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Survey of Harmonics in Non Linear Loads

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Abstract*: The use of non linear loads is increasing day by day. This increasing use of non linear loads has created more distortions in current and voltage waveforms. This increased power quality disturbances has lead to various optimizations techniques and filter designs. Harmonic distortions are the major cause for power quality problems. For this analyzing the harmonics present in non linear loads is significant. Here a survey is made to show details of harmonics present in various non linear loads.

Keywords: Non linear loads, Harmonics, Power quality

I.INTRODUCTION

The main objective of the electric utility is to deliver sinusoidal voltage at fairly constant magnitude throughout their system. This objective is complicated by the fact that there are loads on the system that produce harmonic currents. These currents result in distorted voltages and currents that can adversely impact the system performance in different ways. As the number of harmonic producing loads has increased over the years, it has become increasingly necessary to address their influence when making any additions or changes to an installation. To fully appreciate the impact of these phenomena, there are two important concepts to bear in mind with regard to power system harmonics. The first is the nature of harmonic-current producing loads (non-linear loads) and the second is the way in which harmonic currents flow and how the resulting harmonic voltages develop [1]. In field of acoustics, harmonics is generally a vibration of a string or an air column at a frequency that is a multiple of the base frequency. A harmonic component in a power system is defined as the sinusoidal component of a periodic waveform that has a frequency equal to an integer multiple of the fundamental frequency of the system [2] – [5]. It is given by,

F_h =h* Fundamental frequency, where h is the integer to be multiplied.

If the fundamental frequency is f, then the harmonics have frequency f,2f,3f,4f,5f….Even harmonics are 2f,4f,6f,8f…and odd harmonics are f,3f,4f,5f,7f... Generally even harmonics get cancelled because of their symmetrical nature, but odd harmonics should be eliminated by some filtering or compensation techniques.

II. HARMONICS: CAUSES & EFFECTS

In an ideal power system voltage and current waveforms are purely sinusoidal. In practice, non sinusoidal currents result when the current flowing through the load is non linearly related to the applied voltage. In a simple circuit containing only linear circuit elements (resistance, inductance and capacitance), the current which flows is proportional to the applied voltage. So that it results in a sinusoidal current flow. The situation where the load is simple full wave rectifier, current flows only when the supply voltage exceeds that stored on the reservoir capacitor. It says that waveforms tend to distort from the sine wave and this is the cause for harmonics [6]. Non-linear loads create harmonics by drawing current in abrupt short pulses, rather than in a smooth sinusoidal manner [7] as shown in the fig.1.

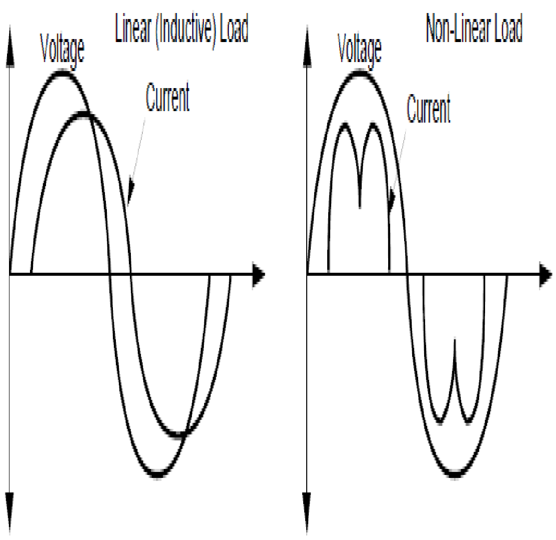

Fig.1. A non linear load drawing current in short pulses when compared to linear load.

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Power system problems related to harmonics are rare but it is possible for a number of undesirable effects to occur. High levels of harmonic distortion can cause several effects such as increased transformer, capacitor, motor or generator heating, false operation of electronic equipment (which relies on voltage zero crossing detection or is sensitive to wave shape), incorrect readings on meters, false operation of protective relays, interference with telephone circuits, etc [8]. Since harmonic distortion is caused by nonlinear elements connected to the power system, any device that has non-linear characteristics will cause harmonic distortion. Examples of common sources of power system harmonics, some of which never cause serious problems, are: transformer saturation and inrush, transformer neutral connections, MMF distribution in AC rotating machines, electric arc furnaces, fluorescent lighting, computer switch mode power supplies, battery chargers, imperfect AC sources, variable frequency motor drives (VFD), inverters, and television power supplies[9]-[10].

III. NON LINEAR LOADS

Due to the changes in the operating conditions and the rapid growth of advanced power conversion devices, electronics equipments, computers, office automation, air-conditioning systems, adjustable speed heating ventilation can cause current distortions. This is due to increase in harmonics drastically. According to the Electric Power Research (EPR) in 1995, 35-40% of all electric power flows through electronic converters. This is expected to increase to 85% by the year 2012 [11]-[15]. All these devices are named as non linear loads and become sources of harmonics. The simple block diagram in Fig.2 illustrates the current distortion problem due to harmonic at low voltage levels.

