Review Article

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The Integral Analysis of Complex Electrical Systems on Non-Linear Capacitive and Inductive Loads (Suggestions and Solutions Based on Faden Spectrum Phenomenon)

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Abstract

During *A Field Visit to The Faden Screen On The Adeer Tower - Al-Khobar/ Sa On 06/11/2021, The High Sound On Capacitive Harmonic Was Clear, Recording More Than 140 Db Despite The Balance Of Loads On The Three Active Phases, Which Required A Complete Electrical System Analysis To Accurately Identify The Problem And Provide Recommendations.*

After Careful Analysis, It Was Found That The Apparent Ampere On The Neutral Line Was High, In Addition To The Presence Of An Ambiguous Quantum-Thermal Phenomenon On The Cables At The Point Where They Passed Through An Opening On The Iron Metal Of The Panel Ceiling, And This Phenomenon Was Later Called The Faden Spectrum Phenomenon.

This Report Provided A Good Picture Of The Nature Of The Problem And Offered Solutions To It, And We Were Successful In Generalizing The Proposed Solutions Contained In This Report To Other Projects Suffering From The Same Problems.

This Method, Along With The Faden Spectrum Phenomenon, Was Discussed At The Ieee - Uk And Ireland Conference At The Advanced Technology Institute (Ati) At The Uk On 15.07.2024.

1. Executive Summary

This report contains the results of the harmonic and power quality measurements that were performed for the Adeer Tower in Al-Khobar City Saudi Arabia.

1.1 Objectives

The objectives of the harmonic and power quality measurements were:

1. Measure current, voltage and power at several Values of LED brightness to measure the level of harmonics.
2. Compare measured current and voltage distortion to IEEE 519-2014 limits.
3. Capture abnormal events during the monitoring period if any.

1.2 Results @ all brightness level

Measured current demand distortion exceeded the standard limits at all brightness levels .The specified distortion limits are directly dependent on the selected value for maximum load current of transformer (2160 A) ; Also the Voltage distortions limits were more the standard values as per the below :

LED BRIGHTNESS (%)	15%	30%	50%	70%	100%
MEASURED CURRENT (A)	347	460	605	744	995
TRANSFORMER LOAD CURRENT (BASED ON 2160A)	16%	22%	28%	35%	46%
ACCEPTED THD-CURRENT AS PER IEEE 519-2014	31%	22%	17%	14%	11%
ACCEPTED THD-VOLTAGE AS PER IEEE 519-2014	5%	5%	5%	5%	5%
MEASURED THD-CURRENT	93%	97%	95%	80%	77%
MEASURED THD-VOLTAGE	5.70%	7.7%	9.90%	11%	13%
RESULT AS PER IEEE 519- 2014	**NOT ACCEPTED**	**NOT ACCEPTED**	**NOT ACCEPTED**	**NOT ACCEPTED**	**NOT ACCEPTED**

LED BRIGHTNESS (%)	15%	30%	50%	70%	100%
MEASURED CURRENT (A)	347	460	605	744	995
MEASURED NEUTRAL (A)	**443**	**638**	**811**	**930**	**1134**

By drawing current in pulses rather than in pure sine-waves, non-linear loads (such as LED Advertising Screen) generate harmonic currents. These harmonic currents causes both overheating in Neutral Conductors and Transformers in a power system , in additional to Nuisance Tripping of Circuit Breakers with high noise that Increases In parallel with increasing brightness level of LED.

1.3 Actions & Recommendations

• In order to reduce the High temperature , we added extra cable for neutral and this was effecting the temperature in the panel .(All infrared photos are available in paragraph #3) .

• In order to neutralize the magnetic field we removed the ceiling of the **FADEN MDB** and the **ADEER MDB-3** and replaced it with Teflon tempered with super-magnetic insulating fiberglass.

• In order to separate the **FADEN MDB** at the critical temperature (60 C°) , we have added a control system that automatically disconnects when the temperature reaches the critical line

• **We highly recommended to install a Harmonic Filter** that is connected in series with the neutral conductor. These components are "parallel resonant" at the 3rd harmonic allowing 60 Hz (normal load) current to flow but are an extremely high impedance for the 3rd harmonic current and do not allow the load to "source" current at that frequency. Applying this type of filter to a distribution transformer blocks all downstream loads from generating 3rd harmonics. This has the added benefit of reducing the load current (rms) from all loads and can significantly reduce the losses in the transformer and conductors between the transformer and the loads.

2.0 Harmonic Measurements

2.1 Standards for Voltage and Current Distortion

Voltage and Current Distortion

IEEE Std 519-2014 defines the maximum distortion limits recommended for industrial, commercial, institutional, and utility electrical distribution systems.

Voltage Distortion

The voltage distortion gives a clear representation of the impact of harmonics on the electrical distribution system. The harmonic voltage distortion from an individual customer is evaluated at the point-of-common-coupling (PCC) where the utility can supply other customers.

Harmonic voltage distortion is defined as:

$$\%THD_V = \frac{\sqrt{V_2^{\ 2} + V_3^{\ 2} + V_4^{\ 2} + \ldots}}{V_1} \times 100\%$$

where V_n is the magnitude (rms Volts) of the n^{th} harmonic

	≤1,0 KV	< 69KV	69 - 161KV	<161KV
Maximum for Individual Harmonic	5.0	3.0	1.5	1.0
Total Harmonic Distortion (THD)	8.0	5.0	2.5	1.5a

* % of Nominal Fundamental Frequency Voltage

Table 2 1: Maximum Voltage Distortion In % At PCC*

As Per IEEE 519-2014 Note that the measurement locations utilized for this report do not strictly meet the definition of PCC. Voltage distortion will be less than measured at the medium-voltage utility supply system, which would more appropriately be characterized as the PCC.

As per IEEE 519-2014, the PCC is commonly at the LV side of the service transformer.

Current Distortion

The harmonic currents from an individual customer are likewise evaluated at the point-of-common-coupling (PCC). The limits depend upon the customer's load with respect to the available fault current at the PCC.

Harmonic current distortion is defined as:

$$\%THD_I = \frac{\sqrt{I_2^{\ 2} + I_3^{\ 2} + I_4^{\ 2} + \ldots}}{I_1} \times 100\%$$

where I_n is the magnitude (rms Amps) of the n^{th} harmonic

I_{SC}/I_L	HARMONIC ORDER (ODD HARMONICS)*					% TDD
	<11	11≤h<17	17≤h<23	23≤h<35	35≤ h≤50	
< 20 *	4.0	2.0	1.5	0.6	0.3	**5.0**
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0
Even harmonics are limited to 25% of the odd harmonic limits above.						
* All power generation equipment is limited to these values of current distortion, regardless of actual I_{SC} / I_L.						
Where I_{SC} = Maximum Short Circuit at PCC. I_L = Maximum Load Current (Fundamental Frequency) at PCC.						
For PCC's from 69KV to 138KV, the limits are 50 percent of the limits above. A case-by-case evaluation is required for PCC's of 138KV and above.						

* Ih in % of I_L

Table 2.2: Maximum Harmonic Current Distortion in Percent of Fundamental

The maximum load current, IL, is often difficult to define. For the purposes of this analysis, the following approximations were used:

- For measurements at a transformer secondary, 75% of the approximate full-load current (base rating) of the transformer was used.
- For other measurement locations, 75% of the approximate design Ampacity was used (details are given for each case).
- Sum of % THID x % of load = % TDD at PCC

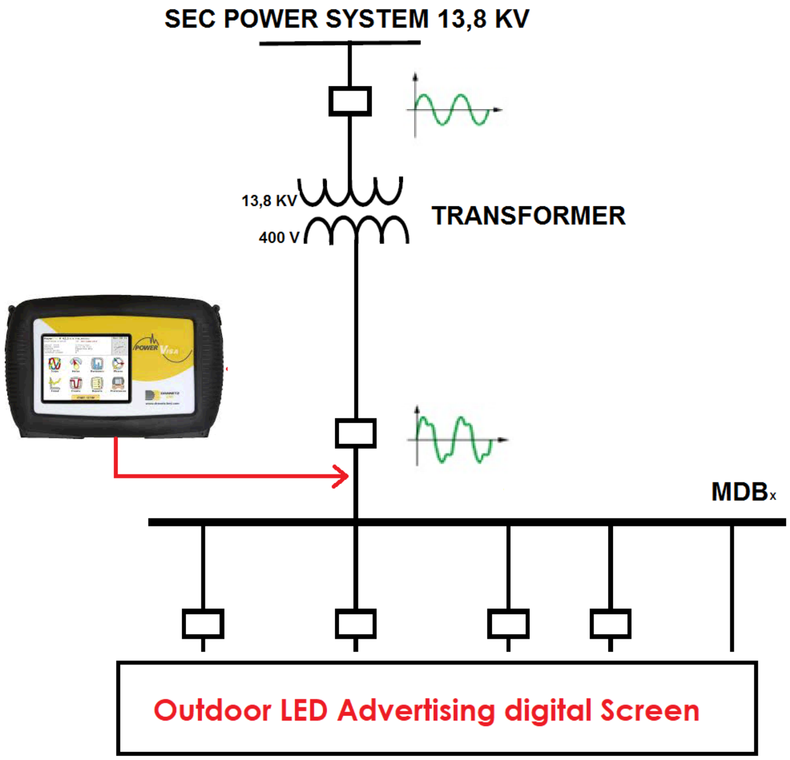
2.2 Measurement Procedure

PA was contracted to perform harmonic and power quality measurements in accordance with the project specification.
The following locations were included in the scope of work:

Transformer	LED BRIGHTNESS %	REMAKRS
1.5 MVA	15 %	
1.5 MVA	30%	
1.5 MVA	50%	
1.5 MVA	70%	
1.5 MVA	100%	

Table 2.3: Measurment Locations and Transformer Information

For the measurement locations above, a DRANETZ model PV440 recorder was connected at each switchboard to provide trending of power quantities throughout the duration of testing. **The DRANETZ was directly connected to the main bus at each switchboard**.



2.3 Results @ 15% LED Brightness

Basic Load Measurements:

The following graphs shows the load changes during the monitoring period

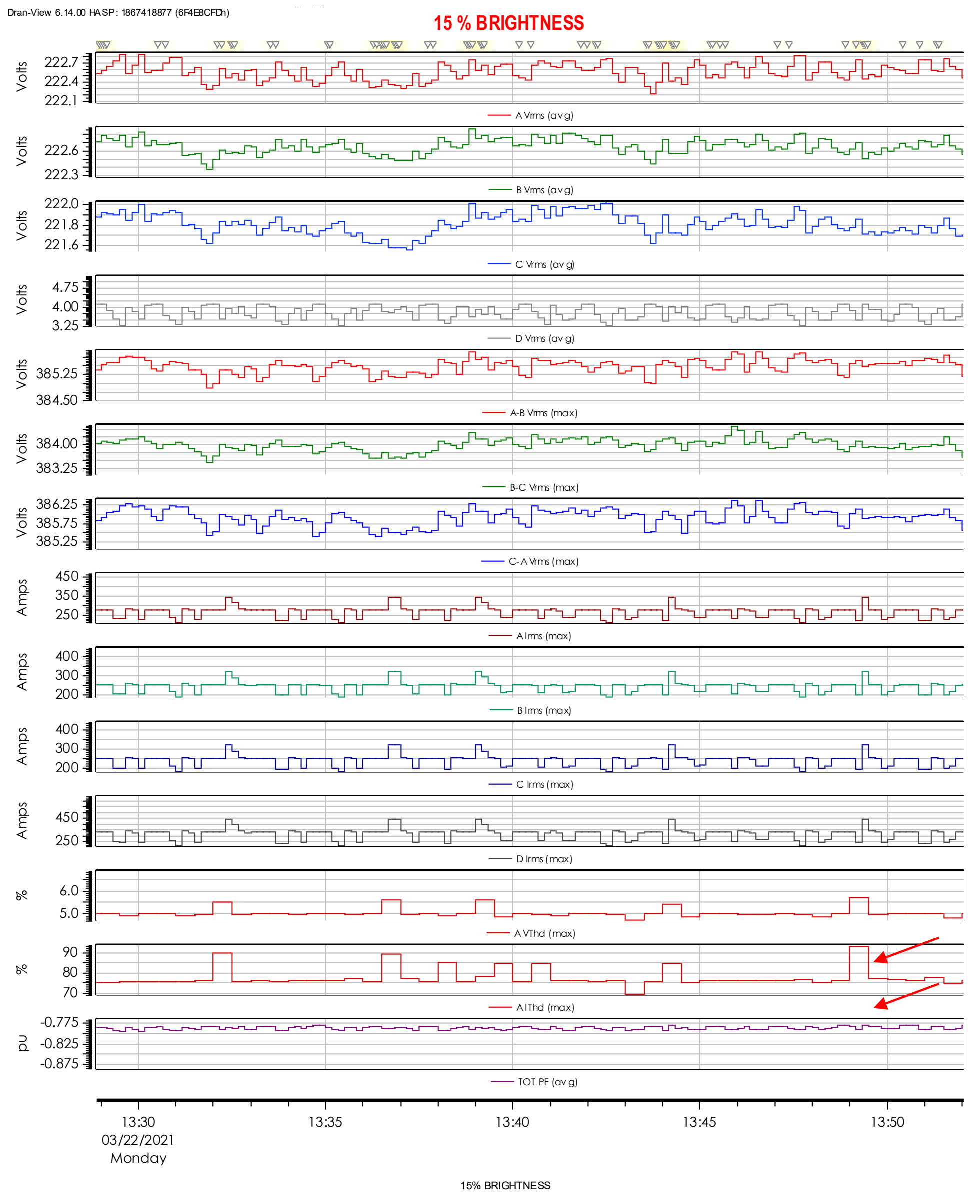


Figure 2 1: Current , Voltage & Harmonics Variations @ 15% LED Brightness

2.4 Results @ 30% LED Brightness

Load Measurements

The following graphs shows the load changes during the monitoring period

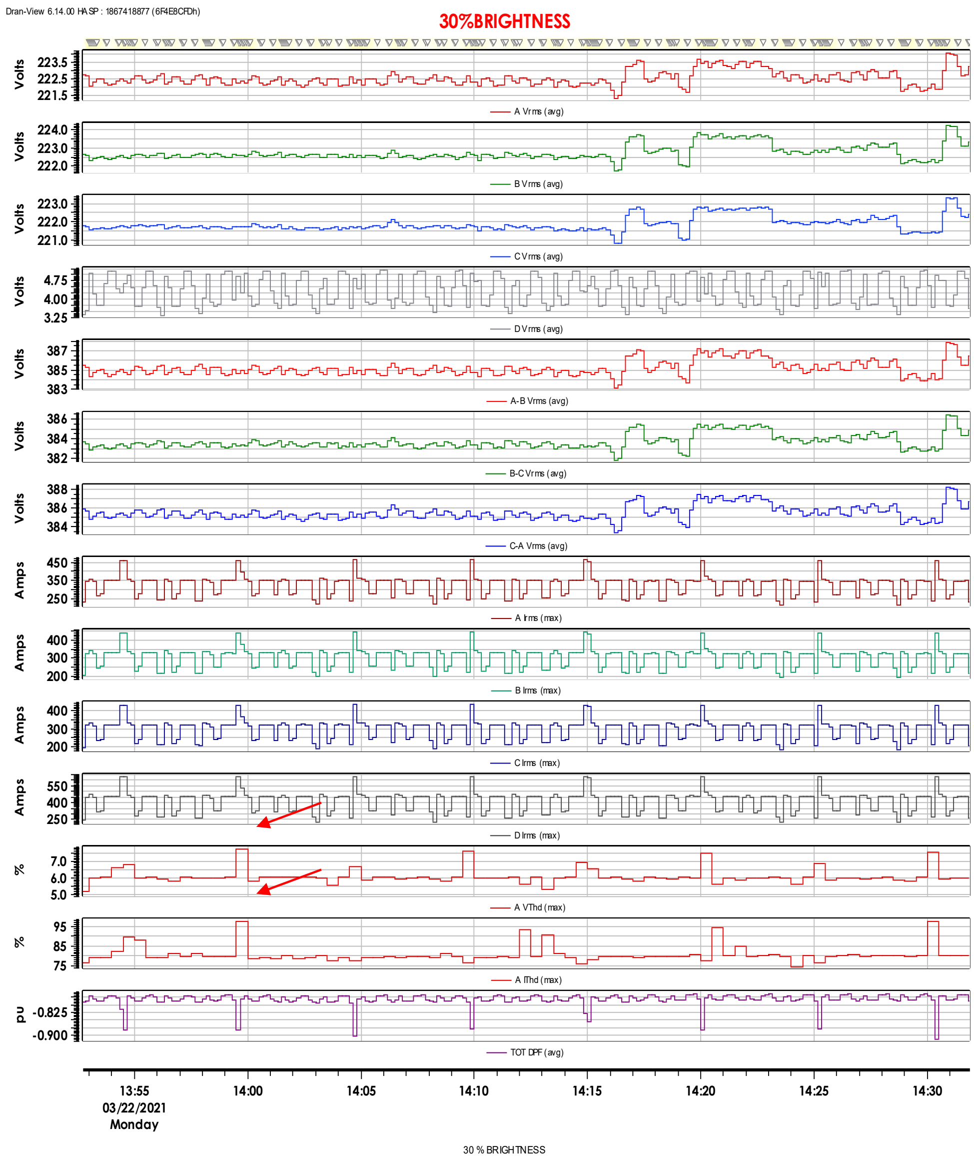


Figure 2.3: Current , Voltage & Harmonics Variations @ 30 % LED Brightness

2.5 Results @ 50% LED Brightness

Load Measurements

The following graphs shows the load changes during the monitoring period

