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Harmonics Distortion Analysis on HT and LT side of 11KV/440V Industrial Transformer

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Abstract – This paper works on the transformer behaviour based upon total harmonic distortion of the transformer LT and HT side by logging a power analyser for a duration and recorded all the parameters like voltage, current, frequency of all the three phase as well as harmonic distortions of voltage and current of all three phases. The average of the whole time distortion of the phases been calculated and comparison for the permissible range of harmonics. The main reason of harmonics are nonlinear loads and due to these loads injection of voltage and current harmonics in the system, and this leads to distortion of system and equipment's. These distortions is analysed to confirm the standard of IEEE of 519-2014 for the distortions exceeding the maximum limit for both voltage and current. For the improvement in the overall system and reduction of harmonics it is necessary to analyse the harmonics values in operating conditions and if required it is necessary to take steps to reduce distortions. The loss addition is responsible for derating of transformer that may shorten device lifetime.

***Key Words*:** *Total harmonic distortion, non-linear loads, distribution transformer, linear-loads*

1. INTRODUCTION

Transformer is a static device and plays a very important role in the power system. The transformers are designed considering frequency, perfect sinusoidal load current and balanced supply voltage. As the population is increasing the demand for reliable and quality power is increasing simultaneously. Hence, the non-linear loads are increasing on the system for better comforts.
One of the major effects of harmonic distortion is to increase the transformer losses, component losses that are affected by the harmonic current loadings are the copper loss, eddy current loss and stray losses.

A. Harmonic current effect on ohmic losses

The ohmic losses are the losses due to primary and secondary distorted currents flowing through the windings. If the root mean square value of the load current is increased due to a harmonic component, the I2R loss will be increased accordingly [1].

B. Harmonic current effect on eddy current loss

The transformer core eddy-current loss in the power frequency spectrum is proportional to the square of the load current and the square of frequency. This characteristic will cause excessive core losses thereby creating abnormal temperature rise in transformers when supplying non-sinusoidal load currents [1].

C. Harmonic current effect on other stray loss

Other stray loss in the core, clamps, and structural parts will also increase at a rate proportional to the square of the load current, but these losses will not increase at a rate proportional to the square of the frequency, as transformer core eddy-current losses. Studies by manufacturers and other researchers have shown that the eddy-current losses in bus bars, connections and structural parts increase due to the harmonic exponent factor of approximately 0.8 or less
For dry-type transformers temperature rise in these regions are less critical than in the windings but it has to be properly accounted for transformers that are liquid filled.

D. Effect on top oil rise

The top oil rise will increase as the total load losses increase with harmonic loading for liquid filled transformers. Any increase in other stray loss will primarily affect the top oil rise [1].

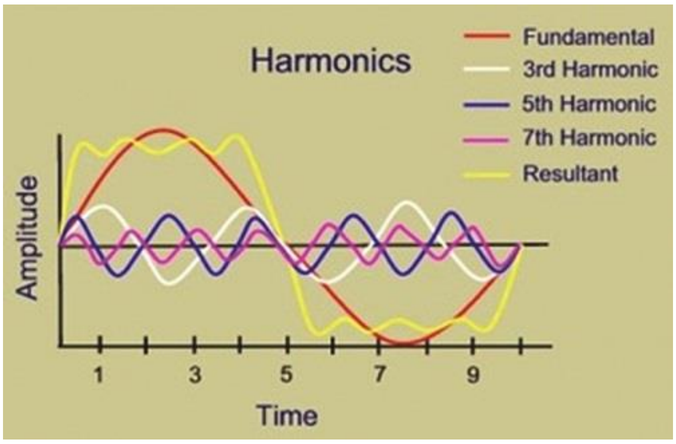

Fig -1: Effect of harmonics in the waveform

The power analyzer of the configuration of PEL transfer, version 2.2.9467 has been connected to the transformer HT and LT side for a particular time during operation and set in the 5 minutes slot for the calculation. After getting all the parameters the total voltage, current, power factor, THD of voltages and currents of all the three phase been measured separately and compiled in the table form and taking average of the harmonic distortions of voltages and currents, so that easily compared with the standard permissible values defined by IEEE.The detailed analysis of the distortions can be done by using this measurement and valuation method. If the values find out is not in the permissible range so various steps to be taken to reduce the distortions.

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2. Parameters Obtained by the Analyzer

Transformer HT side load

Table 1: Parameters of HT side of Transformer

Parameter	Unit	Min	Max	Average
L12 RMS Voltage	V	11176.8	11259.6	11224
L23 RMS Voltage	V	11131.6	11211.3	11177.4
L31 RMS Voltage	V	11244	11328.5	11293.2
L1 RMS Current	Amp	8.134	10.09	9.00
L2 RMS Current	Amp	6.72	8.33	7.493
L3 RMS Current	Amp	6.11	7.99	6.93
L1 PF	-	0.99	0.99	0.99
L2 PF	-	0.97	0.99	0.98
L3 PF	-	0.97	0.99	0.98
L1 Active Power	KW	52.6	65.67	58.27
L2 Active Power	KW	42.79	53.32	47.61
L3 Active Power	KW	38.85	51.18	44.19
Total Active Power	KW	134.78	170.18	150.10
L1 Apparent Power	KVA	52.79	65.79	58.43
L2 Apparent Power	KVA	43.32	53.93	48.32
L3 Apparent Power	KVA	39.54	51.89	44.83
Total Apparent Power	KVA	136.22	171.62	151.58
L1 THD Voltage	%	2.11	2.45	2.30
L2 THD Voltage	%	2.2	2.5	2.3
L3 THD Voltage	%	2.1	2.6	2.4
L1 THD Current	%	4.3	6.2	5.2
L2 THD Current	%	5.4	7.6	6.6
L3 THD Current	%	4.5	6.6	5.7

Transformer LT side load

Table 2: Parameters of LT side of Transformer

Parameter	Unit	Min	Max	Average
L12 RMS Voltage	V	405.2	405.7	407.2
L23 RMS Voltage	V	408.7	409.5	410.5
L31 RMS Voltage	V	408.7	409.4	410.8
L1 RMS Current	Amp	180.29	181.9	181.4
L2 RMS Current	Amp	147.5	160.6	160.11
L3 RMS Current	Amp	158.5	169.1	170.3
L1 PF	-	0.98	0.99	0.99
L2 PF	-	0.99	1	0.99
L3 PF	-	0.99	0.99	0.99
L1 Active Power	KW	41.4	41.7	41.5
L2 Active Power	KW	34.5	35.7	35.7
L3 Active Power	KW	37.2	39.3	38.01
Total Active Power	KW	113.2	118.4	115.4
L1 Apparent Power	KVA	42.35	42.66	42.48
L2 Apparent Power	KVA	34.7	37.6	35.9
L3 Apparent Power	KVA	37.6	39.6	38.4
Total Apparent Power	KVA	114.6	119.7	116.7
L1 THD Voltage	%	0.8	0.9	0.85
L2 THD Voltage	%	1.1	1.3	1.2
L3 THD Voltage	%	1	1.1	1.0
L1 THD Current	%	16.3	17.8	16.9
L2 THD Current	%	5.6	7.4	6.3
L3 THD Current	%	6.3	9.5	7.1

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Table 3: Average Parameters of HT Side

Particulars	**TR**
Overall	
Voltage Harmonics (V THD)	
"R" Phase	2.3
"Y" Phase	2.3
"B" Phase	2.4
Current Harmonics (A THD)	
"R" Phase	5.2
"Y" Phase	6.6
"B" Phase	5.7

Table 4: Average Parameters of HT Side

Particulars	**TR**
Overall	
Voltage Harmonics (V THD)	
"R" Phase	0.85
"Y" Phase	1.2
"B" Phase	1.0
Current Harmonics (A THD)	
"R" Phase	16.9
"Y" Phase	6.3
"B" Phase	7.1

3. RESULTS

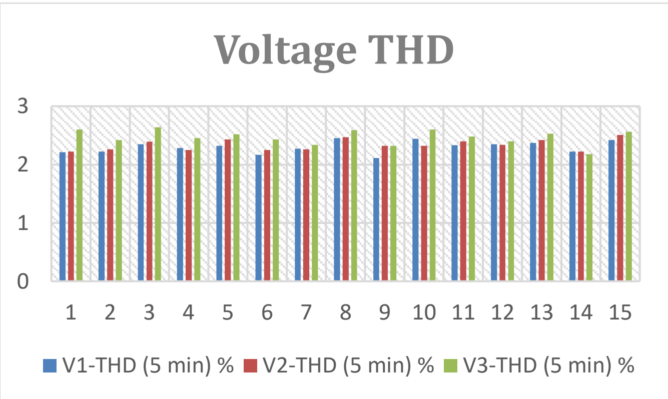

Fig -2: Voltage harmonics of three phase HT side

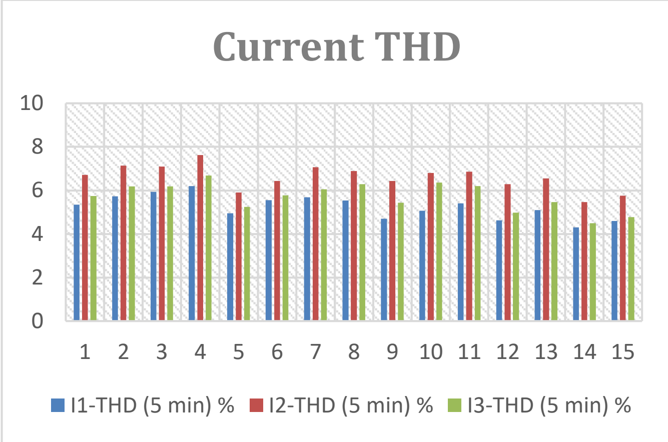

Fig -3: Current harmonics of three phase HT side

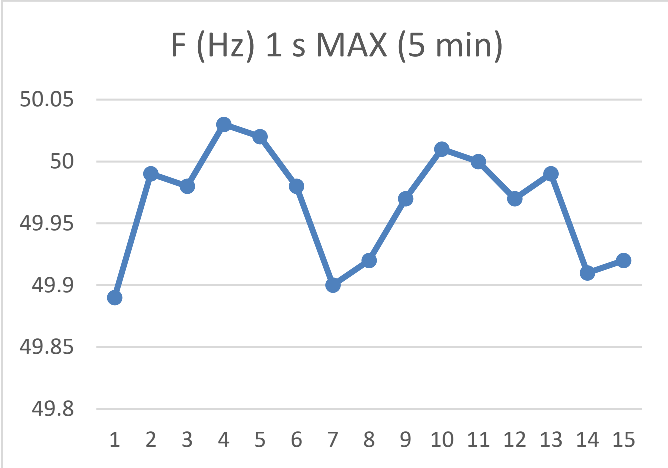

Fig -4: Frequency variation response of 5 minutes

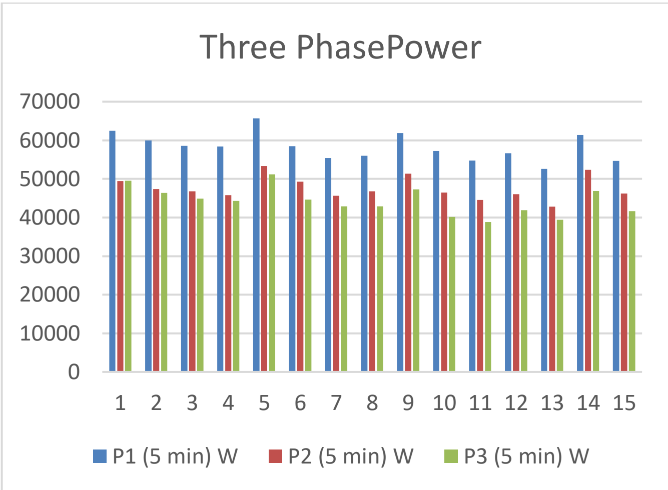

Fig -5: Three Phase Power of HT side

Transformer HT side

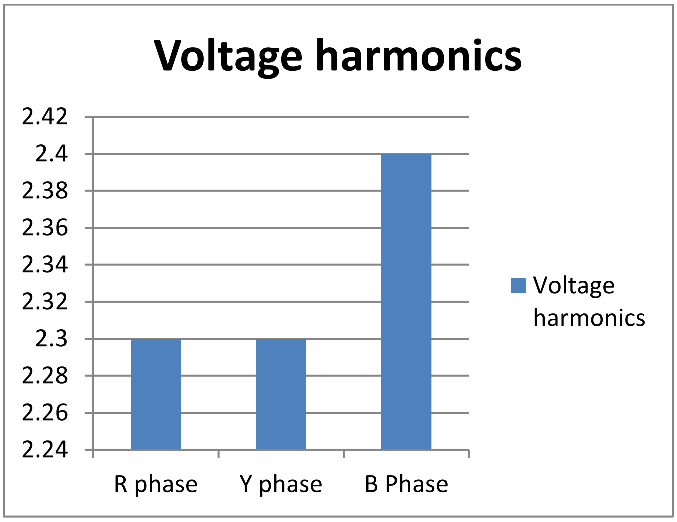

Fig -6: Average of voltage harmonics HT side

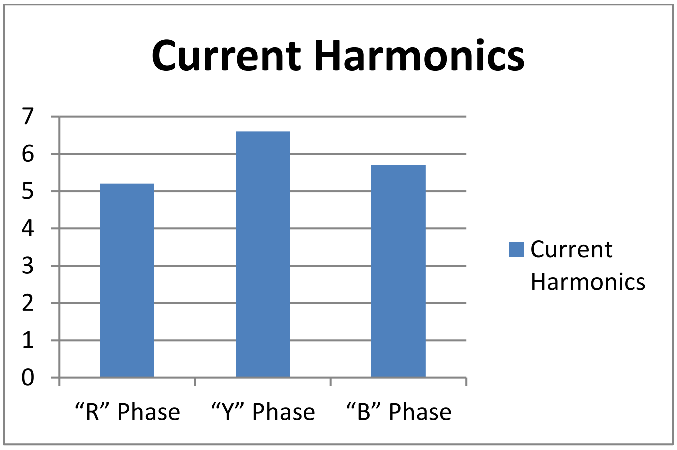

Fig -7: Average of Current harmonics HT side

Transformer LT side

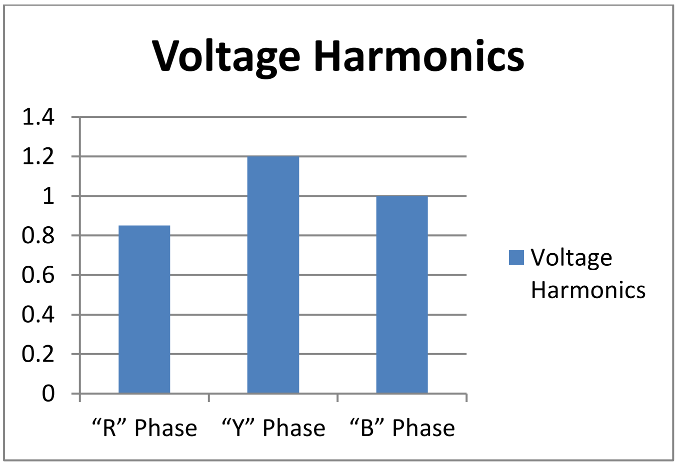

Fig -8: Average of Voltage harmonics LT side

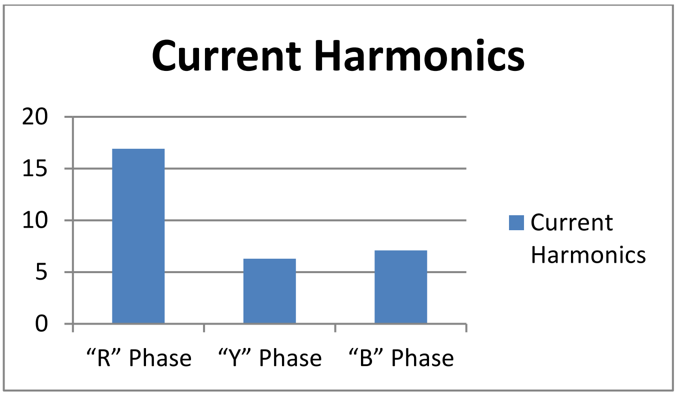

Fig -9: Average of Current harmonics LT side

From the above graph details we can see that the HT side voltage harmonic range is in between 2.2-2.4. The current total harmonic distortion of HT side of transformer is in the range of 5.0 -6.4. Similarly in LT side the voltage harmonic lies in the range of 0.85-1.3 and current total harmonic distortion level in the range of 6.2-16.9 percentage.

According to IEEE 519 harmonic voltage distortion on power system 69 KV and below is limited to 5%. Total Harmonic Distortion with each individual harmonic is limited to 3%. The current harmonics vary based on the short circuit strength of the system based on the system injected into. Essentially more the system is able to handle harmonic currents, the more the customer is allowed to inject.

Table 5: Power Analyzer Configuration

Configuration	
PEL Transfer, Version 2.2.9467	
1 s trend	Yes
1 s harmonics	Yes
Instrument ID	
PEL model	PEL103
PEL serial number	156153RGH
PEL name	PEL103-156153RGH
PEL location	Office
Firmware DSP version	1.24
Firmware microprocessor version	1.18
Hardware version	A.D
Measurement configuration and status	
Aggregation period	5 min
Electrical hook-up	3-phase 4-wire Y
Nominal frequency	50 Hz
Primary nominal voltage	11000 V phase-to-phase
Secondary nominal voltage	110 V phase-to-phase
Current sensor I1	MN93A clamp (5 A)
Current sensor I2	MN93A clamp (5 A)

Current sensor I3	MN93A clamp (5 A)
Line CT Primary (MN93A)	50 A
Line CT Secondary (MN93A)	5 A

4. CONCLUSION

As we can see from the data of power analyzer. It is very clear that the voltage harmonics values are in the specified limit and controllable range, whereas current harmonics of LT side are in the higher side of range may be due to some nonlinear loads. So it is suggested to install detuned harmonic suppressors to mitigate the harmful effects of harmonics. Tuned Harmonic filters consisting of a capacitor bank and reactor in series are designed and adopted for suppressing harmonics, by providing low impedance path for harmonic component. The Harmonic filters connected suitably near the equipment generating harmonics help to reduce THD to acceptable limits.

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