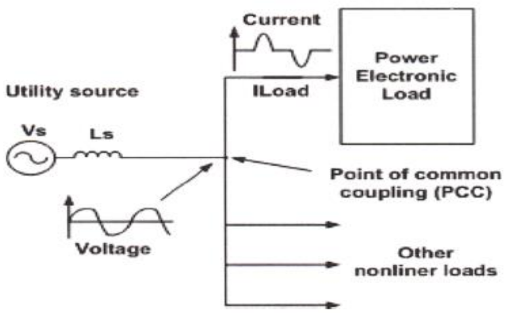

Fig.2. Current distortions at point of common coupling

Fig.2 shows that the voltage waveform at the Point of Common Coupling (PCC) is distorted due to harmonic current generated by the power electronic or non linear load. The measurement results for the several modem set of non linear based on Figure 2 is tabulated in Table.1 [11]

Table.1 The measured results for the modern set of non-linear loads

Modern set of non linear loads	Power factor	THDi (%)	3rd (%)	5th (%)	7th (%)	9th (%)	11th (%)
Fluorescent lamp	0.57	11.1	10.7	2	1.8	0.9	0.6
Freezer	0.44	61.8	11	4.7	11	7.1	7.1
Amplifier	0.71	48.1	32.1	30.7	14.2	7.8	2.6
Television	0.66	72.5	55.1	36.8	20.3	11.4	10.8
Photostat	0.68	69.9	37.7	40.2	30.7	21.9	15.2
Laptop	0.52	83.8	49.6	43.8	36.2	27.5	17.7
PC	0.53	60.1	52.8	43.5	31.6	19.3	8.4
Printer	0.49	83.6	46.7	41.3	36.2	28.6	21.5

In this paper a survey is done for various non linear loads to know the levels of harmonics present in each loads. These surveys are generally conducted with the objectives such as

- Identify the trends of harmonic distortion level present in the system,
- Identify the future trends of metering in the presence of non sinusoidal current and voltage waveforms. And increased awareness and concern for customer's quality of service.

Here various loads and its harmonics are studied in detail.

A. Rectifiers

Rectifiers are the basic load employed in every system. Rectifiers are used to convert AC to DC current, while converting due to the involvement of thyristors (non linear load) produces harmonics. It consumes the current in the circuit and which at last will have dc output with ac components (i.e. harmonics).This distorted current also leads to distortion in line voltage. Total harmonic distortion in line current in single phase rectifier is 88.81%. But, three phase diode rectifier has total harmonic distortion of 52.84% [16]. Comparison of the line-current waveforms shows that the line current in a single-phase rectifier contains significantly more distortions compared to a three-phase rectifier. A 3 phase, six pulse (per cycle) converter produces the 5^{th}, 7^{th}, 11^{th}, 13^{th}, 17^{th}, etc., and contains no harmonic lower than the 5^{th}; for a 12-pulse converter the lowest is the 11^{th} harmonic [17]. These are represented below in Table.2.

Table.2 Harmonic currents produced by rectifiers

Harmonic	Six-pulse, 3-phase		12-pulse, 3-phase	
	Theoretical	Typical	Theoretical	Typical
f_5	20%	17.5%	-	2.6%
f_7	14.3	11.1	-	1.6
f_{11}	9.1	4.5	9.1	4.5
f_{13}	7.7	2.9	7.7	2.9
f_{17}	5.9	1.5	-	0.2
f_{19}	5.3	1	-	0.1
f_{23}	4.3	0.9	4.3	0.9
f_{25}	4.0	0.8	4.0	0.8

Generally lower order harmonics are significant and most dominant one is 3^{rd} harmonics in rectifier [18] - [21].

B. Fluorescent lamps

Recent governmental initiatives of a number of countries to ban selling of incandescent light bulbs have brought some attention on the question of the quality of current drawn by energy saving lamps. Energy saving lamps requires considerably smaller amounts of active power than incandescent lamps when they have the same luminous flux.

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On the other hand, due to their non-linear characteristics, energy saving lamps injects harmonic currents into the network. That creates a concern that a very high penetration level of these types of lamps may increase the overall voltage harmonic distortion considerably [22]. In order to compare the different harmonic behavior of the various ceiling light the current total harmonic distortion (I_{THD}) has been also calculated with many measurements [23]. The results are shown in Table.3.

Table.3 THD for fluorescent lamps in %

Current Harmonics	I-THD [%]		
	Measurement n,1	Measurement n,2	Measurement n,3
Type n,1 FL	32.2	31.11	31
Type n,2 FL	27.5	27	26.2
Type n,3 FL	6.8	7.8	8.8
Type n,4 FL	6.5	7.7	8.6

In order to inform utilities how current distortion varies among today's CFLs, EPRI (Electric Power Research Institute) carried out extensive testing in its lab. Fig.3 illustrates the spread of input total harmonic current distortion for the 51 samples of CFLs that were used in the project. These CFLs were purchased off-the-shelf from retail establishments where end users commonly shop for CFLs. From the figure one can see that the I_{THD} ranges from 20 % to 170 %.The trend among this sample set is higher I_{THD} as the majority of the CFLs tested had I_{THD} above 100 [24]-[27].