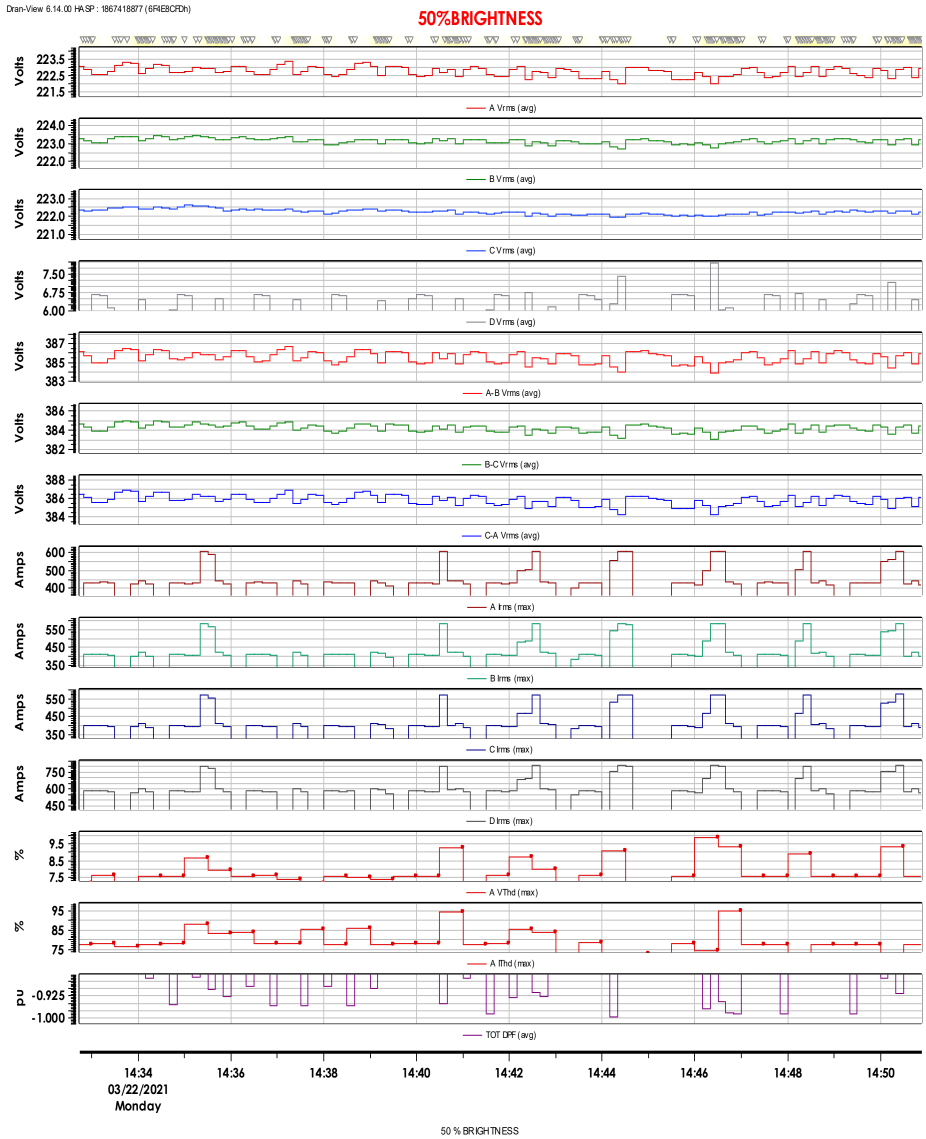


Figure 2.4: Current, Voltage & Harmonics Variations @ 50 % LED Brightness

2.6 Results @ 70% LED Brightness

Load Measurements

The following graphs shows the load changes during the monitoring period

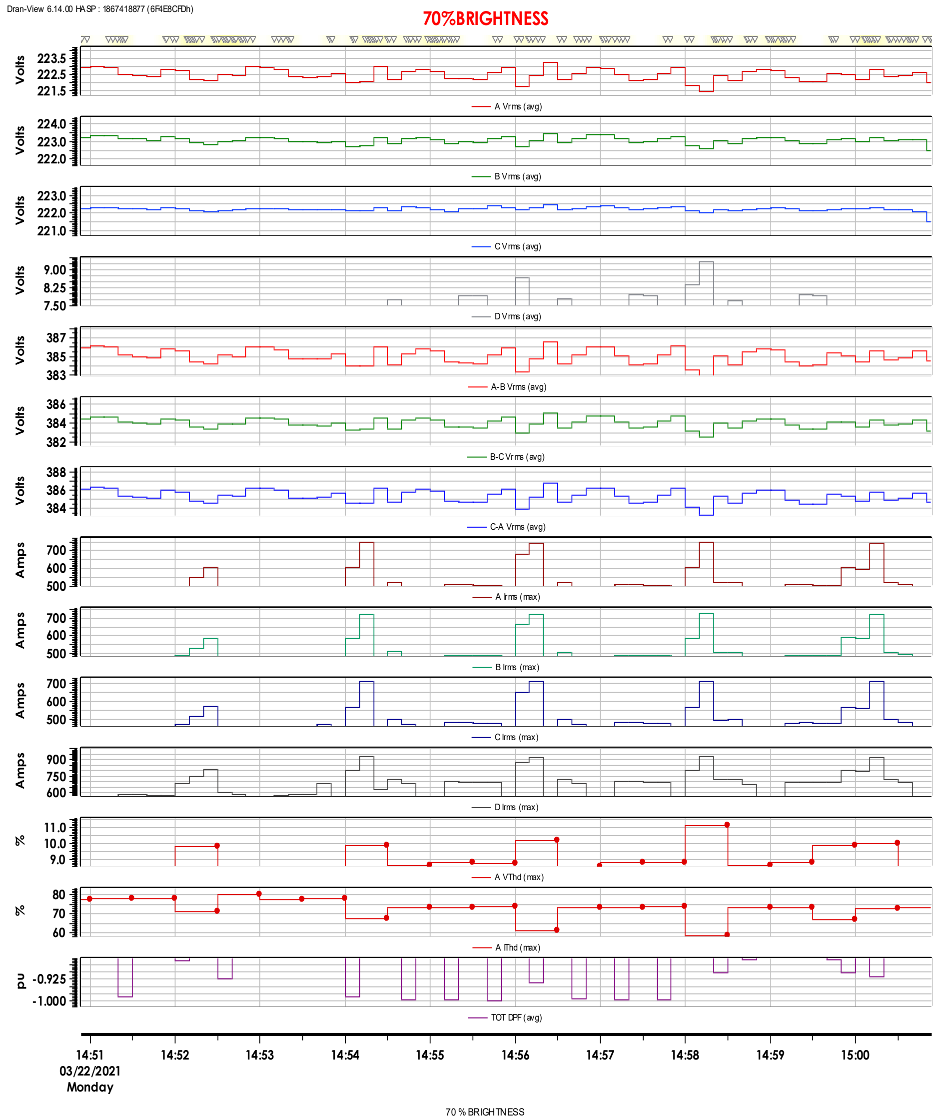


Figure 2.5: Current, Voltage & Harmonics Variations @ 70 % LED Brightness

2.7 Results @ 100% LED Brightness

Load Measurements

The following graphs shows the load changes during the monitoring period

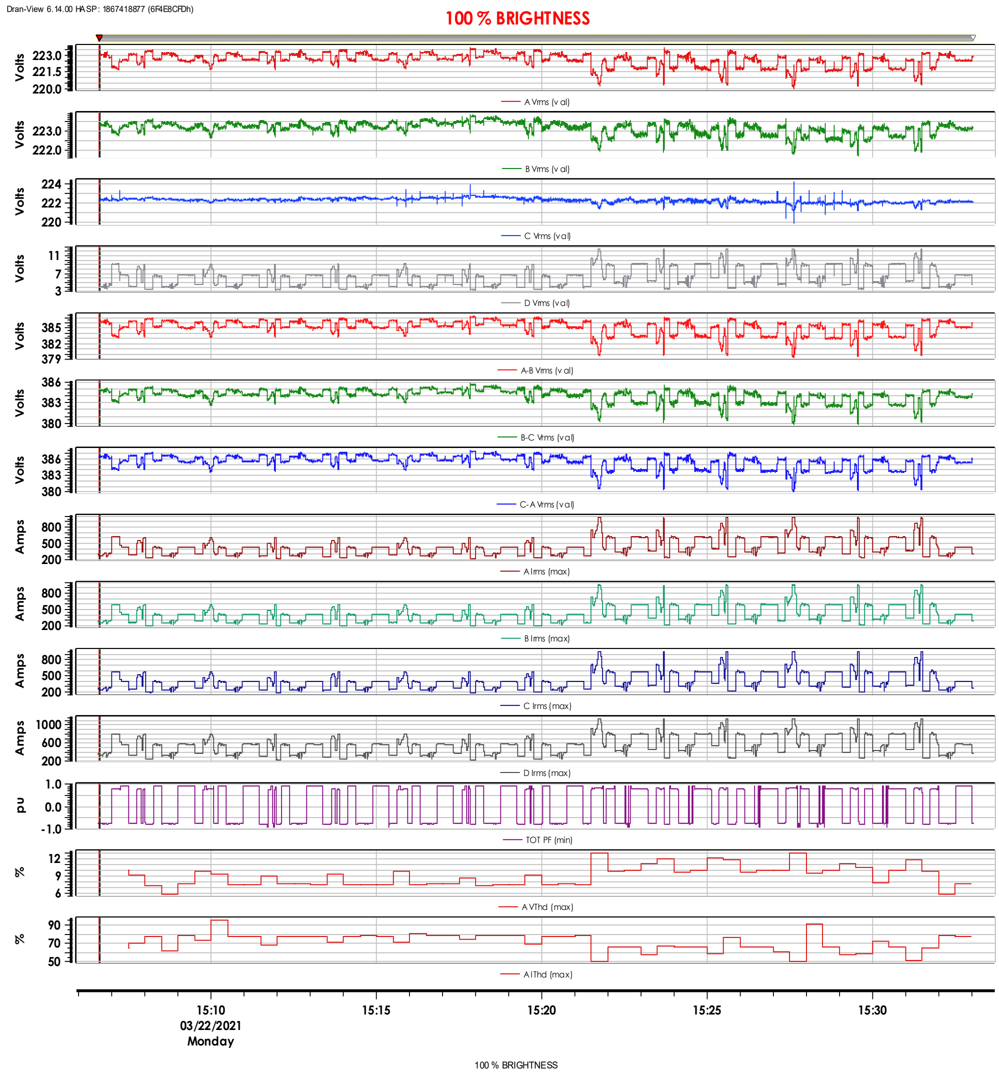
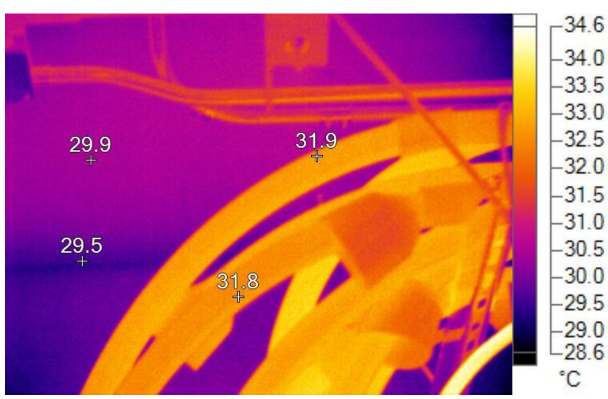
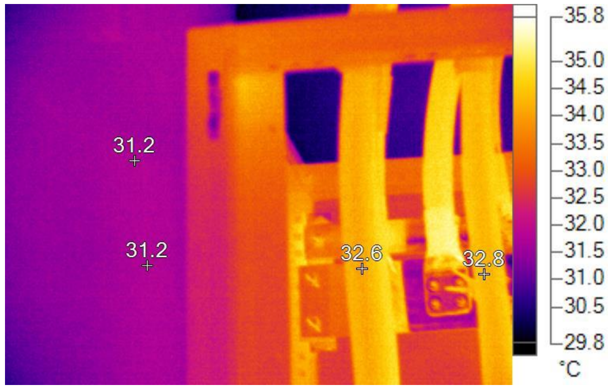
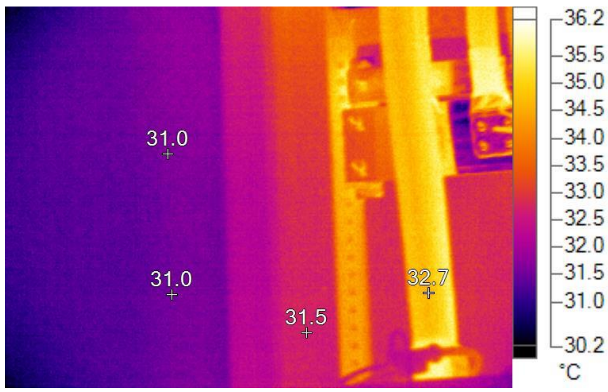


Figure 2.6: Current, Voltage & Harmonics Variations @ 100 % LED Brightness

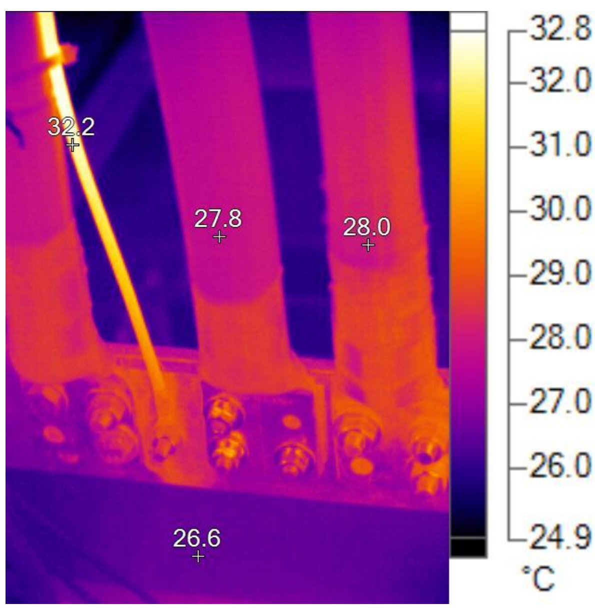
2.0 Temperature Measurements of MDB-3

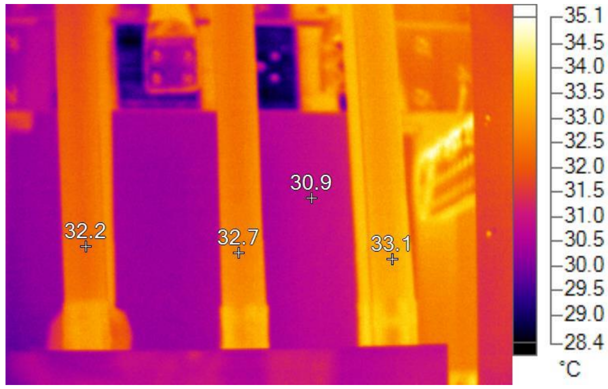


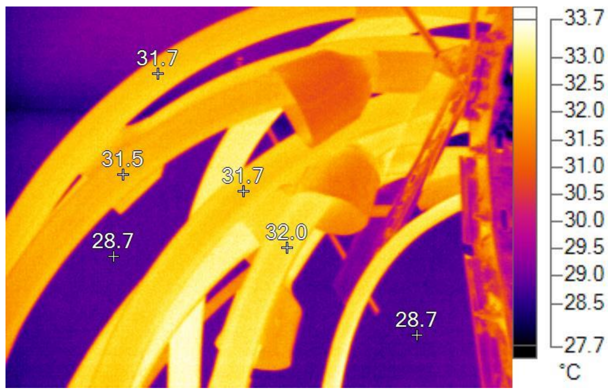




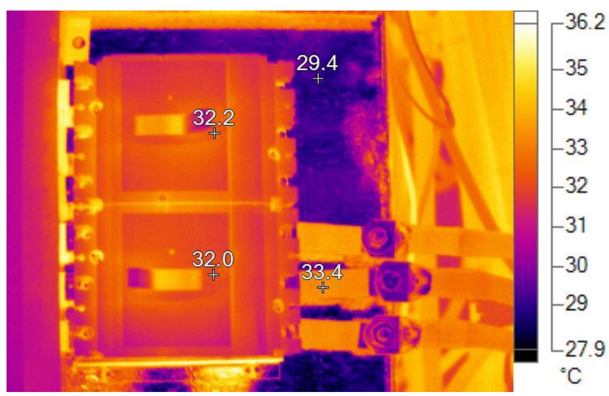
IR Image for MDB Volume



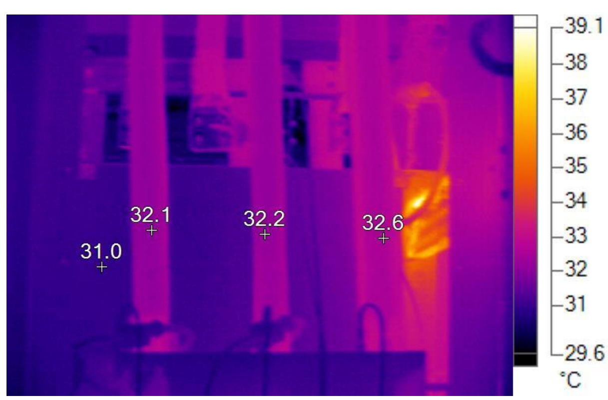




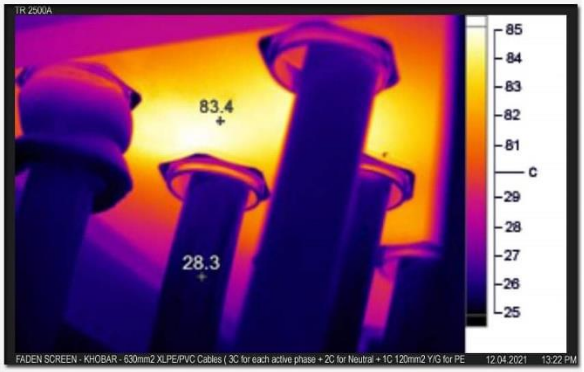
IR Image for MDB Volume



IR Image for MCC Volume



IR Image for MCC Volume



IR Image for MDB-3 Ceiling

3. Result of Thermal Status

The Temperature is up normal on ceiling of MDB even during the 50% Brightness, and normal in other places.

The final result for general situation:

The Electrical Grid is not Accepted

We highly recommended to:

Supporting Zero-Point of Transformer by Linear Grounding 240mm2 in minimum

And:

- **install a Harmonic Filter (AHF)**

or

- **Use ZIGZAG Transformer**

or

- **Divide the load on two transformers**

References

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