A CASE STUDY FOR HARMONIC PRESENCE INVESTIGATION AND MITIGATION IN A CNC MACHINE PLANT

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ABSTRACT

In this paper analysis of two different cases is being compared for the presence of harmonics at manufacturing plant. Case 1, is a normal system configuration duly interfaced with CNC, AC servo drives, Spindle drive along with adaptive and in-process gauging system, High voltage Module, Isolation transformer and switchgear items and in case 2 additionally part compensated filter is added to reduce both system THvD and THiD levels. Simulation results proved that the proposed harmonic mitigation method is limiting the harmonic level at all three locations satisfactorily within 5% as mentioned in IEEE 519 Standard.

Keywords: Harmonic Mitigation, Harmonic Filter, CNC System.

I INTRODUCTION

Harmonic distortion of the voltage and current in an industrial facility is caused by the operation of nonlinear loads and devices on the power system. A nonlinear load is one that does not draw sinusoidal current when a sinusoidal voltage is applied. High harmonic currents can have several negative effects on a facility.

- High levels of distortion can lower power factors, overheat equipment, and lead to penalties from the local utility for exceeding recommended limits. Each of these effects can result in higher cost to the facility.
- Harmonic currents increase the volt-amperes required for a load without increasing the watts.
- ANSI/IEEE Standard C57 series states that a transformer can only be expected to carry its rated current if the current distortion is less than 5 The overheating is caused primarily by the higher eddy-current losses inside the transformer than were anticipated by the designer. The overheating can be avoided by either de-rating the transformer.
- Another effect of harmonic currents, is the overheating of neutral wires in wye-connected circuits. This effect occurs because the third harmonic (180-Hz) and any multiples thereof do not cancel in the neutral as do the other harmonic currents.
- This potential for overheating can be addressed by over-sizing neutral conductors or reducing nonlinear currents with filters.

By using a combination of a pre-stored database and new interpolation techniques the software can very fast provide the harmonic data on real applications. The harmonic results obtained with this software have acceptable precision even with limited input data. The evaluation concludes here that this approach is very practical compared to other advanced harmonic analysis methods. The results are supported by comparisons of calculations and measurements given in a publication "Power Electronics and Applications, 2005 European Conference".

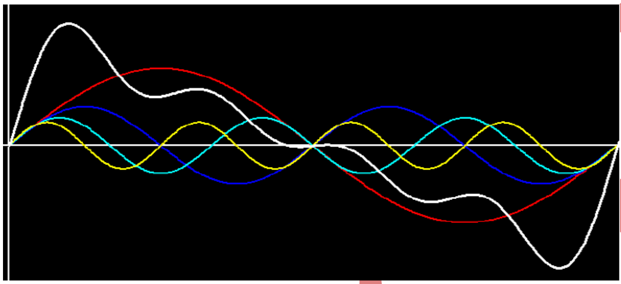


Figure 1 Third harmonic wave forms in phase with each other

1.1 Determining phase sequence with corresponding harmonic order

Negative sequence odd numbered harmonics are more distructive for heating and torque development.The following table 1 provides the sequence pattern of harmonics:

Table 1 Harmonic Sequence determination

Fundamental	R 0˚	Y 120˚	B 240˚	A-B-C Positive sequence
3rd Harmonic	$3 \times 0^0 = 0^0$	$3 \times 120 = 360^0$ 0^0	$3 \times 240^0 = 720^0$ 0^0	Zero sequence
5th Harmonic	$5 \times 0^0 = 0^0$	$5 \times 120^0 = 600^0$ 720: (-)120	$5 \times 240^0 = 1200^0$ 1440: (-) 240^0	Negative sequence
7th Harmonic	$7 \times 0^0 = 0^0$	$7 \times 120 = 840^0$ 720: (+) 120	$7 \times 240^0 = 1680^0$ 1440:(+) 240^0	Positive sequence
9th Harmonic	$9 \times 0^0 = 0^0$	$9 \times 120^0 = 1080^0$ 1080: (+)0^0	$9 \times 240^0 = 21600^0$ 2160: 0^0	Zero sequence

1.2 Effects of harmonics

- Harmonics affects wave shape and power quality; while power factor is a measure of power quantity.
- Neutral current in 3 phase 4 wire system, is very high,; consequently over heating of conductor, is observed.
- Reduced Power factor
- Failure of capacitor banks to improve power factor.
- Over heating of transformer due to circulating negative sequence harmonic current.
- Failure of protective relay
- Increased power losses and

- Nuisance tripping of devices
- Incorrect Meter functioning (Reading mistakes).

II HARMONICS VOLTAGE DISTORTION LIMITS AS PER IEEE 510-1992 STANDARDS

The THVD and THiD limits are given in following tables 2 and 3.

Table 2 Harmonic THD limits

Supply range	Individual harmonic Distortion voltage limit	Total voltage Distortion harmonic limit THvD%
≤69 kV	3.0%	5.0%
69≤V≥161 kV	1.5%	2.5%
≥161 kV	1%	1.5%

Load Current Distortion limits as per IEEE 519-1992 Standards

Table 3 Harmonic THD limits

Current ratio I_{SC}/ I_L	Maximum harmonic current distortion in % of I_L						
	Individual Harmonic order (Odd)						
≤ 20	≤	11-17	11-17	17-23	23-25	≥35	TDD
		4.0	2.0	1.5	0.6	0.3	5.0

I_{SC}: Short Circuit Current of supply system

I_L: Load current at Fundamental

III SYSTEM DESCRIPTION AND RESULTS ANALYSIS

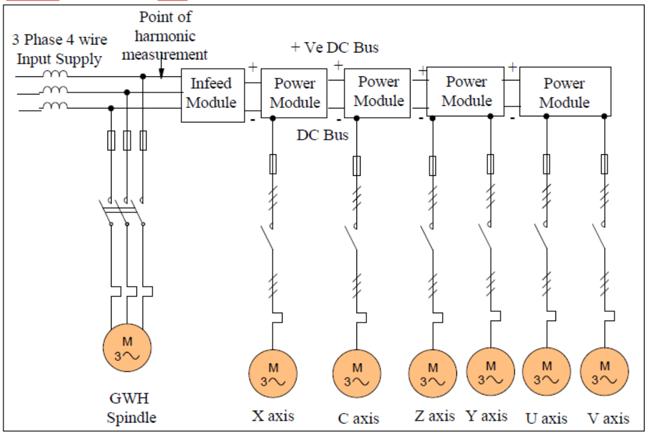


Figure 2 Description of system under consideration

Even harmonics are limited to 25% of odd harmonic limit.Comparison of Performance Data and Harmonics Level Before (case 1) and after (case 2) harmonic Mitigation: In our study, two cases are being compared. Case 1, is a normal system configuration duly interfaced with CNC, AC servo drives, Spindle drive along with adaptive and in-process gauging system, High voltage Module, Isolation transformer and switchgear items.

In case 2 additionally part compensated filter is added to reduce both system THvD and THiD levels. The comparison is given table 4 below: and associated data

Table 4 Harmonic data comparison in both cases

S no.	Parameter	Unit	Before Case 1 Without filter	After Case 2 with partly compensated
1	Short circuit Power	MVA	1.1	1.1
2	Short circuit current	kA	1.6	1.6
3	Short Circuit ratio		21.3	19.9
4	Total harmonic voltage distortion THvD	%	7.7	2.8
5	Total harmonic voltage distortion THvD	%	27.7	7.6
6	Total Demand Distortion TDD	%	26.5	7.5
7	Total RMS Current	Amp	73.1	78.0
8	Transformer Current Loading	%	52.1	55.8
9	Displacement Power factor DPF		0.97	1.0
10	Power Factor		0.94	1.0
11	Harmonic Loss Factor		3.6	1.3
12	De-rating of transformer due the harmonic Eddy current	%	100	100
13	Total current Losses at nominal rated current	kW	0.8	0.8
14	Resistive losses at nominal current	kW	0.8	0.8
15	Eddy current losses at nominal load current	kW	0.1	0.1
16	Total losses at load current	kW	0.3	0.3
17	Resistive losses at load current	kW	0.2	0.2
18	Eddy losses at load current	kW	0.1	0.1

3.1 Case 1 System without any measures (without Filter)

Harmonic spectra at secondary side of transformer

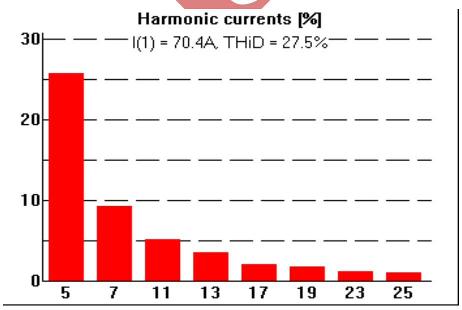


Figure 3 Case 1 without Filter

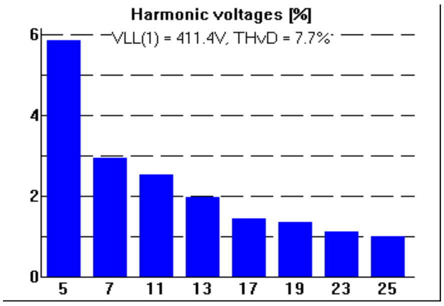
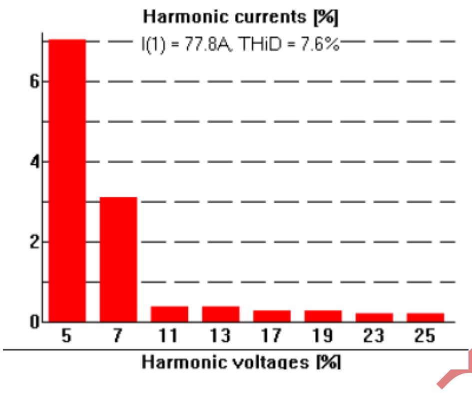


Figure 4 Case 1 without Filter

From graph in figure 3 and 4 above, it is illustrated that total current distortion level is 27.5% with dominant impact of Harmonic order 5,7 and 11. It needs mitigation from clean power quality view point so as to ensure the compatibility of input power to all electronically sensitive equipment. Apart from reducing thermal effect, the accuracy and malfunction must be avoided; by eliminating or at least bringing down to acceptable limits as defined in table 3 and 4 above.

3.2 Case 2 after partly compensation using Filter

Harmonic spectra at secondary side of transformer



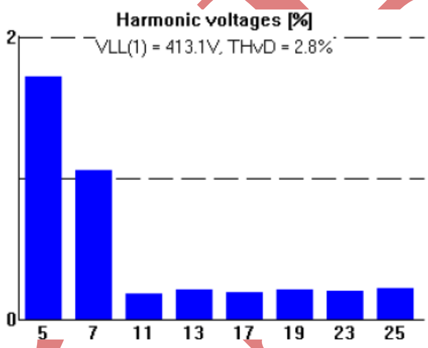


Figure 5 Case 2 after Filter compensation **Figure 6 Case 2 after Filter compensation**

From graph in figure 5 above, it is illustrated that total current distortion level is reduced to 7.6% as compared to previous value of 27.5%. Voltage harmonic distortion is also reduced to 2.8% from 7.7% as in figure 6 and figure 4 respectively.

IV CONCLUSION

In this paper two different cases are considered for the analyzed and the power quality is maintained by mitigation of harmonics. In case 1, without any corrective measures, it is found that harmonic presence due to AC servo drives is (THvD=7.8%, THiD=27.8%) and after part compensation of filters; the harmonic level reduced to (THvD=2.8%, THiD=7.7%).Such improvement gives intangible benefits in form of enhanced life of equipment and free from un-foreseen un-predictable supply wave form and magnitude deformations.

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