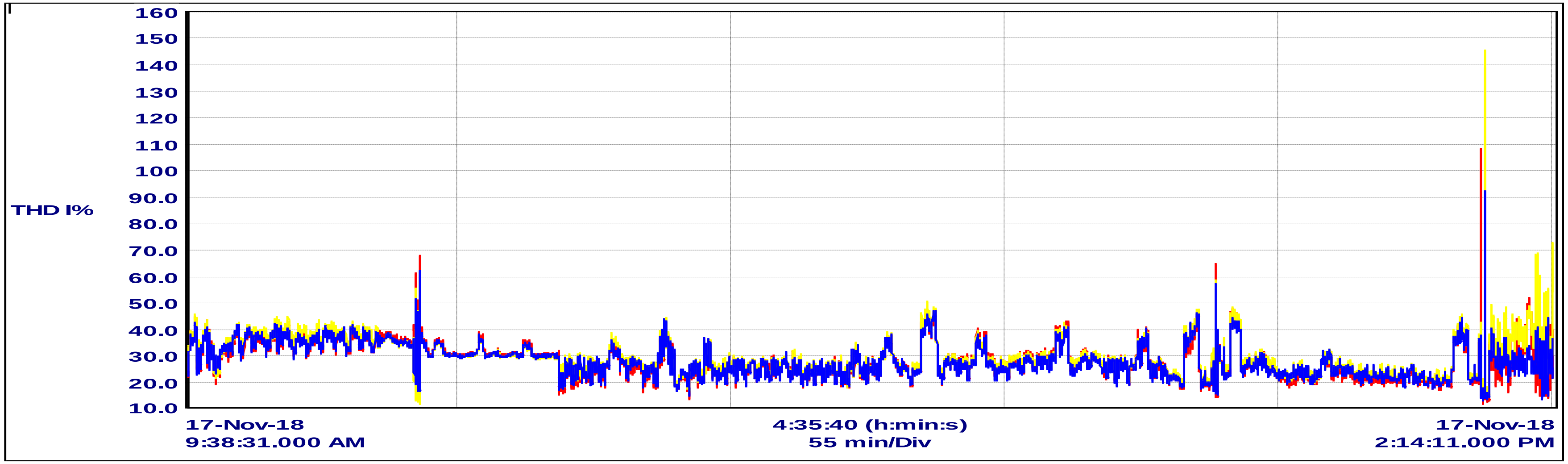


TR-12 HT:

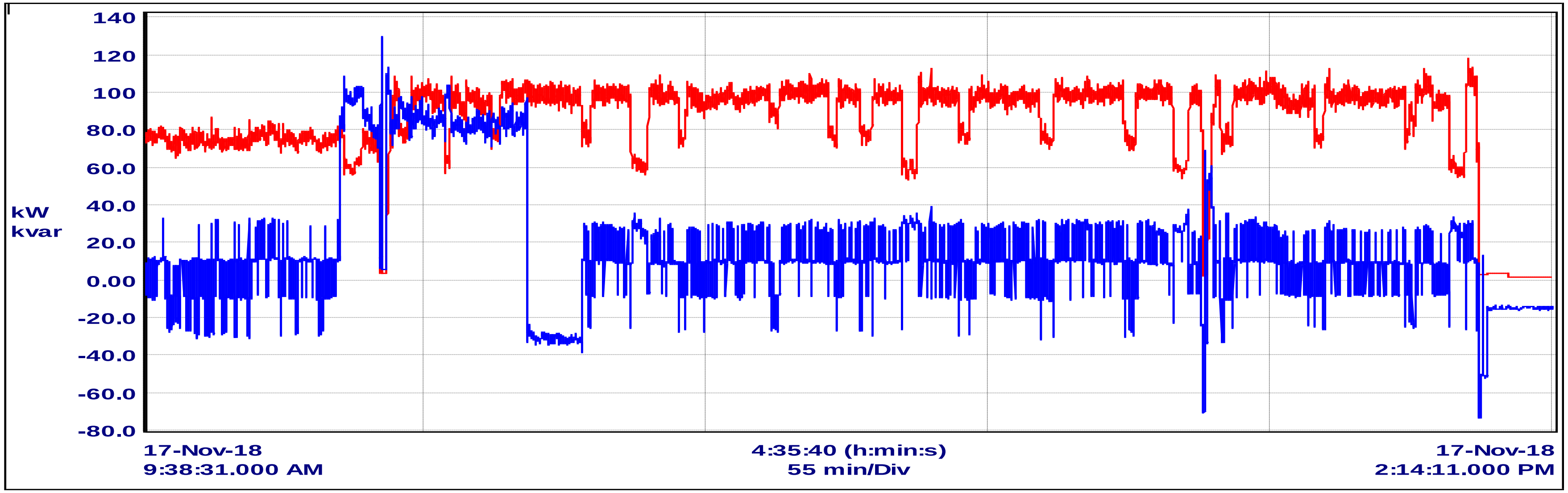
Voltage Harmonic Distortion



Current Harmonic Distortion

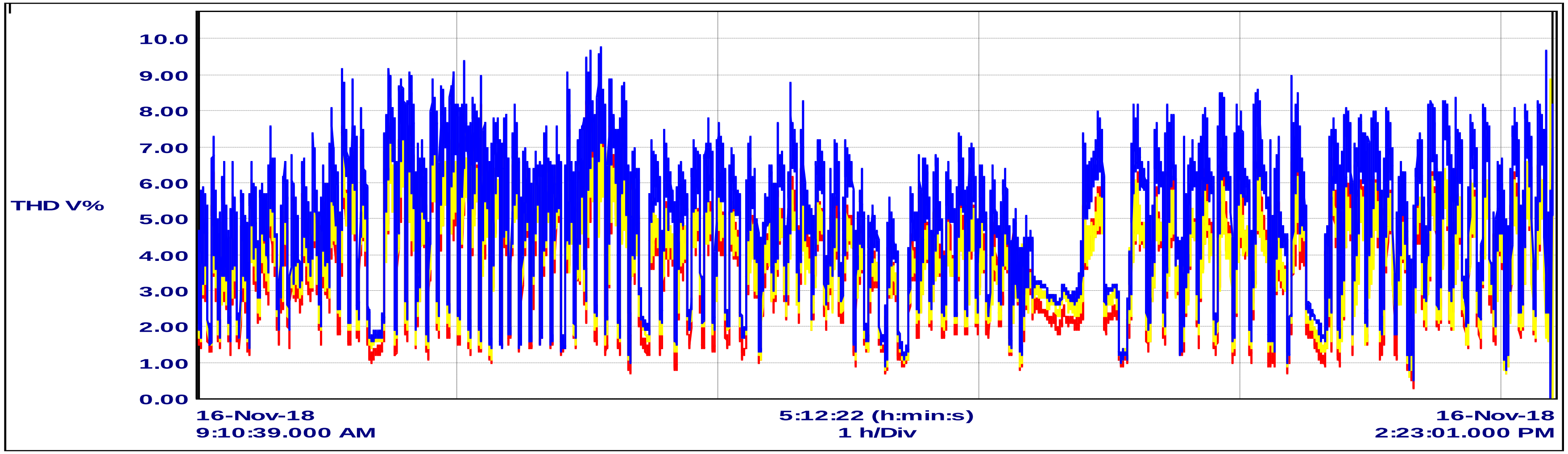


KW, KVAR

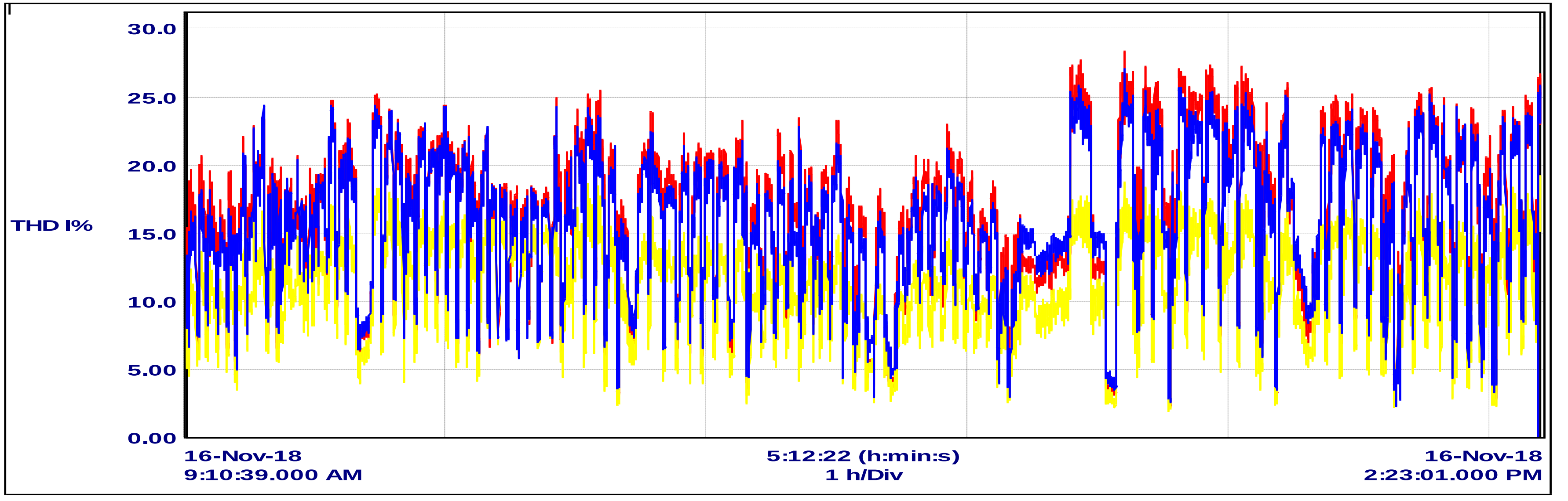


TR-2 HT:

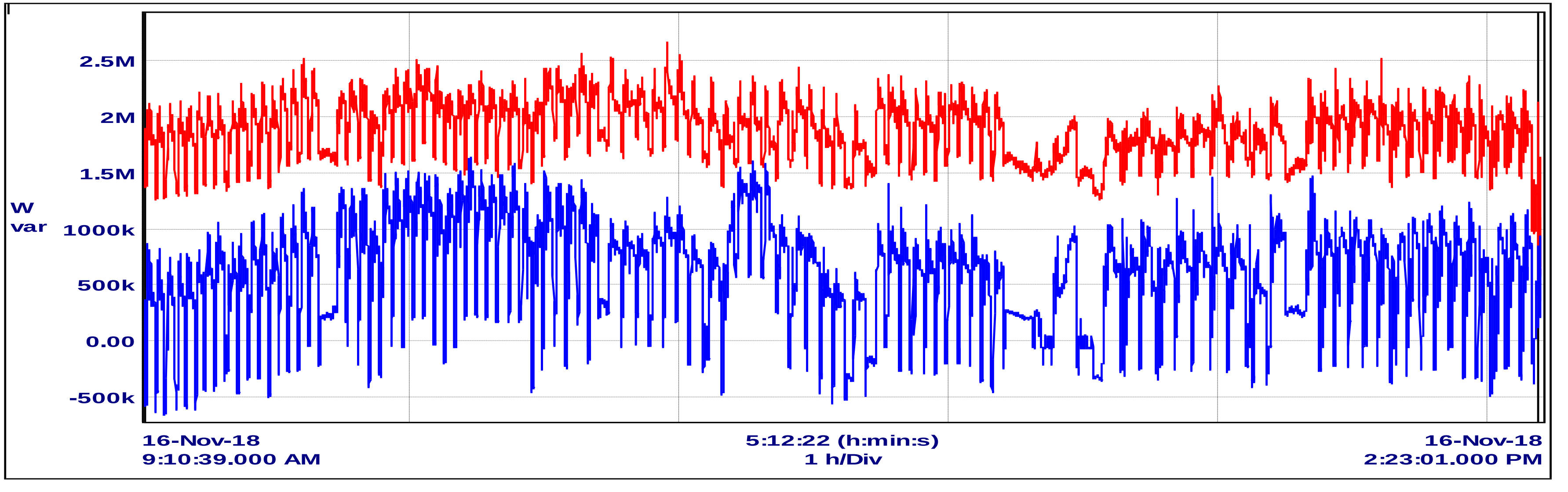
Voltage Harmonic Distortion



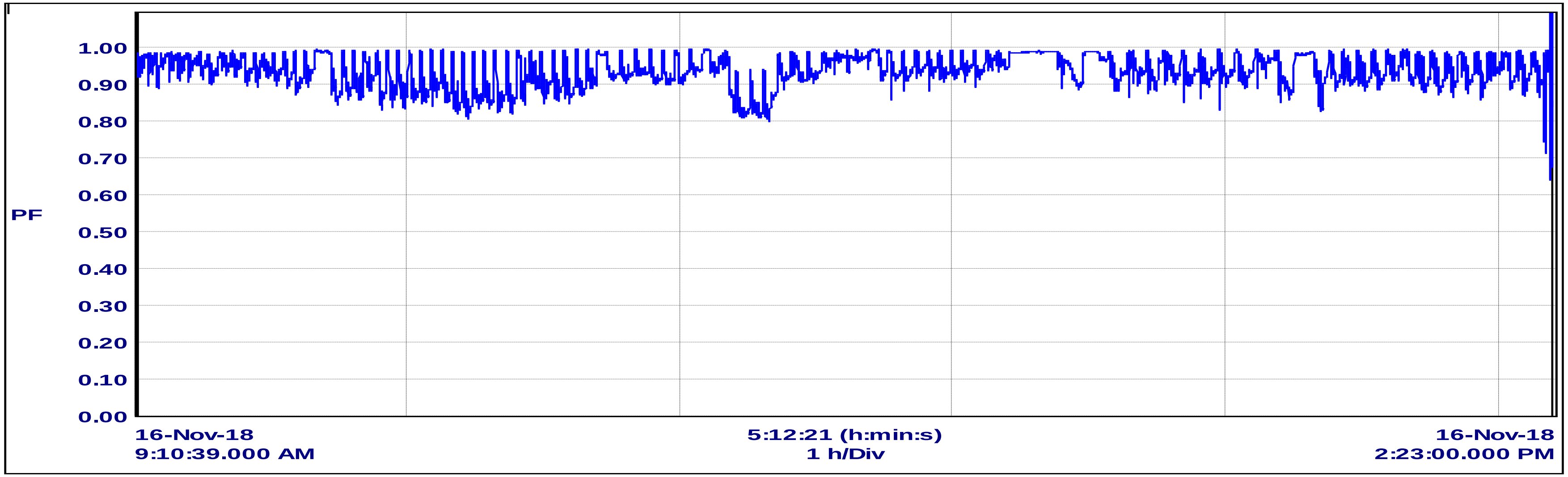
Current Harmonic Distortion



KW, KVAR

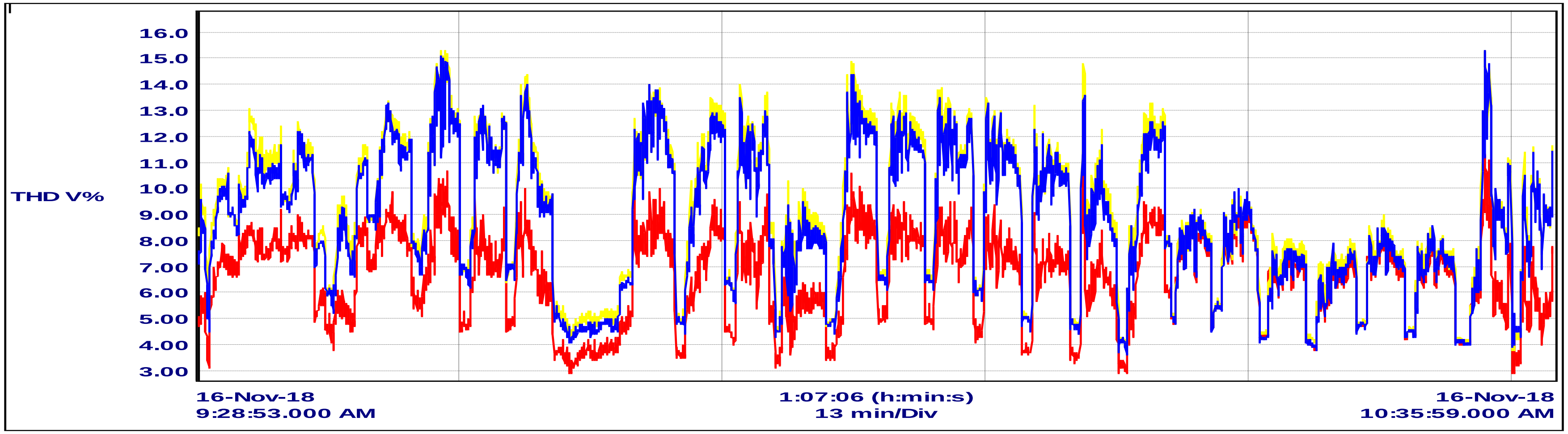


PF

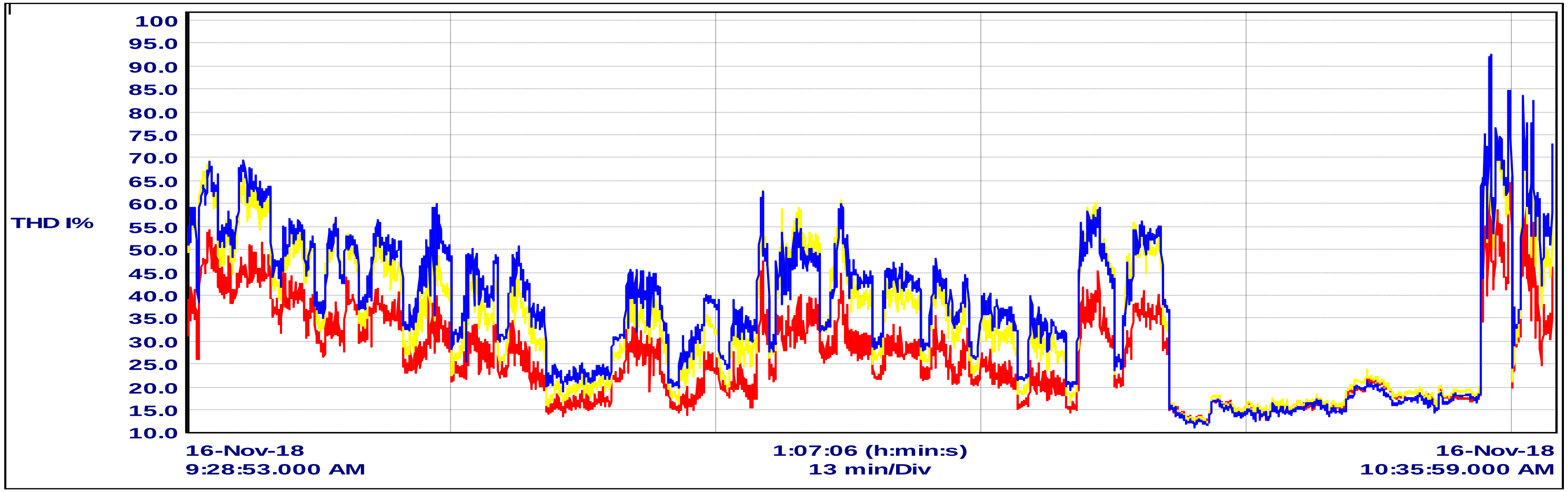


TR-6 LT:

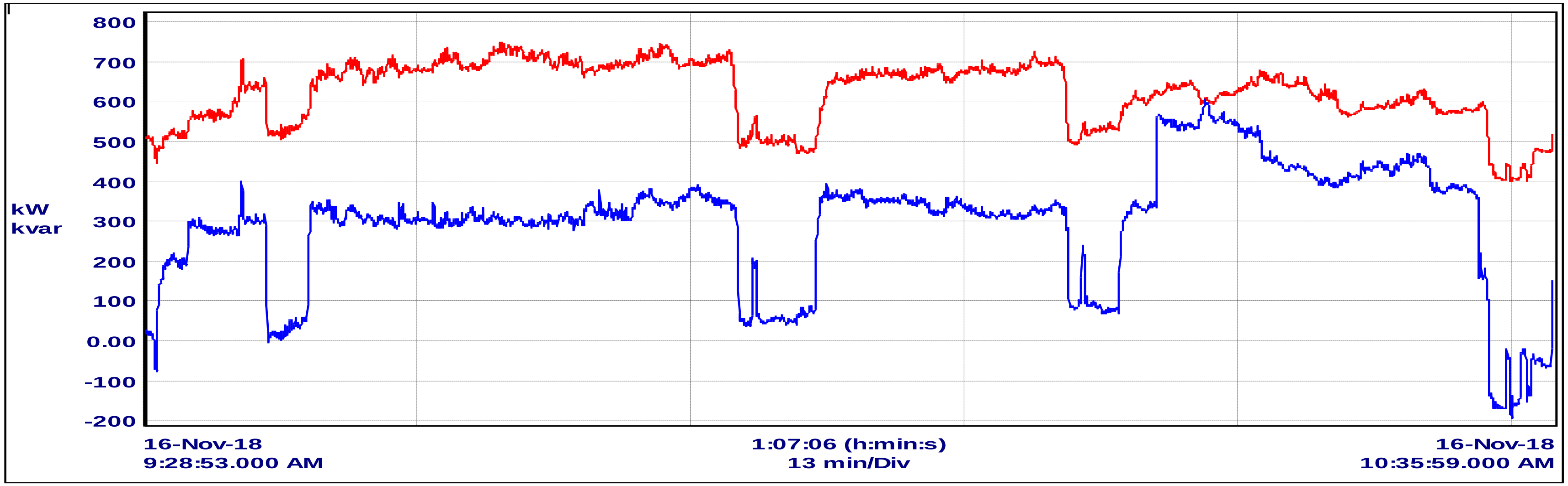
Voltage Harmonic Distortion



Current Harmonic Distortion

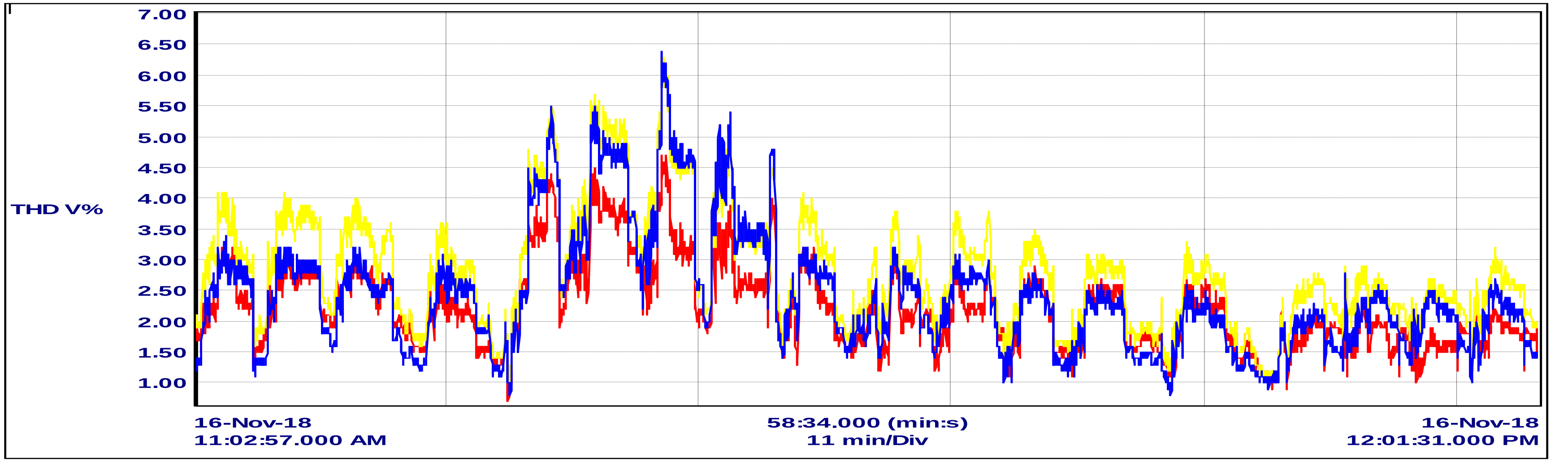


KW, KVAR

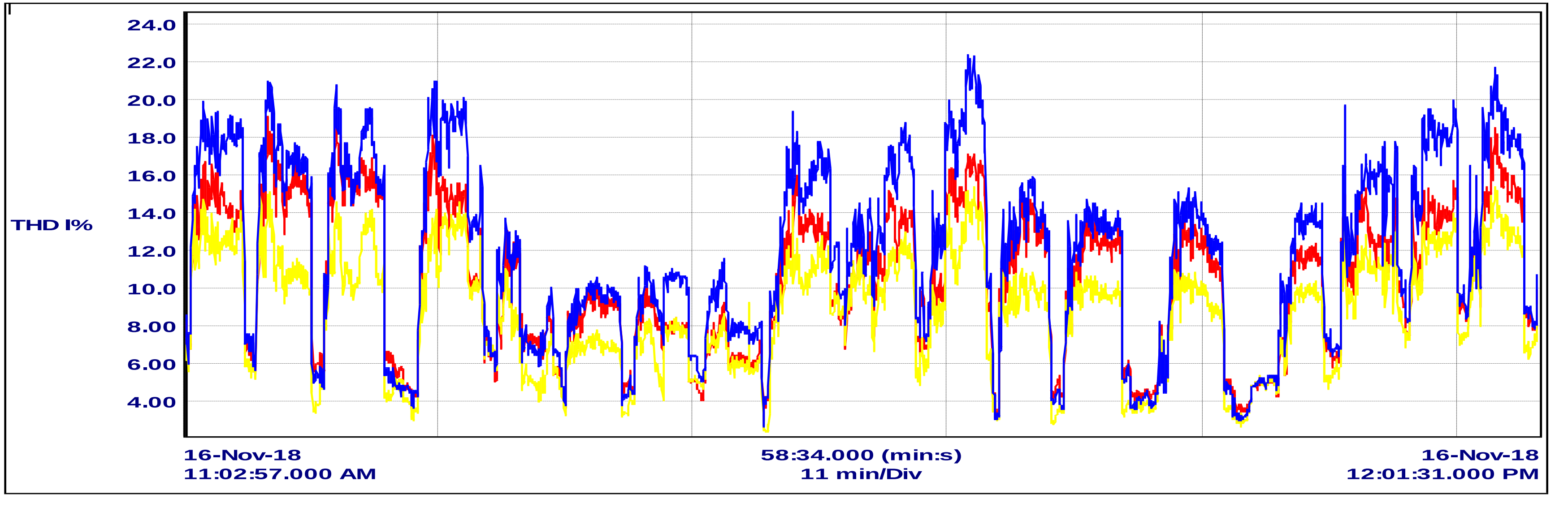


TR-8 LT:

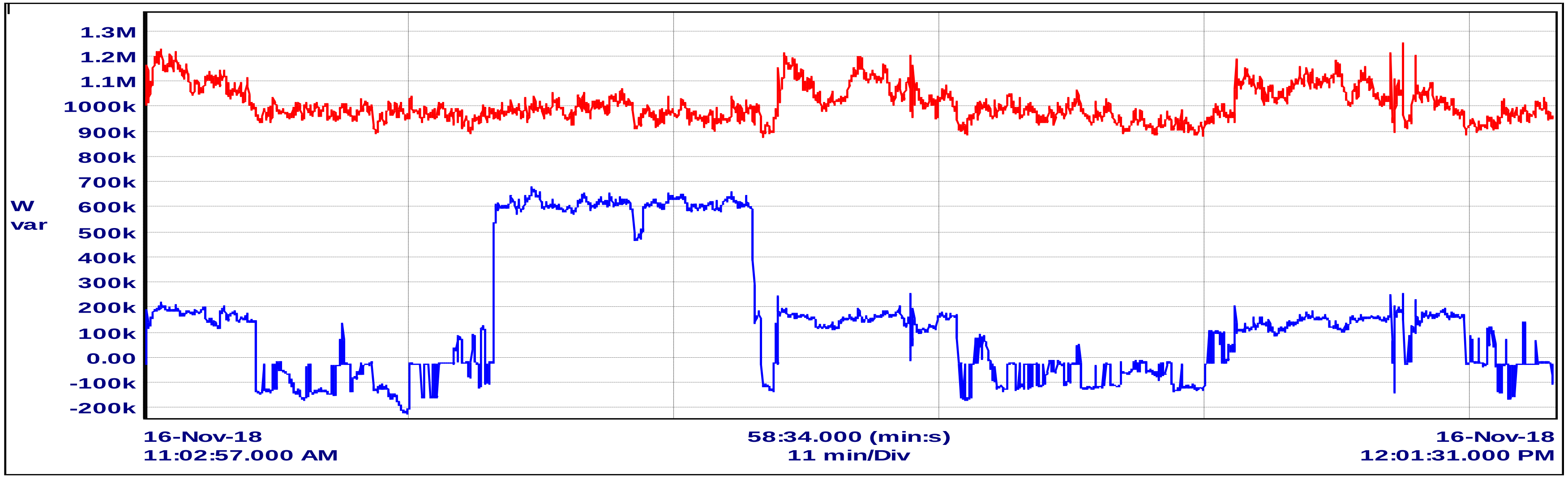
Voltage Harmonic Distortion



Current Harmonic Distortion

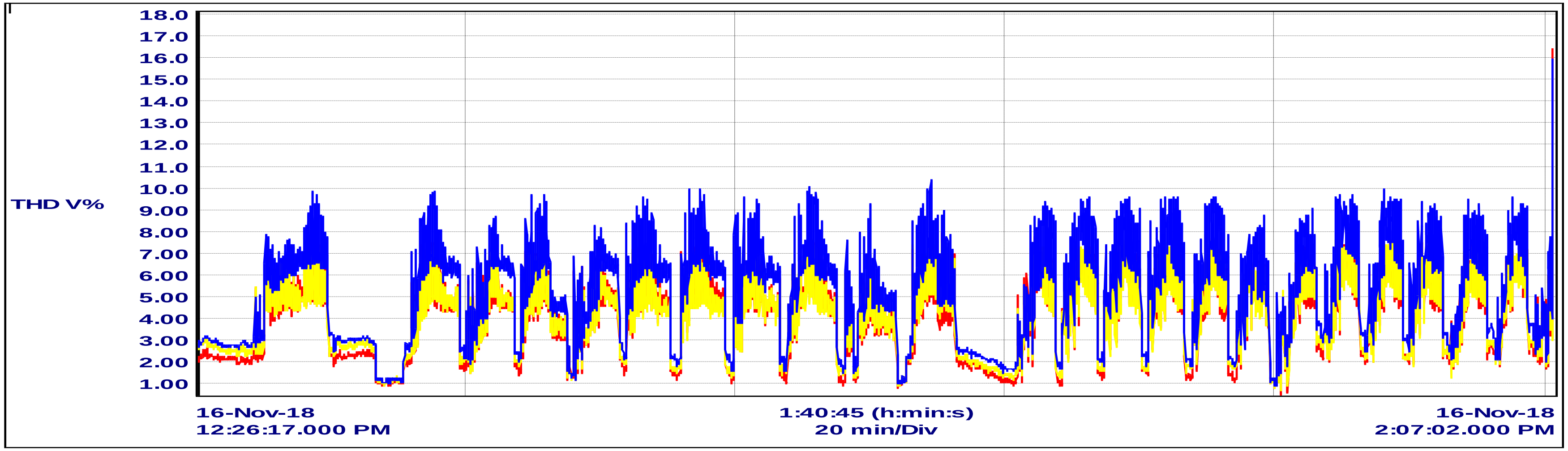


KW, KVAR

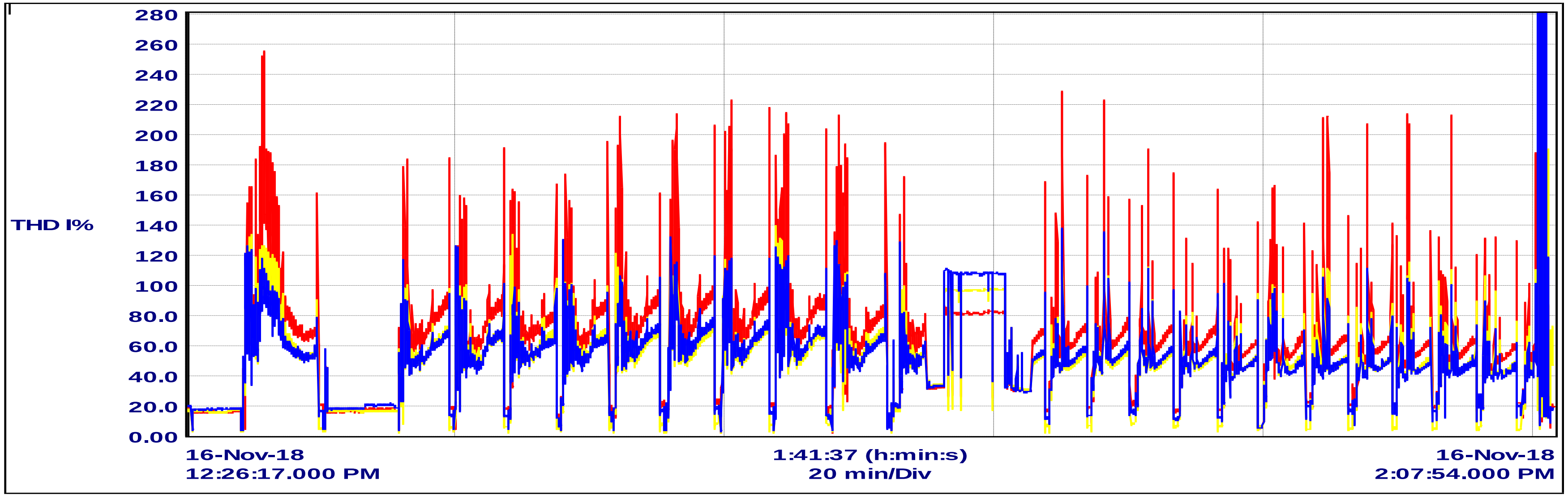


TR-15 LT:

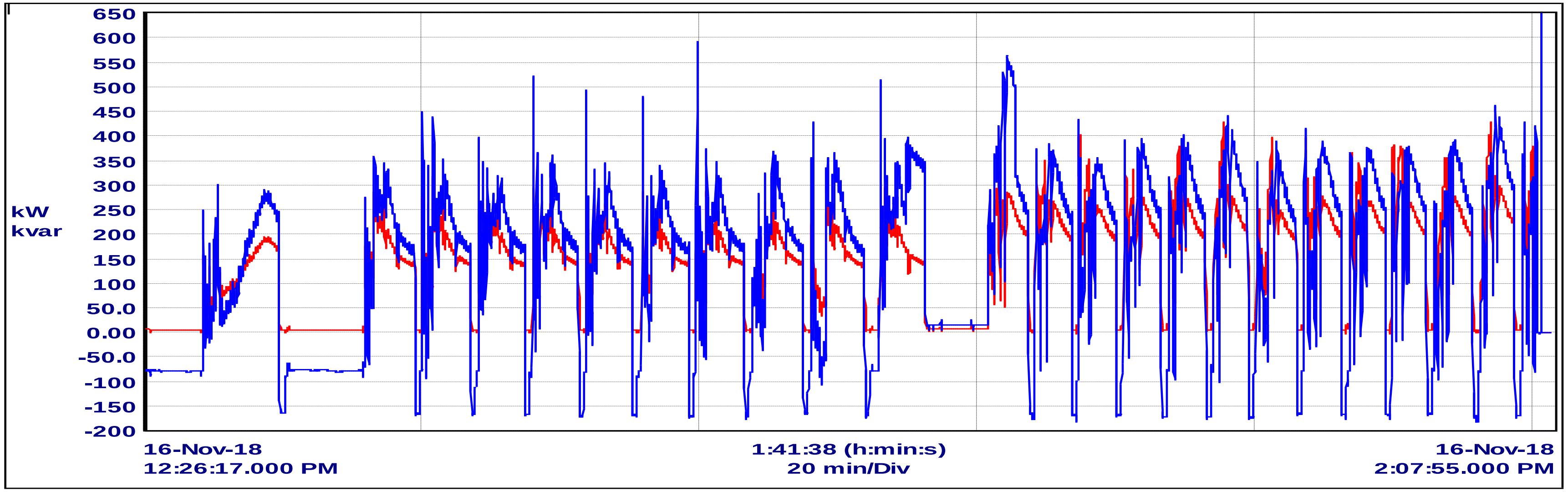
Voltage Harmonic Distortion



Current Harmonic Distortion

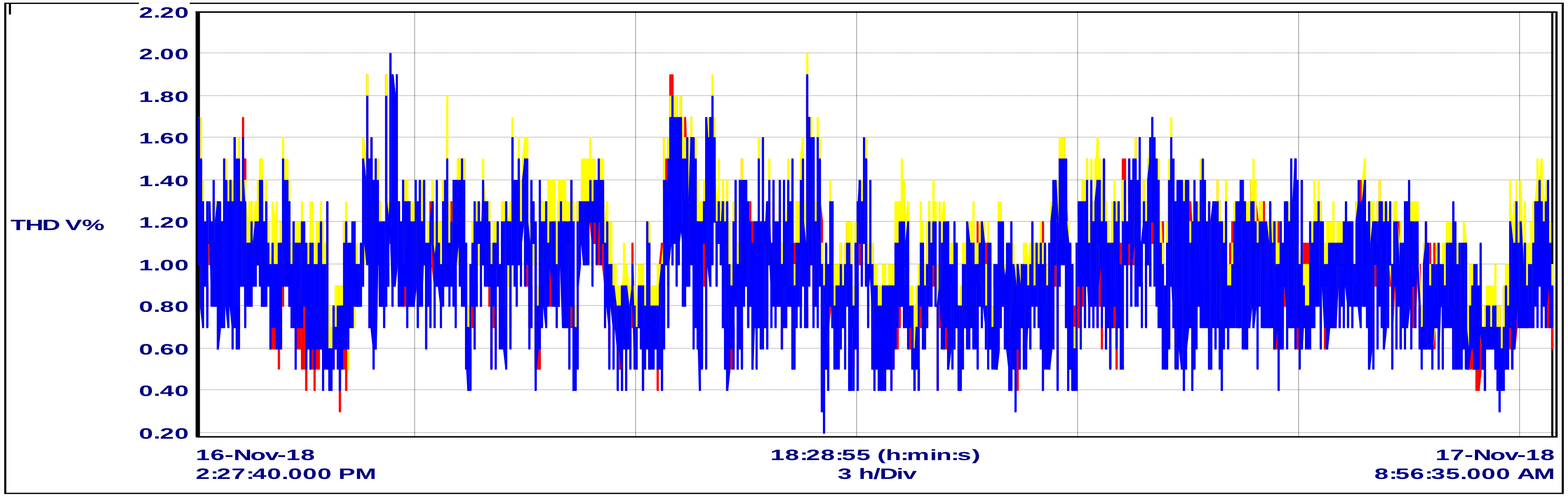


KW, KVAR

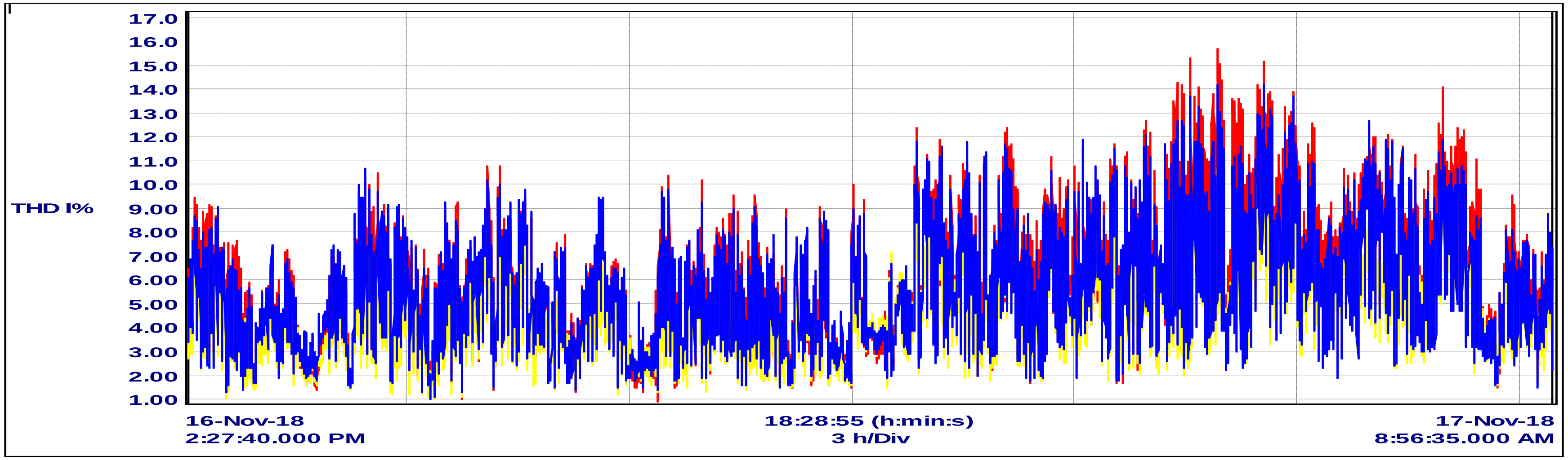


TR-3 HT:

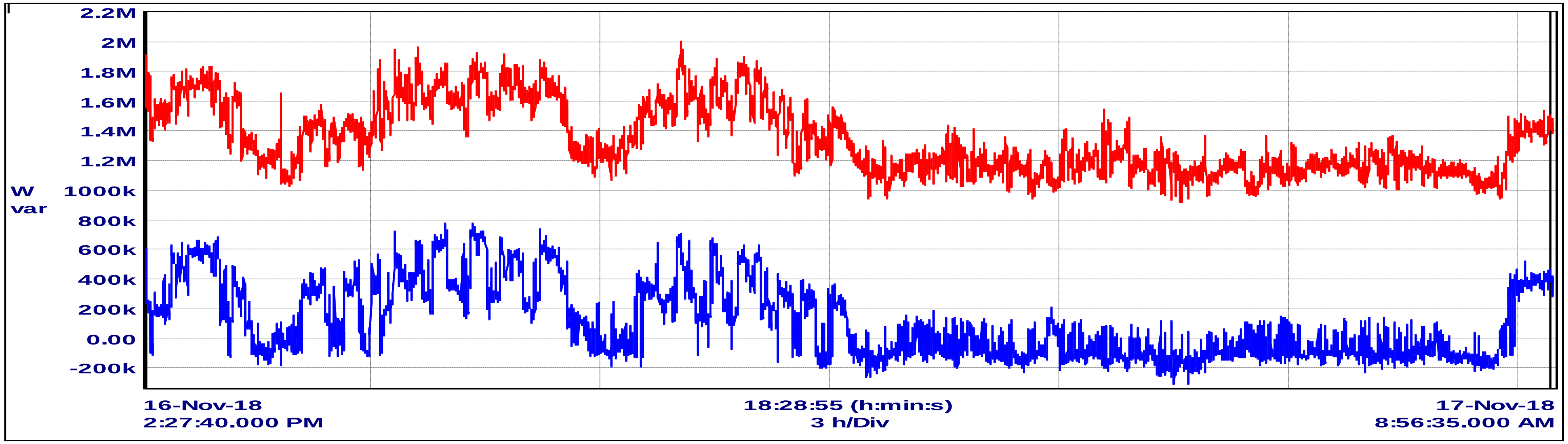
Voltage Harmonic Distortion



Current Harmonic Distortion

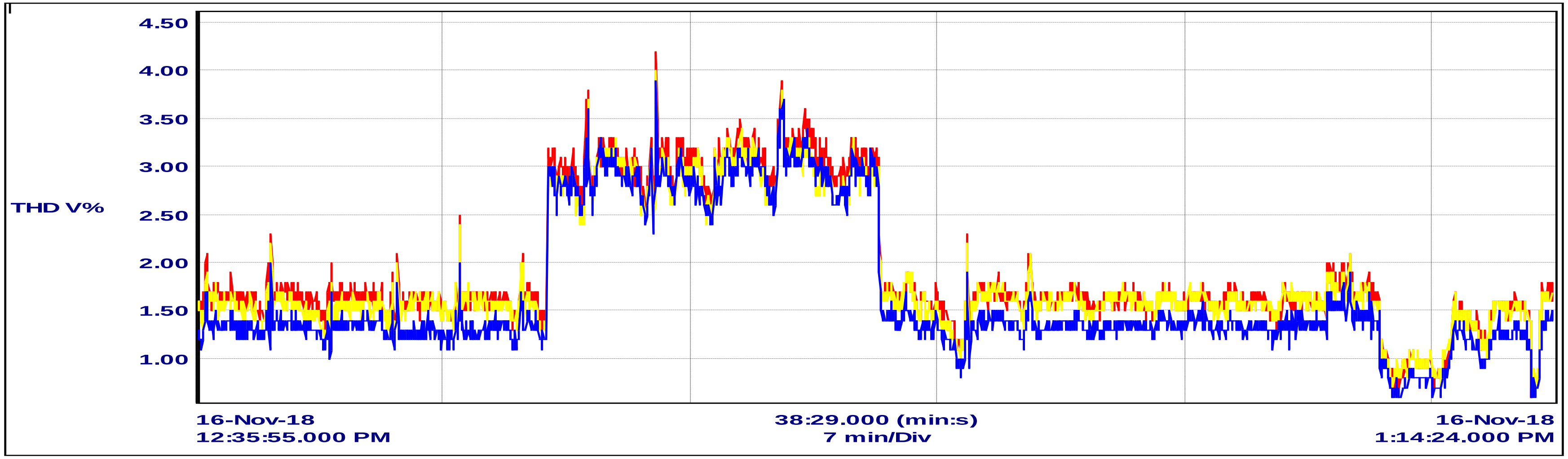


KW, KVAR

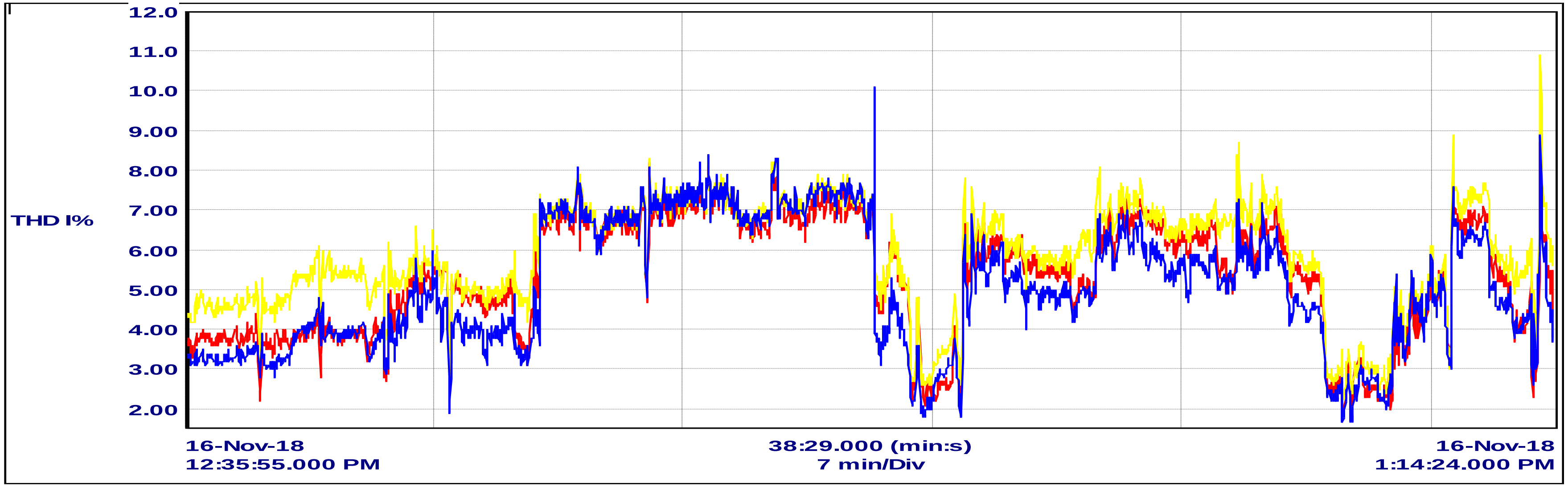


TR-7 LT:

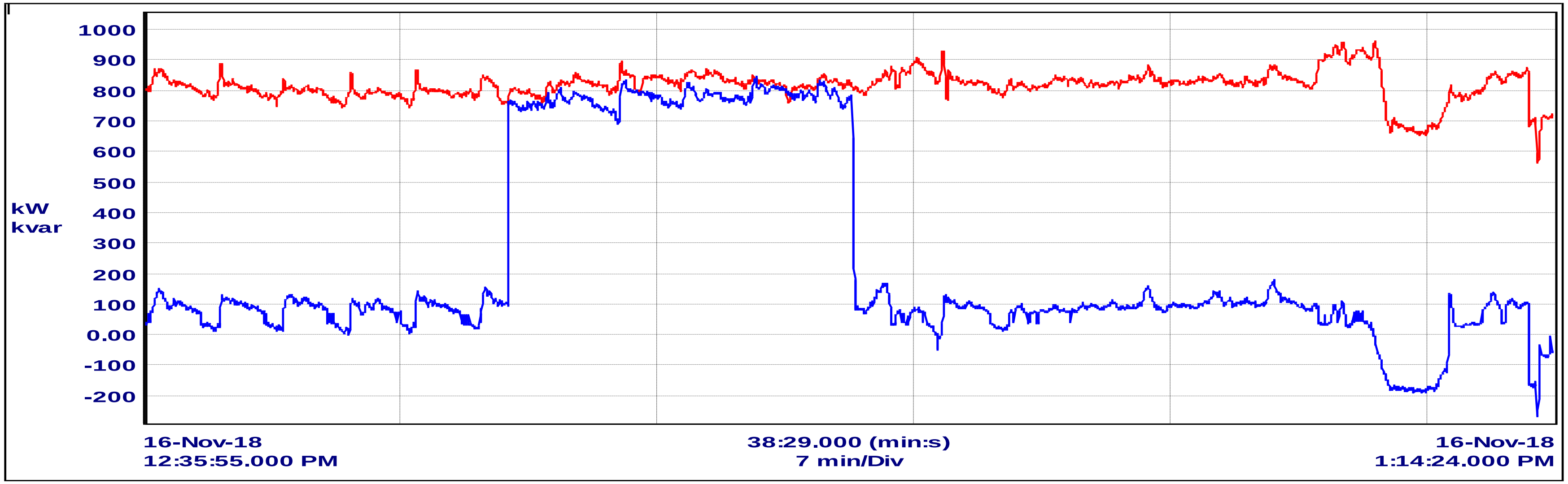
Voltage Harmonic Distortion



Current Harmonic Distortion

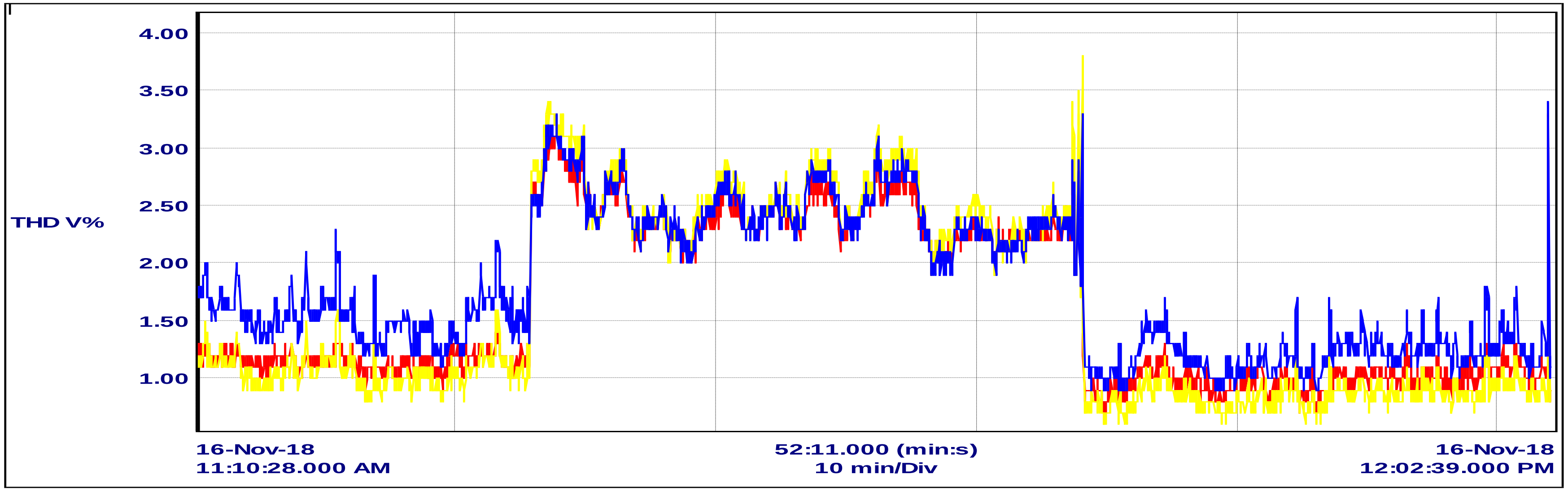


KW, KVAR

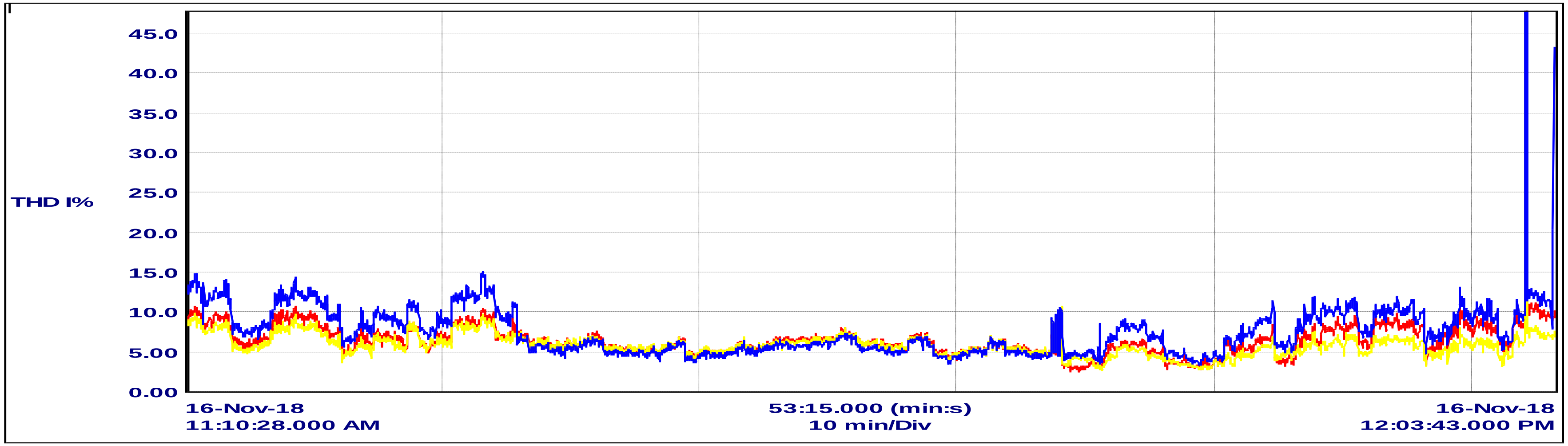


TR-9 LT:

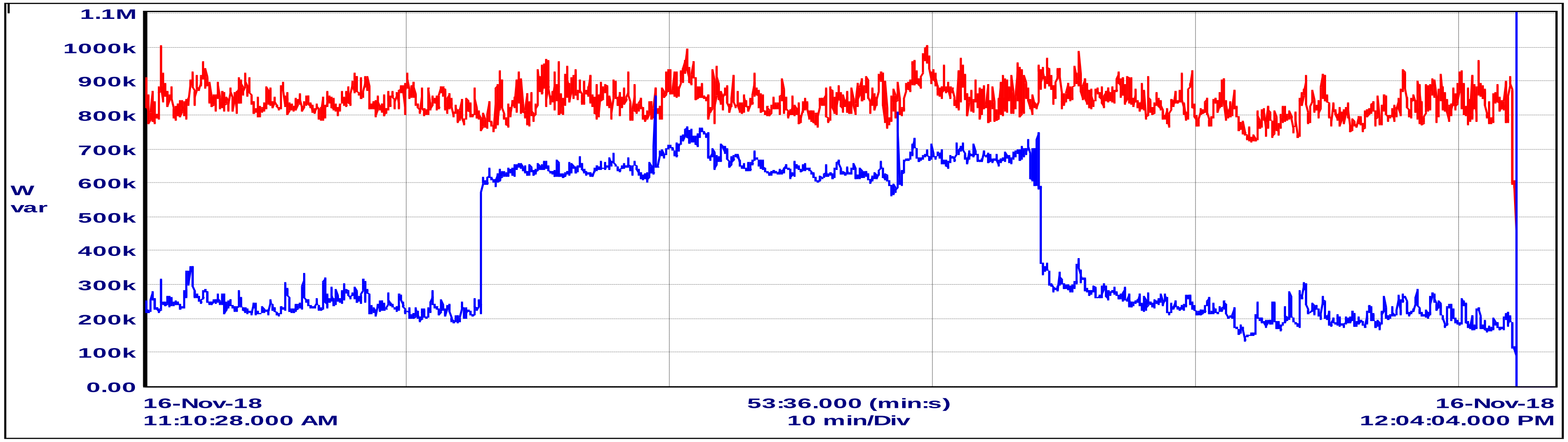
Voltage Harmonic Distortion



Current Harmonic Distortion

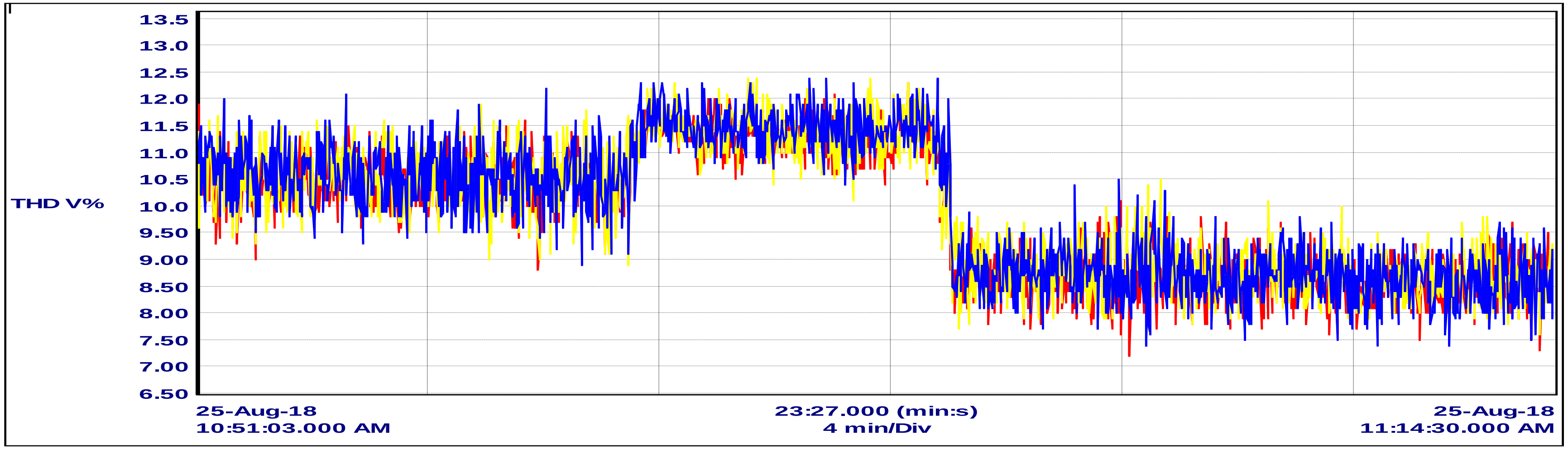


KW, KVAR

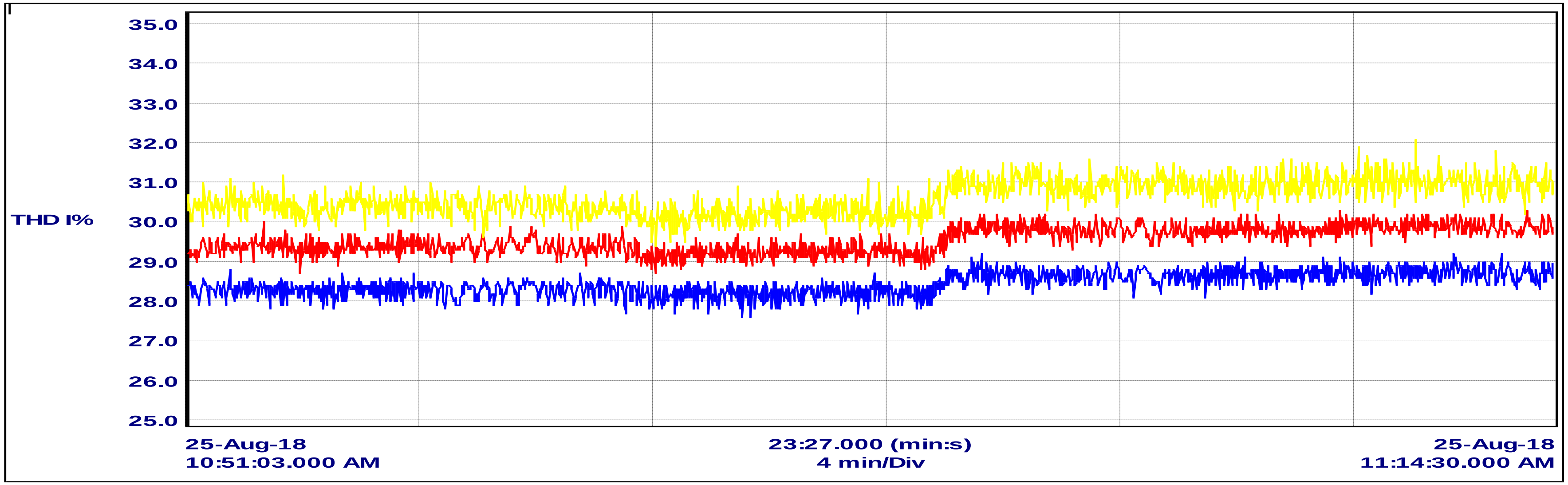


TR-13 LT:

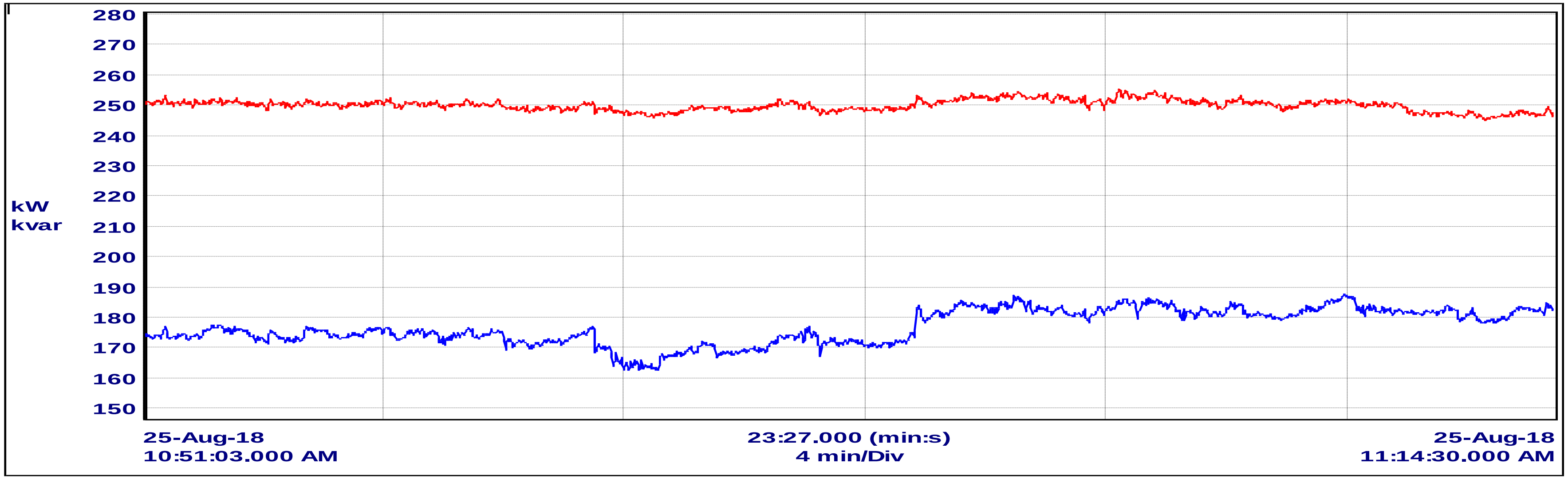
Voltage Harmonic Distortion



Current Harmonic Distortion

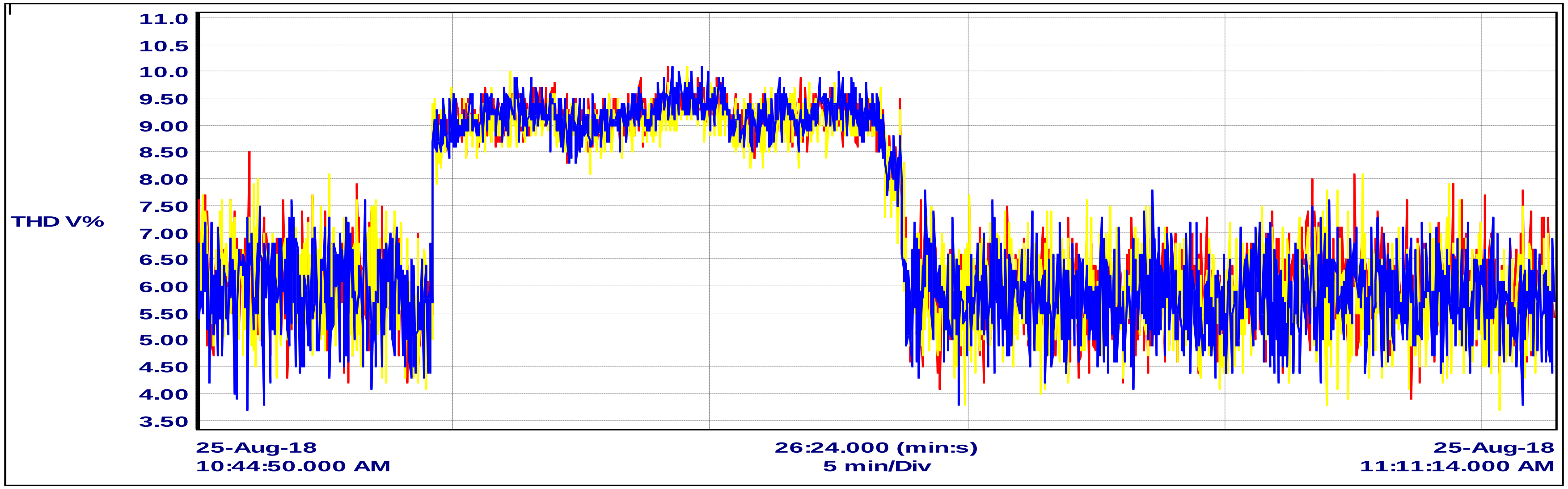

35.0
34.0
33.0
32.0
31.0
THD I%
30.0
29.0
28.0
27.0
26.0
25.0
25-Aug-18
10:51:03.000 AM
23:27.000 (min:s)
4 min/Div
25-Aug-18
11:14:30.000 AM

KW, KVAR

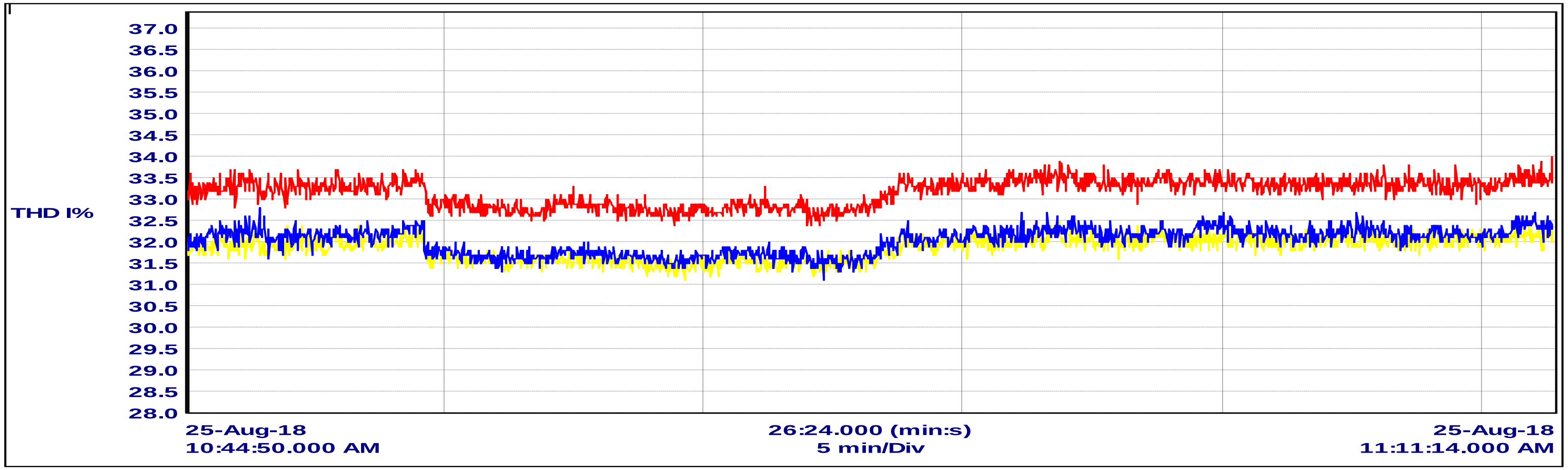

280
270
260
250
240
230
220
kW
kvar
210
200
190
180
170
160
150
25-Aug-18
10:51:03.000 AM
23:27.000 (min:s)
4 min/Div
25-Aug-18
11:14:30.000 AM

TR-14 LT:

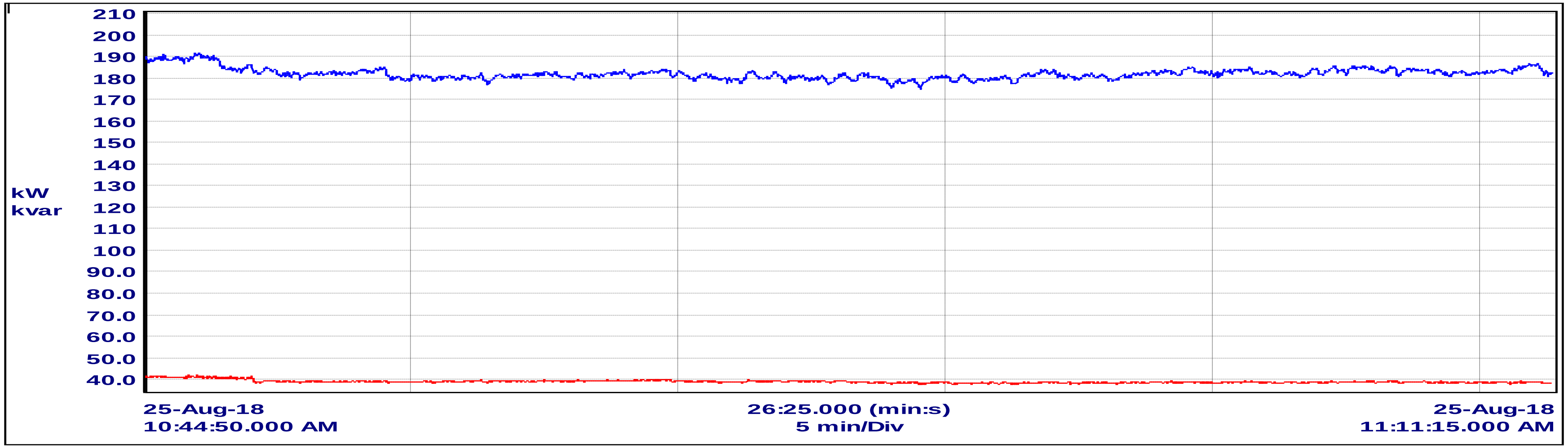
Voltage Harmonic Distortion



Current Harmonic Distortion

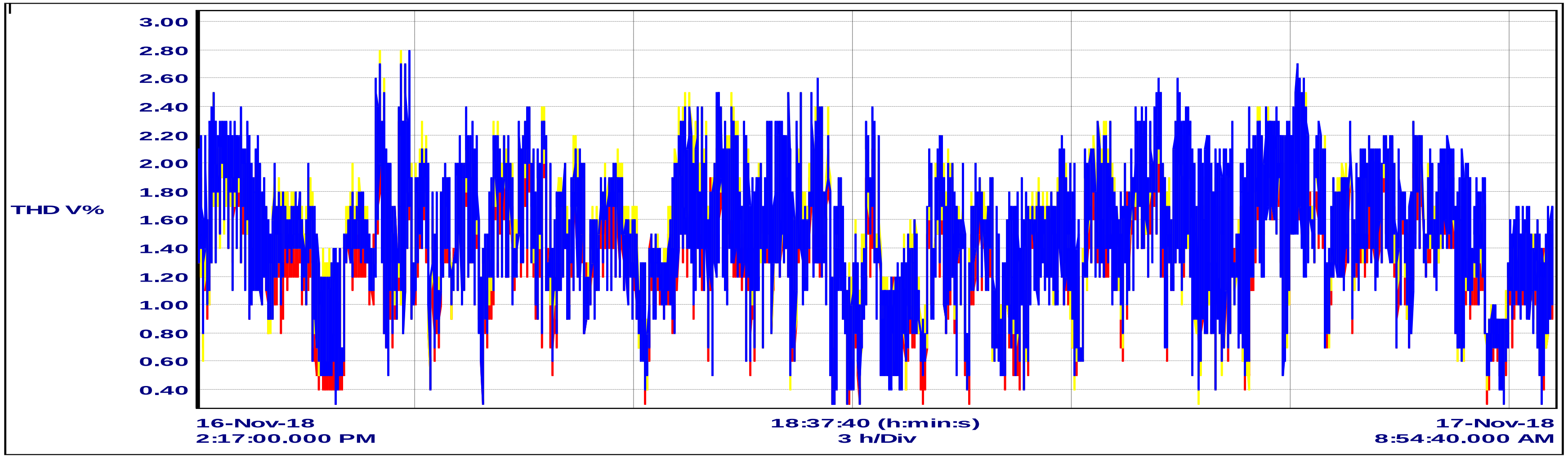


KW, KVAR

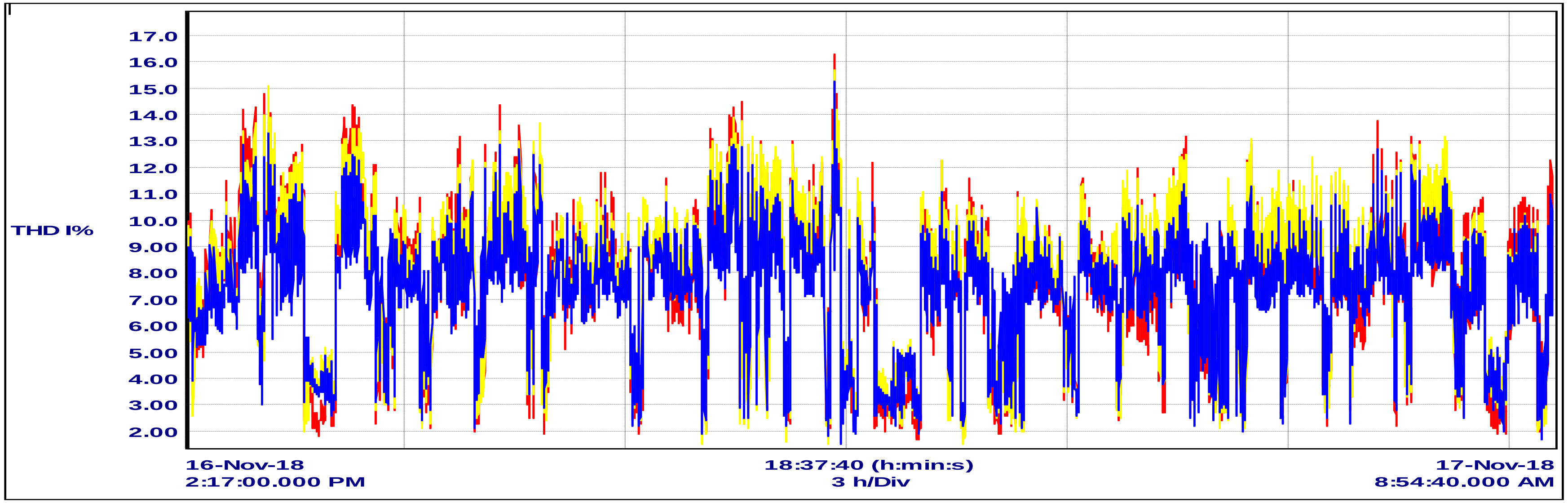


TR-4 HT:

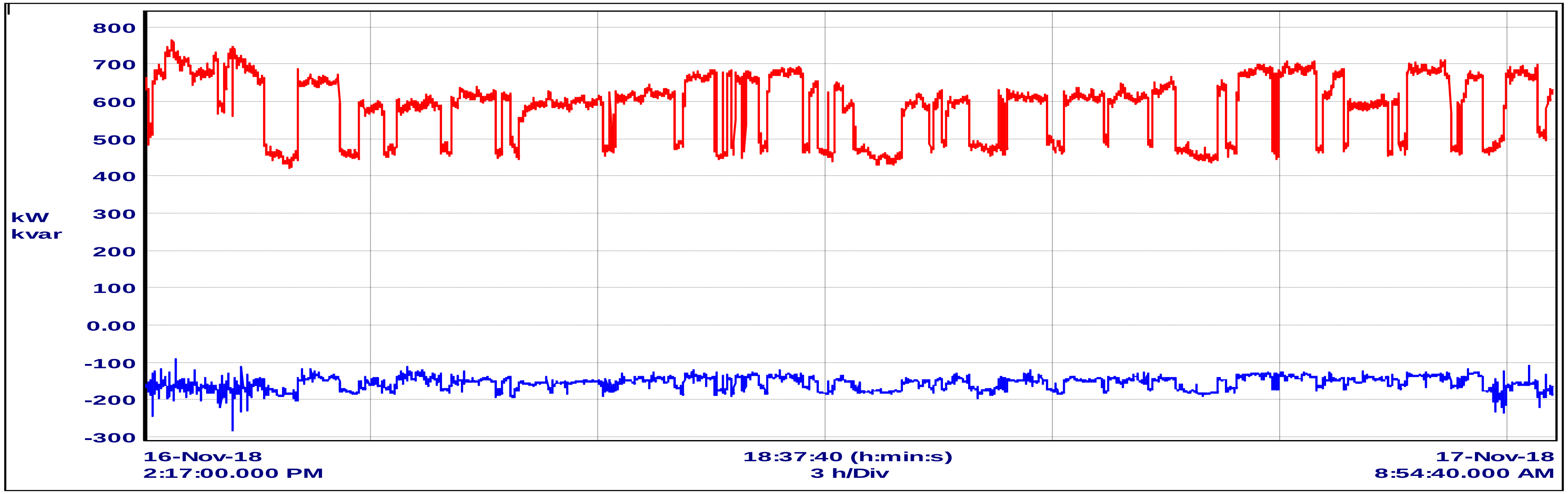
Voltage Harmonic Distortion



Current Harmonic Distortion



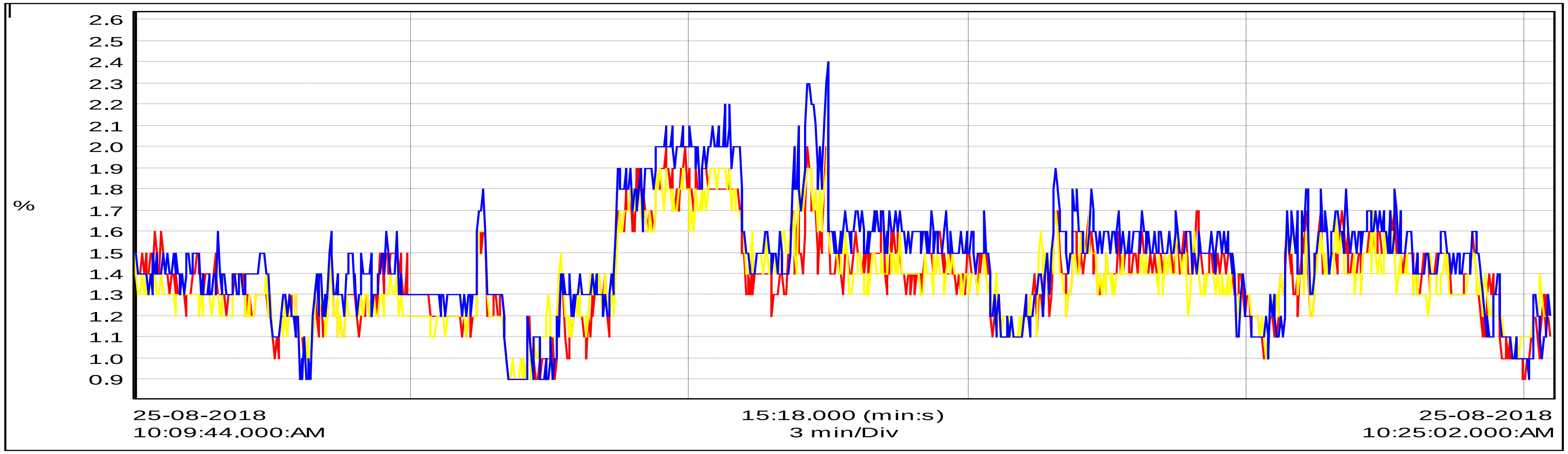
KW, KVAR



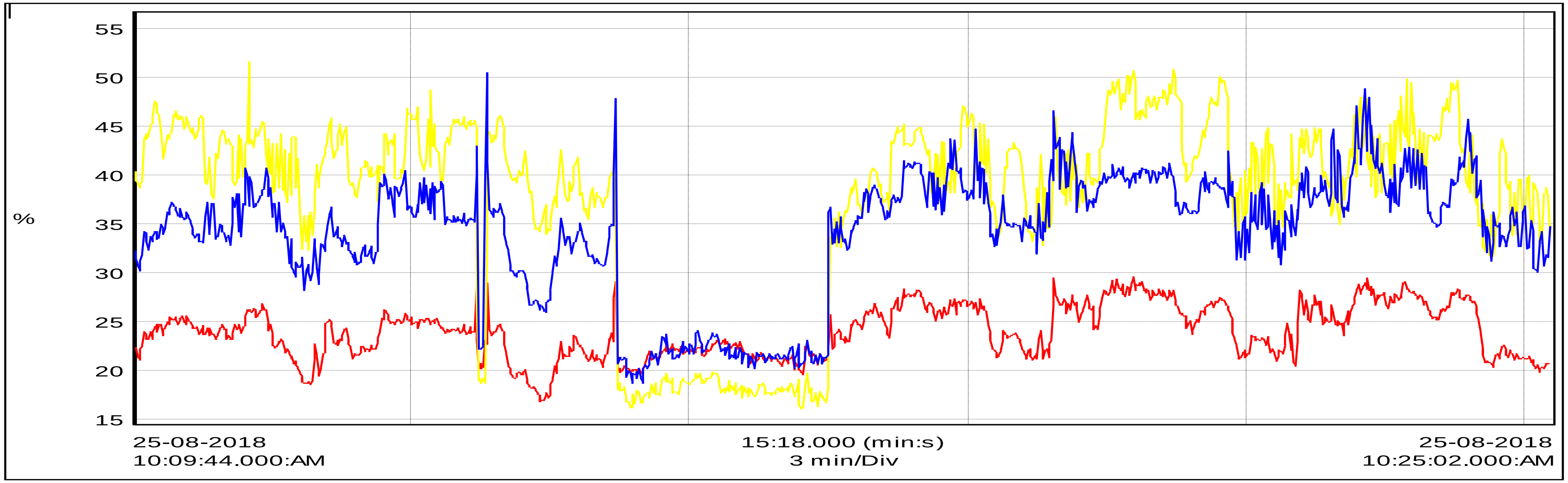
TR-16 LT:

Voltage Harmonic

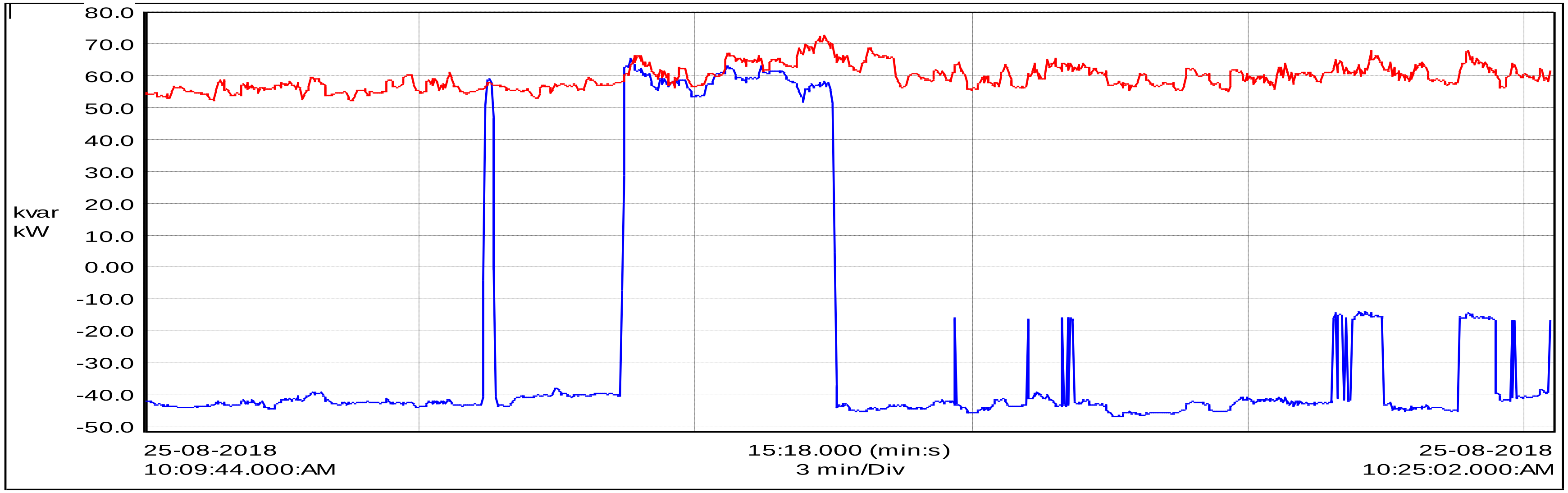
Distortion



Current Harmonic
Distortion

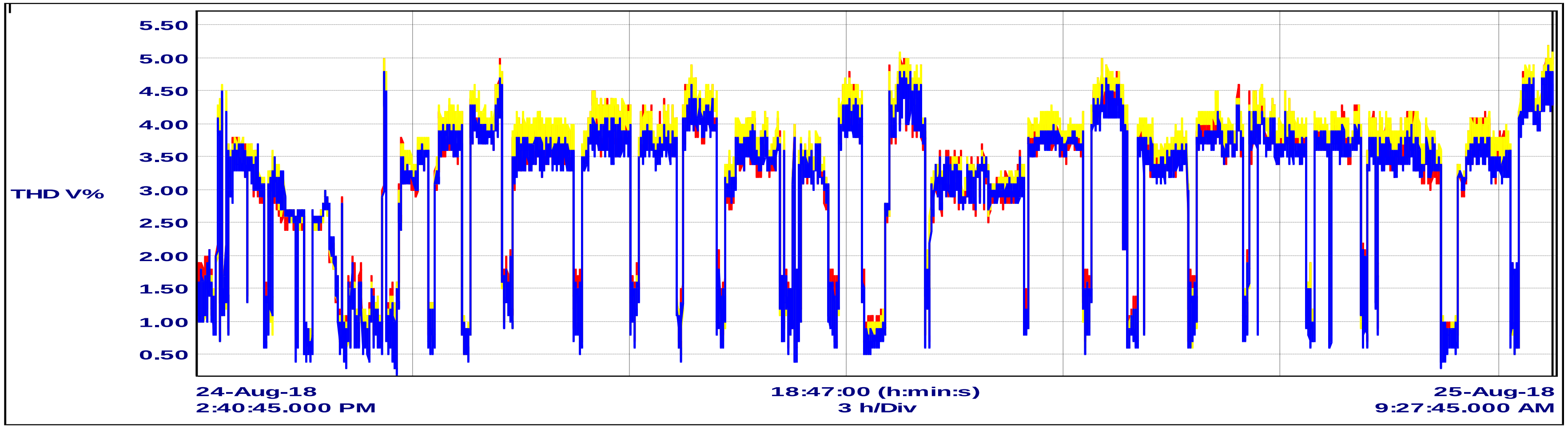


KW, KVAR

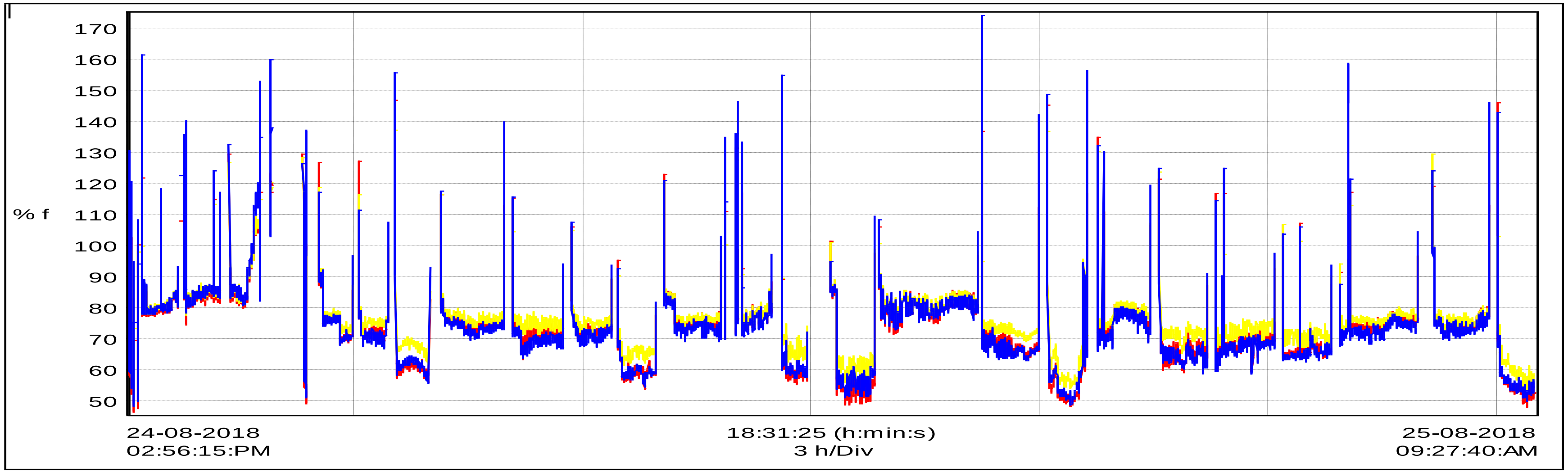


TR-17 LT:

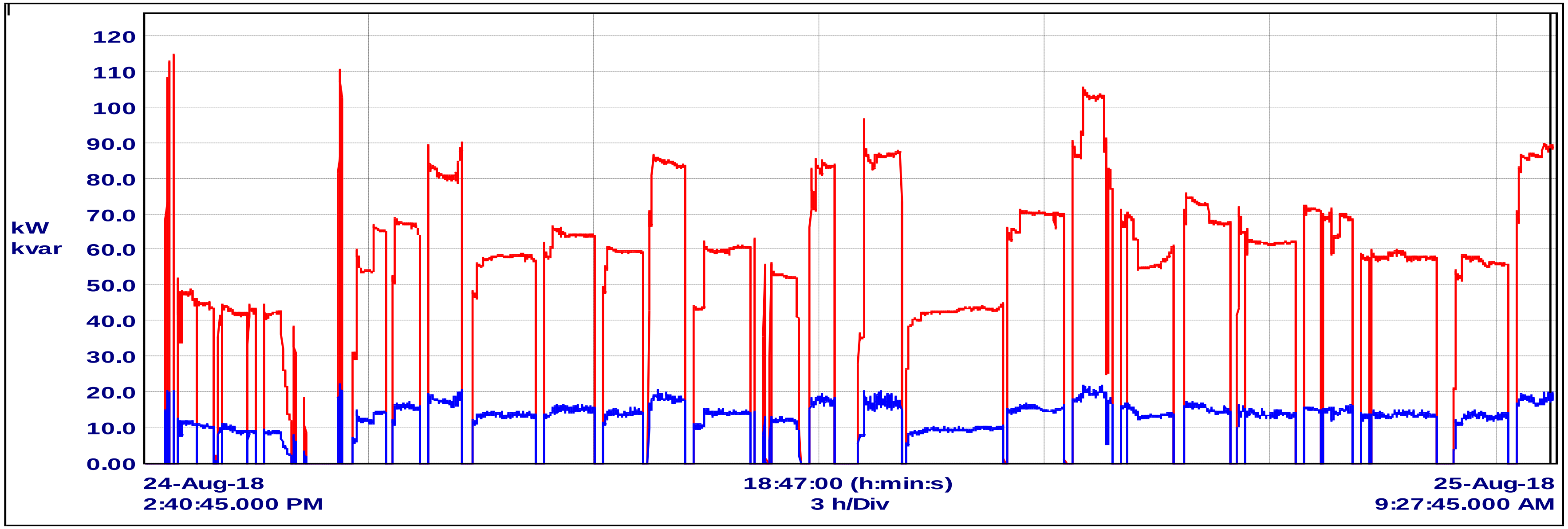
Voltage Harmonic Distortion



Current Harmonic Distortion

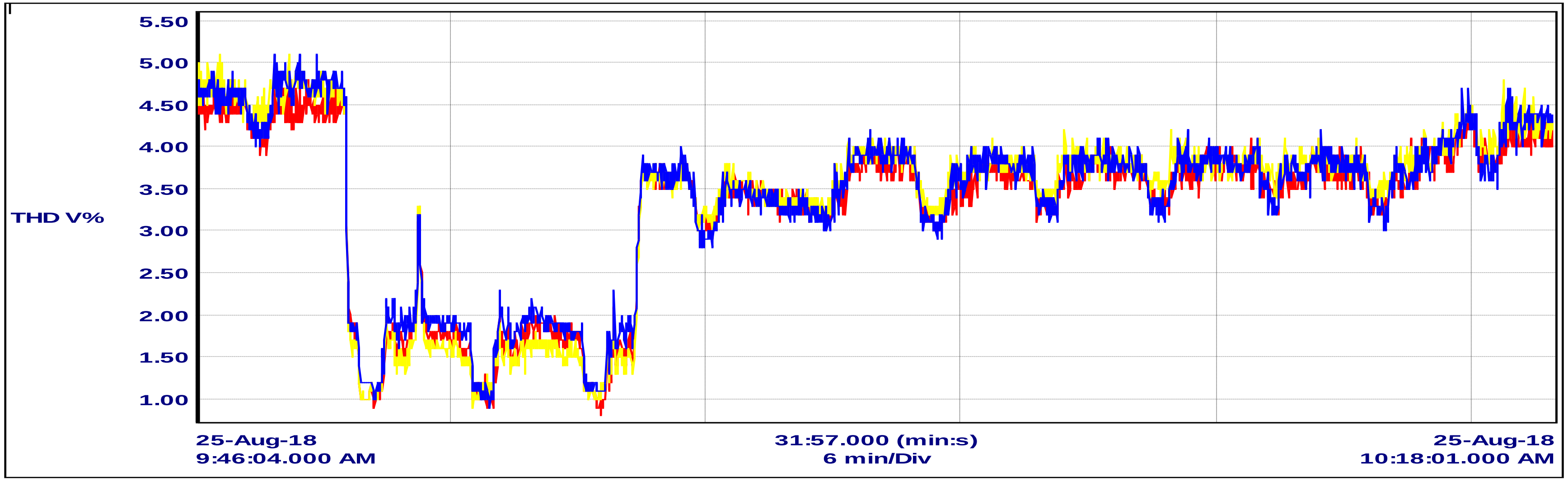


KW, KVAR

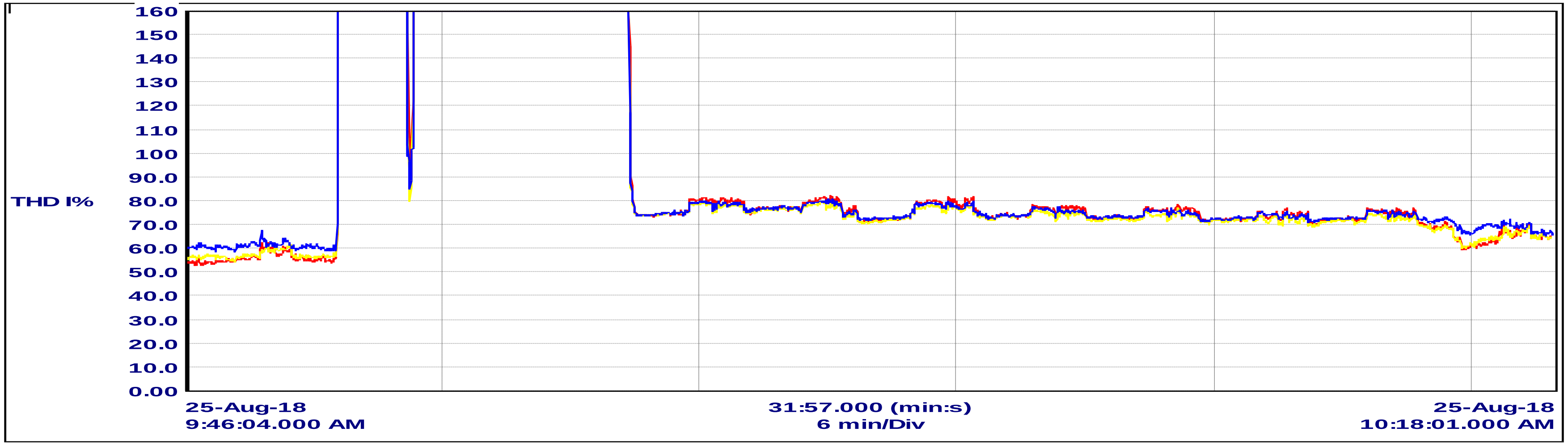


TR-18 LT:

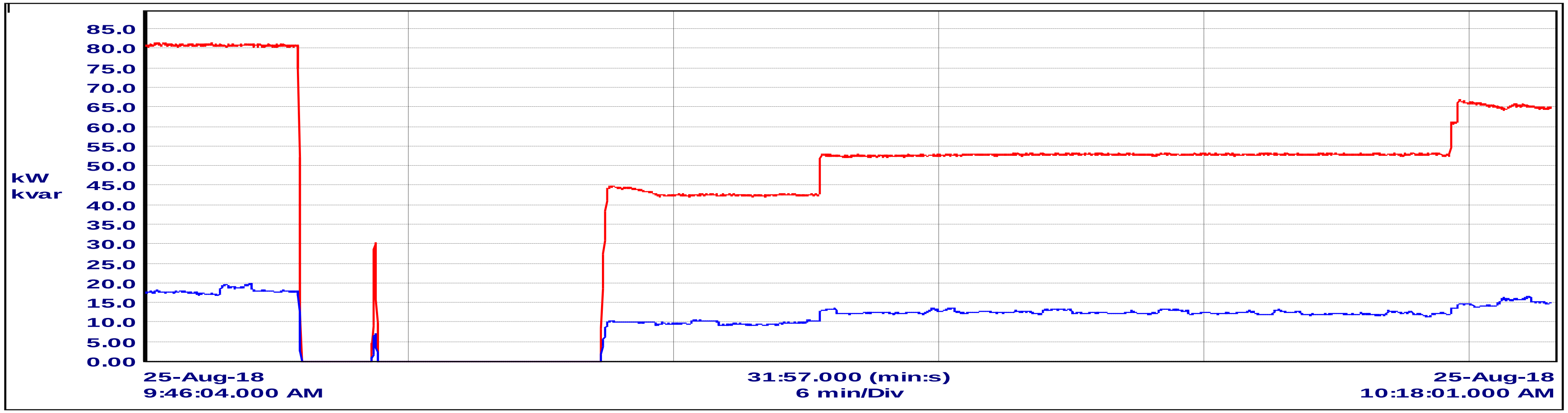
Voltage Harmonic Distortion



Current Harmonic Distortion

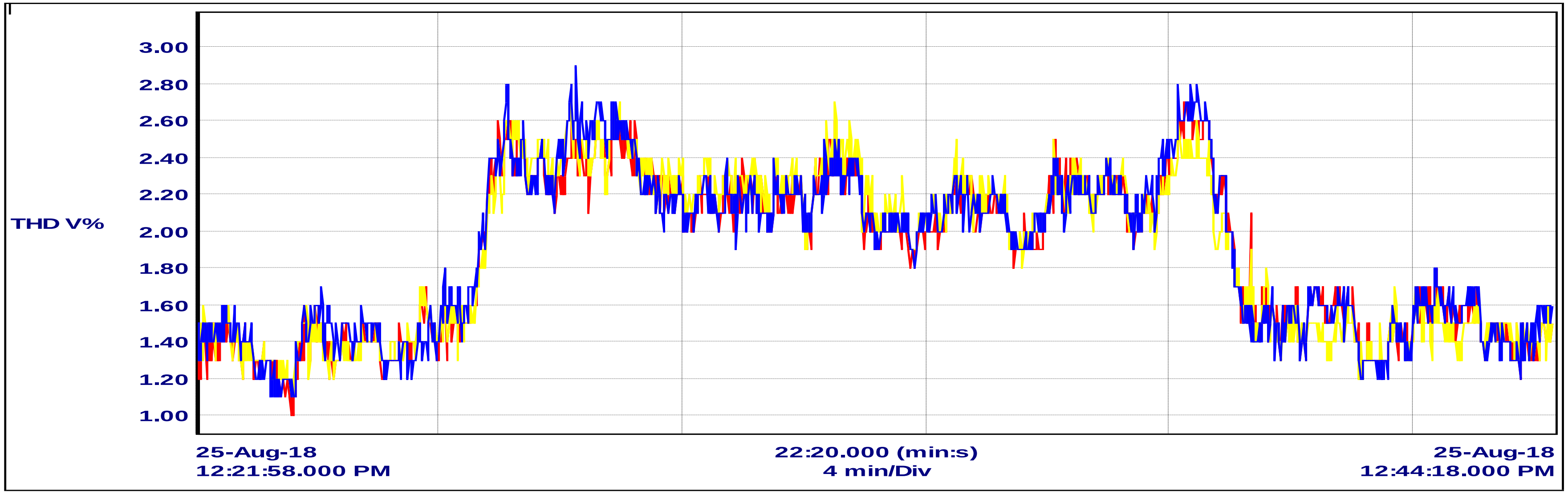


KW, KVAR

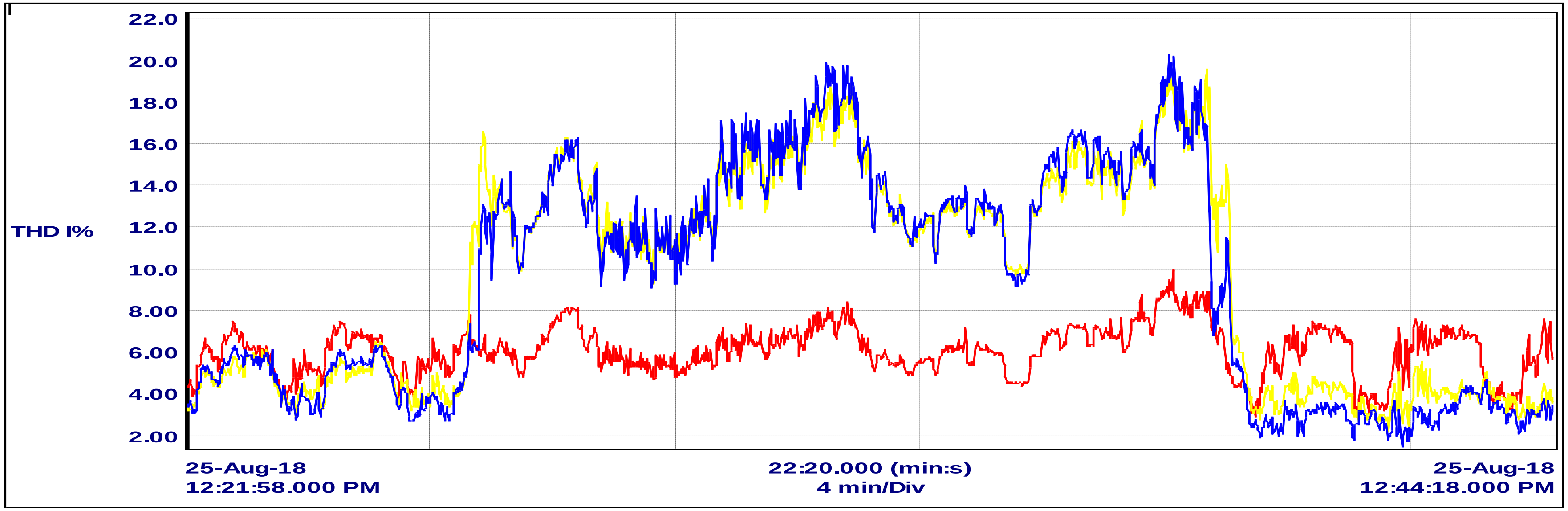


TR-19 LT:

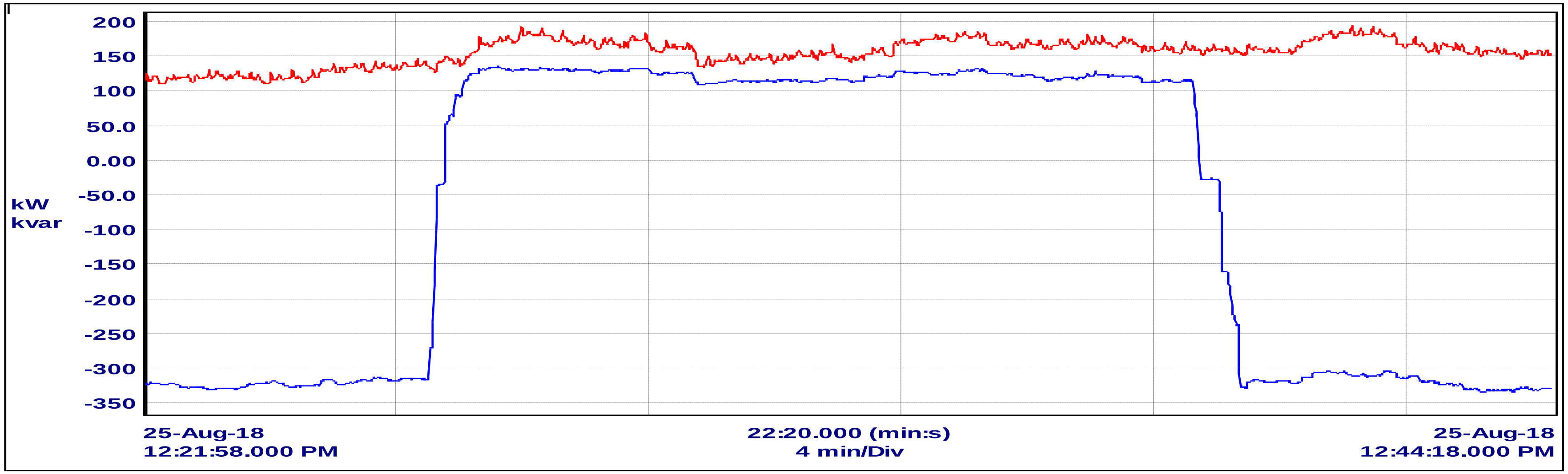
Voltage Harmonic Distortion



Current Harmonic Distortion

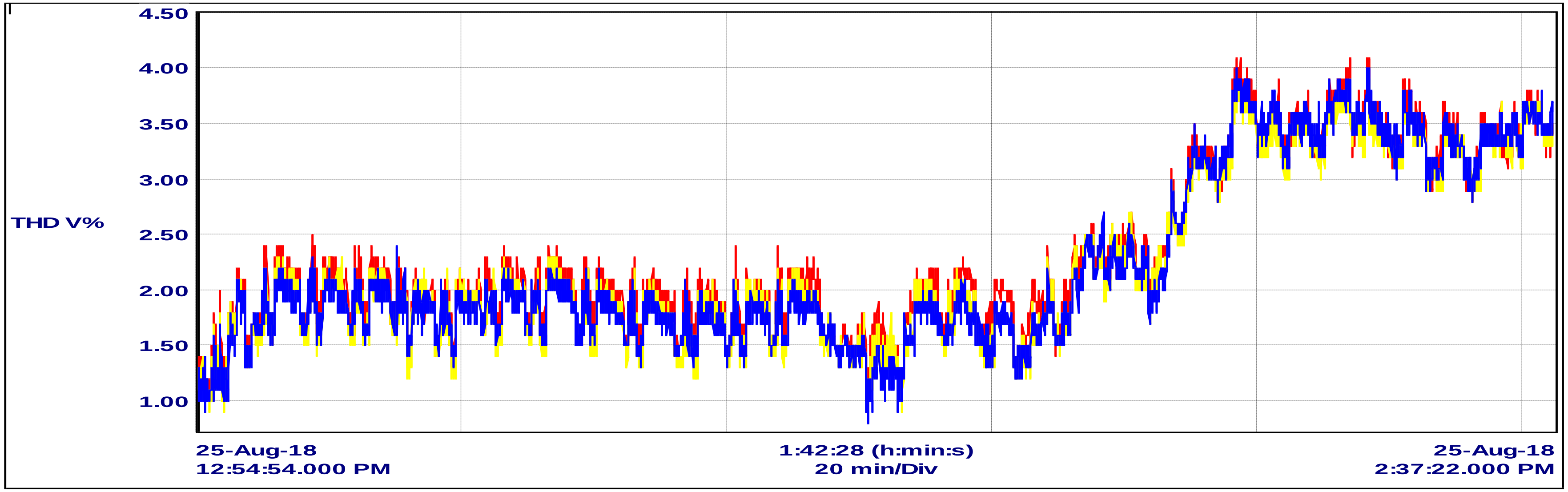

22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.00
6.00
4.00
2.00
THD I%
25-Aug-18
12:21:58.000 PM
22:20.000 (min:s)
4 min/Div
25-Aug-18
12:44:18.000 PM

KW, KVAR

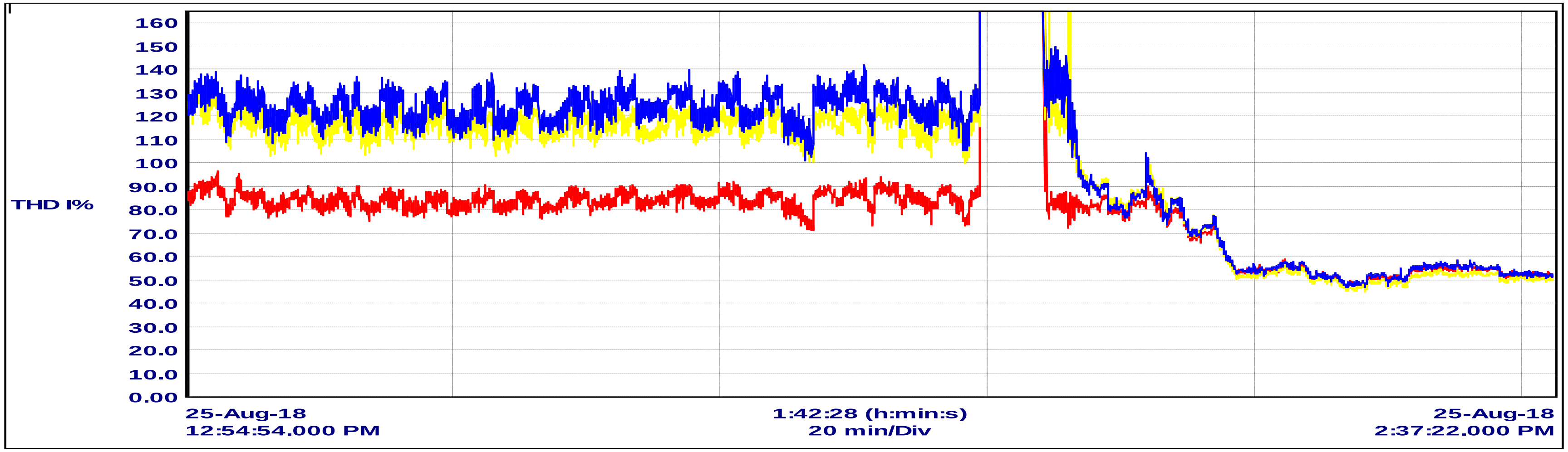

200
150
100
50.0
0.00
-50.0
-100
-150
-200
-250
-300
-350
kW
kvar
25-Aug-18
12:21:58.000 PM
22:20.000 (min:s)
4 min/Div
25-Aug-18
12:44:18.000 PM

TR-20 LT:

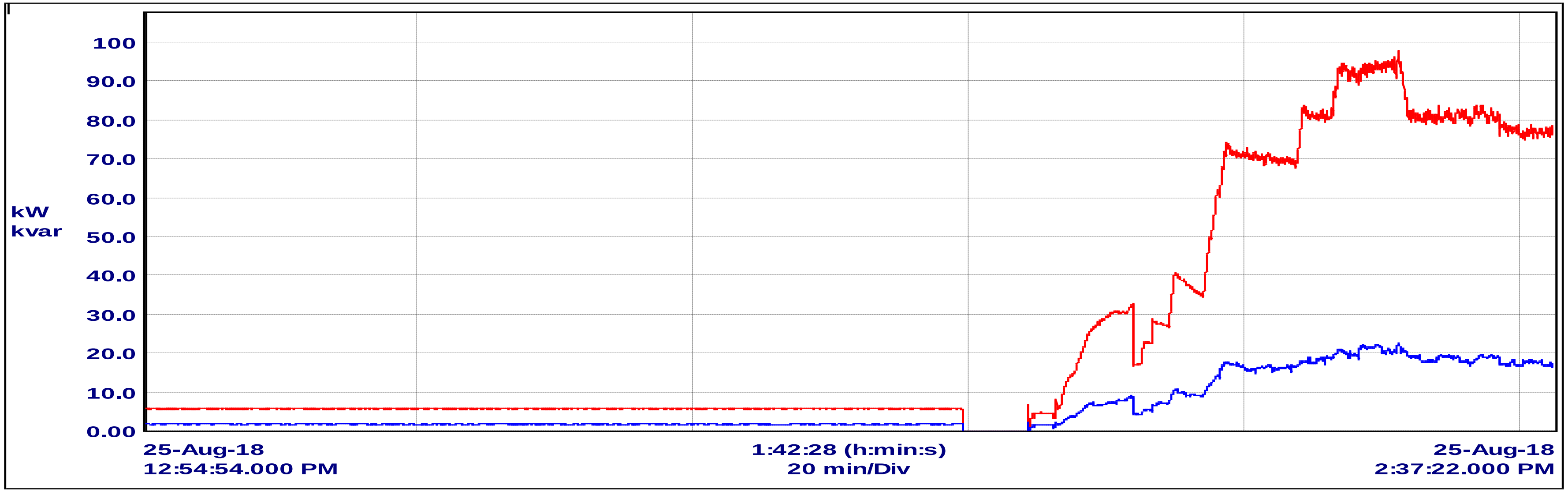
Voltage Harmonic Distortion



Current Harmonic Distortion



KW, KVAR

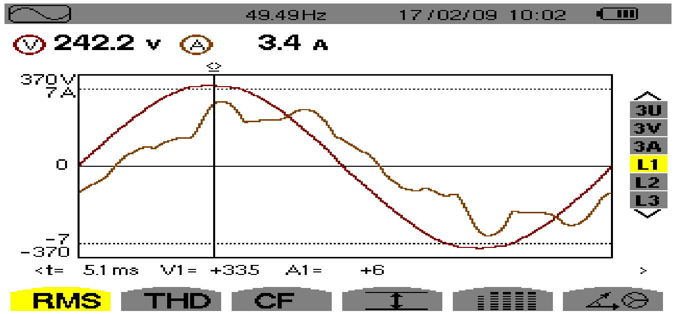


100
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.00
kW
kvar
25-Aug-18
12:54:54.000 PM
1:42:28 (h:min:s)
20 min/Div
25-Aug-18
2:37:22.000 PM

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 overheating 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.