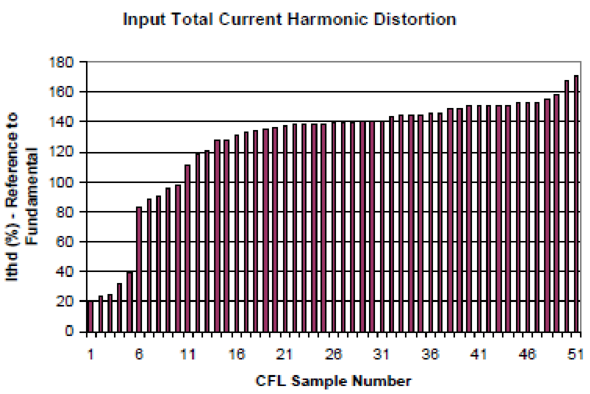

Fig.3. Input THD for 2009 Market sample CFLs

C. Electric arc furnace

ARC furnaces are used for melting and refining metals, and highly efficient steel-making process achieved with electric furnace led to their widespread development and together with the large increase in their individual ratings enabled the electric furnace to become one the most important non-linear loads in the electric power network. So it is a time varying, non-linear loads [28].

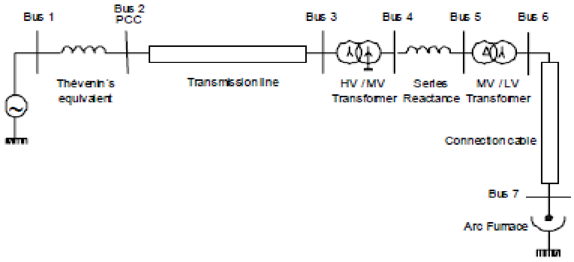

Fig.4. Electrical network supplying the arc

In fact, arc furnaces may be the most prominent harmonic producers because of their great capacity lumped together at one place. Using a program developed in MATLAB, based on a Fourier analysis of the time-domain waveforms, the Total Harmonic Distortion (THD) is computed at the PCC and Arc Furnace (Table.4 and Table.5). Results are presented in percentage of the 50 Hz component [29].

Table.4 Voltage THD at the PCC and Arc Furnace

	THD (%) - Voltage
PCC (Bus 2)	0.25
Arc Furnace (Bus 7)	32.53

Table.5 Current THD at the PCC and arc furnace

	THD (%) Current
PCC (Bus 2)	2.08
Arc Furnace (Bus 7)	13.26

The content of harmonics which is dominant is 2nd, 3rd, 4th, 5th, 6th and 7th. The waveform of the electric current is badly distorted containing a large number of higher order harmonics [30] – [32].

D. Television

Television receivers have power supplies which create current harmonics. Whilst the harmonic current levels are small in magnitude, the cumulative effect of large numbers of receivers can be significant. One way to examine the effect of television receivers on network harmonic levels is to monitor harmonic levels during periods of increased television viewing [33].

Table.6 Harmonic current spectra for television

Harmonics	Television	
	Magnitude (A)	Phase angle
1	100	1
3	79.8	-173
5	49.2	12
7	20.5	-159
9	4.0	81
11	5.5	-13
13	3.1	175
15	0.8	-138

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In this a television is served by the small wall outlet. The corresponding current spectra are given in Table.6.Because of phase cancellation; the current flowing through the wall outlet has lower THD [34].

The problem of the 3rd-harmonic tuning of the television horizontal-deflection circuit has been examined experimentally, as well as theoretically. A well known method is to use the 2-8th harmonic to obtain good pictures without ringing oscillations and with high fly back pulses. The resonant-frequency ratio recommended by this method, however, seemed to show some discrepancies with empirically determined conditions. As this problem is directly related to the quality of television pictures, the optimal conditions to attain good results have been sought by television manufacturers [35] [36].

E. Personal computers

Computer loads and systems are being increasingly used in all industrial, commercial and residential sectors. The nature of these loads is such that they not only draw distorted current from the source, but can significantly distort the supply voltage waveform causing disruption in system performance. The

SMPS used in computer loads draw highly distorted current from the source. Significant amount of odd harmonics including triplens are present.

The THD observed in personal computers is shown in Table.7 [37].

Table.7 %THD with reference to fundamental

Harmonic No.	%THD
3rd	91.63
5th	86.61
7th	69.87
9th	44.76
11th	54.81
13th	46.44
15th	46.44
17th	33.05
19th	24.70
23rd	11.74
25th	7.900
29th	5.120
% THDi	178.97

The proliferation of personal computer (PC) loads in residential, commercial and industrial buildings has increased the harmonics levels found on electrical power distribution networks. Generally in computers as load, 3rd and 5th harmonics are dominant [38] – [42].

IV. CONCLUSION

A survey of harmonics present in the voltage and current waveforms is conducted with an objective to know the existing level of harmonic distortion present in the Power System and future trends. Harmonics injected by some very commonly used nonlinear loads are studied. It is observed that significant distortion in the current exists due to the use of computers and other electronic equipments in residential and commercial areas too. Increasing use of these equipments may result in serious problems in near future. The current distortion differs widely from one section to the next. