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Power Quality Analysis of Distribution Network for Harmonic Reduction and Implementation

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Abstract – This paper is about the analysis of a simple 220/440 distribution network by implementing a power analyzer in the distribution transformer. This analyser logged in the system for a certain duration of four hours and recorded the parameters like voltage, current, power, active and reactive power of all the three phases. The average of all the voltage and current unbalance has been calculated and harmonic distortion of voltage and currents also been measured for the comparison of harmonics with the permissible range. As the networks consisting of nonlinear loads and due to this harmonics increases in the system. So a solution has to be find out like active power filters to be include in the system and to reduce the harmonics up to the permissible limit. The harmonic distortions are compared from the IEEE standards and after implementing the solutions the distortion should not exceed the maximum value for both voltage and current.

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

1. INTRODUCTION

Harmonics - Whenever a sinusoidal voltage is applied to the load, the current drawn by the load is directly proportional to the voltage and impedance and follows the envelope of voltage waveform. Various loads cause the current to vary disproportionately with the voltage and the resulting waveforms contain distortions, creating multiple frequencies with in the 50 Hz sinusoidal waveform. A harmonic is a component of a periodic wave having a frequency that is integer multiple of the fundamental power line frequency. Harmonic loads causes power loss and a negative impact on utility distribution systems and components.

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].

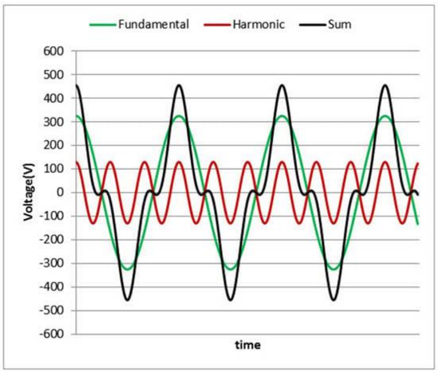

Fig -1: Effect of harmonics in the waveform

The power analyzer of the configuration firmware 5.0 has been connected to the transformer HT and LT side for a particular time during operation and set in the 10 minutes slot for the calculation. The parameters like voltage, current, total active power, total reactive power as well as harmonic distortion in voltages and currents. The conventional method of finding voltage unbalance has also been done manually by mathematical equation. The harmonics of the voltages and currents are then compared with the standard values defined by IEEE. Various solutions also been described for the reduction of harmonics.

2. Parameters Obtained by the Analyzer

Table 1: Parameters of Voltage THD

Time:	V1-2 THDf	V2-3 THDf	V3-1 THDf
	% f	% f	% f
19:10:00	2.1	2.1	2
19:20:00	2.1	2.1	2
19:30:00	2.1	2.2	2
19:40:00	2.2	2.2	2
19:50:00	2.1	2.2	2
20:00:00	2.1	2.2	2
20:10:00	2.1	2.1	2
20:20:00	2.1	2.1	2
20:30:00	2.1	2.1	2
20:40:00	2.1	2.1	2
20:50:00	2.1	2.1	2
21:00:00	2.1	2.1	2
21:10:00	2.1	2.1	1.9
21:20:00	2	2	1.9
21:30:00	2	2	1.9
21:40:00	1.9	1.9	1.8
21:50:00	1.9	1.9	1.8
22:00:00	1.9	1.9	1.7
22:10:00	1.8	1.8	1.7
22:20:00	1.7	1.7	1.7
22:30:00	1.7	1.7	1.6
22:40:00	1.6	1.7	1.5
22:50:00	1.6	1.6	1.5
23:00:00	1.6	1.6	1.4
23:10:00	1.6	1.6	1.4

Table 2: Parameters of Current THD

Time:	A1 THDf	A2 THDf	A3 THDf
	% f	% f	% f
19:10:00	50.1	44.1	10.4
19:20:00	72.4	48.7	10.2
19:30:00	71	42.5	11.1
19:40:00	71	45.2	12
19:50:00	71.7	45	12
20:00:00	73.2	49.4	12.2
20:10:00	73.6	61.9	12.9
20:20:00	72.8	55.2	13.5
20:30:00	74.3	47.8	13.4
20:40:00	73	54.2	13.1
20:50:00	72.8	54.2	13.6
21:00:00	72.9	55.2	13.5
21:10:00	73.2	52.6	13.1
21:20:00	72.8	52.6	13.6
21:30:00	73.7	62.7	13.5
21:40:00	73.1	54.8	12.9
21:50:00	73.6	56.2	14.4
22:00:00	73.3	54.5	12.8
22:10:00	74.7	56.5	12.4
22:20:00	74.7	54.1	12.9
22:30:00	73.9	55.8	13.1
22:40:00	75.5	58.7	12.6
22:50:00	75.4	60.3	13
23:00:00	75.1	54.9	12.9
23:10:00	74.9	56.1	12.6

Table 3: Average Parameters of HT Side

Time:	PT (W)	QT (var)	PFT
	W	var	
19:10:00	5385	-87.9	0.946
19:20:00	5077	-90.3	0.936
19:30:00	5551	-86	0.946
19:40:00	4475	-115.7	0.933
19:50:00	4349	-81.2	0.934
20:00:00	3902	113.1	0.926
20:10:00	3185	164.6	0.899
20:20:00	3084	206.2	0.907
20:30:00	3320	470.5	0.912
20:40:00	3167	204.5	0.911
20:50:00	3113	202.4	0.909
21:00:00	3067	199.5	0.907
21:10:00	3225	206.4	0.914
21:20:00	3170	205.4	0.912
21:30:00	2882	192.2	0.892
21:40:00	3119	199.8	0.909
21:50:00	2911	212.1	0.902
22:00:00	3128	202.2	0.909
22:10:00	3097	192.2	0.906
22:20:00	3142	198.3	0.91
22:30:00	2999	206.4	0.905
22:40:00	2936	203.1	0.9
22:50:00	2872	198.5	0.895
23:00:00	3017	197.8	0.906
23:10:00	3005	191.6	0.906

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2. RESULTS

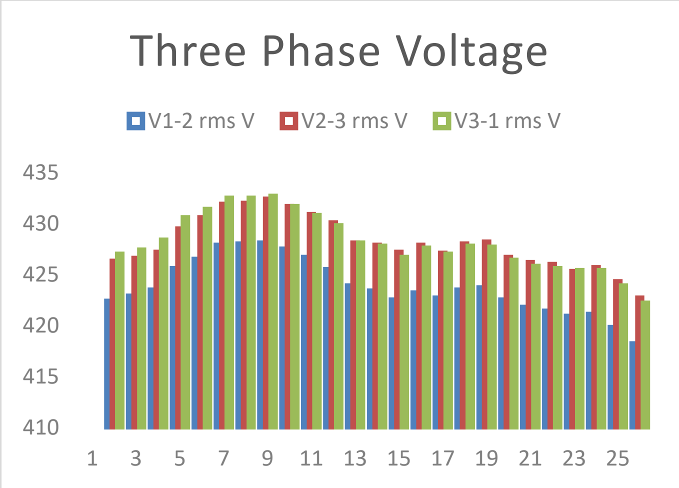

Fig -2: Voltage output of three phase HT side

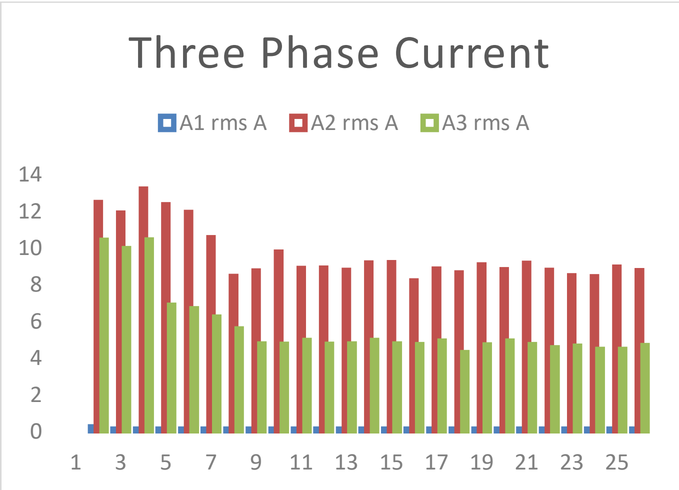

Fig -3: Current harmonics of three phase HT side

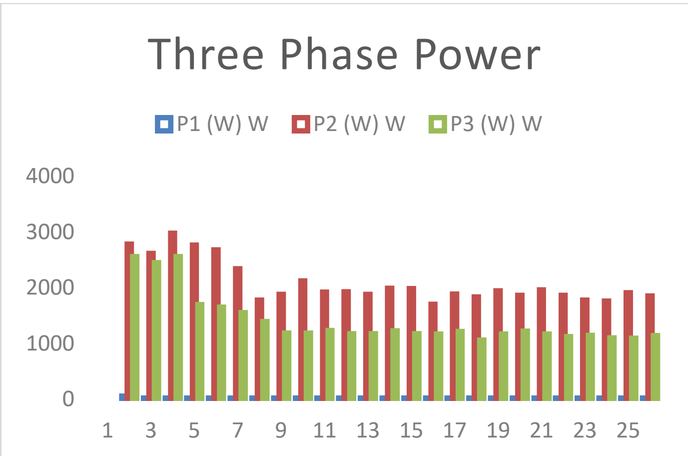

Fig -4: Three Phase Active power

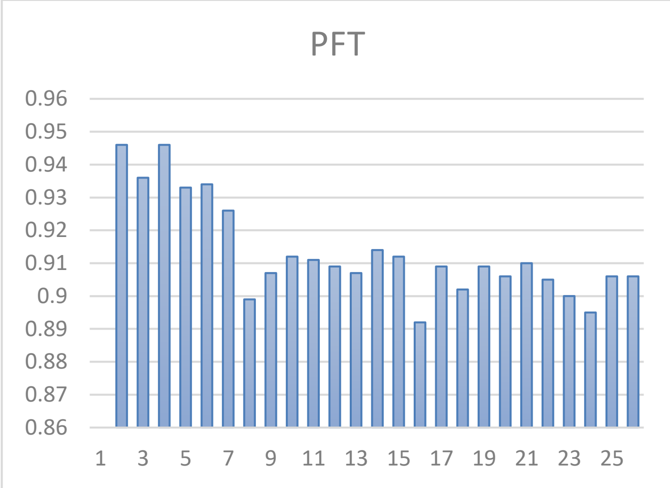

Fig -5: Total power factor of three phase

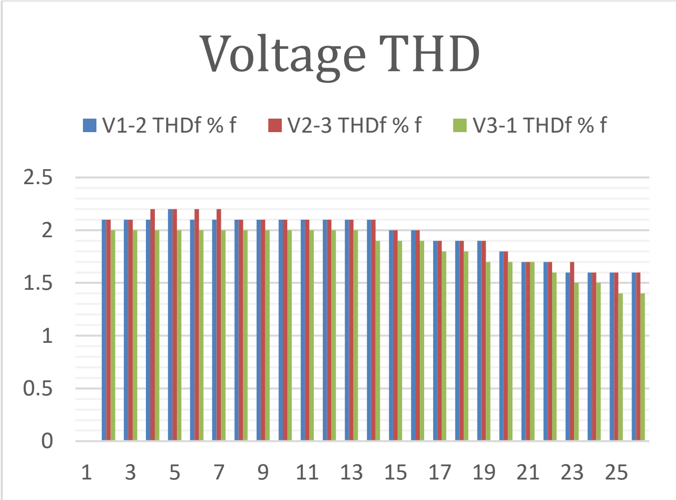

Fig -6: voltage harmonics HT side

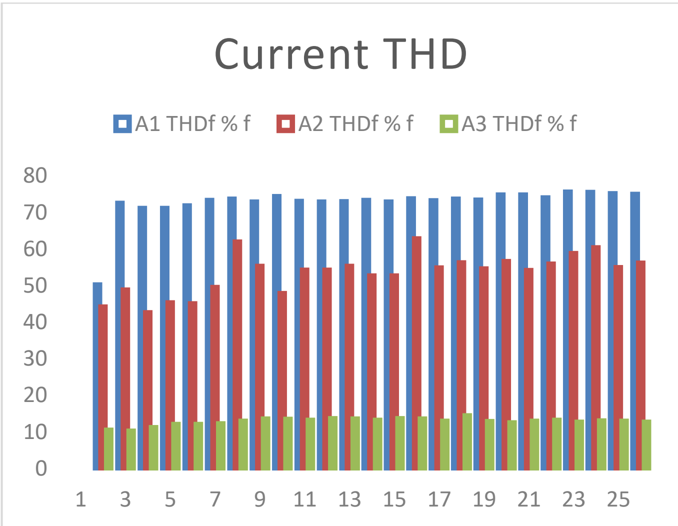

Fig -7: Current harmonics HT side

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Table 4: Voltage Unbalance table

Line voltage	RMS value	Mean Value	Maximum deviation from mean	Voltage unbalance= (Max deviation/mean value) * 100
Vr	415.9		2.2	
Vy	419.1		-1	
Vb	419.3	418.1	-1.2	0.53%

Fig -8: Average of Voltage harmonics LT side

Table 5: Current Unbalance table

Line current	RMS value	Mean Value	Maximum deviation from mean	Current unbalance= (Max deviation/mean value) * 100
Ir	19.89	17.54	-2.4	
Iy	16.86		0.7	9.52%
Ib	15.87		1.7	

Fig -9: Average of Current harmonics LT side

From the above results it can be seen that the Three phase voltage, current, power of the distribution transformer is in a desirable range, the power factor of all the three phases has also been observed and the total power factor of all the three phases is also in the range so no need to improve the power factor by the power factor controller. The THD range of voltage is around 2 and 2.5 which is in a very nominal range and no need for improvement whereas the current harmonic distortion values of all the three phases has a very higher ranges like in phase one 50-70 and in phase two about 30-50 similarly in phase three 10-20 in range. So some filter is been required to improve the current harmonics and to improve the range of harmonic distortion. Voltage and current values and the voltage unbalance and current unbalance has also been calculated and find out that the voltage unbalance is 0.53 % is in permissible range similarly current unbalance calculated and it's been around 10 % which is in higher side and needs to improve.

Table 6: Power Analyzer Configuration

Electrical hook-up	3-Phase 4-Wire 3V
Probes	A193 AmpFlex (100 A)
Reactive values (var) Q or N calculation	Q. Separated (Without Harmonics)
Phase Harmonic Ratios	Fundamental Value as reference (%f)
Long-Term Flicker (Plt)	Sliding Window
Transformer Factor K	q = 1.7 e = 0.10
Current ratio	1:1
Voltage ratio phase to neutral	1:1
Aggregation	10 min
Recorded measurements Vφ-φ	CF, rms, THDf
Recorded measurements Vφ-N	CF, Pst, rms, THDf, unb (u2)
Recorded measurements A	CF, FHL, rms, THDf, unb (u2), FK
Recorded measurements other	Cos φ (DPF), Hz, PF, Tan φ, S (VA), Q (var), P (W), D (var)
Recorded harmonics Vφ-N	0 - 50
Recorded harmonics A	0 - 50
Recorded harmonics S (VA)	0 - 50

4. CONCLUSION

The power logging has been done in a building premises transformer to analyze the nature of voltage and current harmonics. We can see that all the parameters like voltage, current, active power, power factor all are in a permissible range and the voltage THD and current THD has also been verified by the analyzer and it seems that the current THD has a very high value due to some nonlinear loads. So a solution is been required for the current harmonic elimination and a calculation has been done for the voltage and current unbalance and after the calculation result shows that the current unbalance is very high, this problem can also be resolved with the help of active power filter and in our next work we will see the impacts after implementation and make sure that the THD should be in a permissible limits.

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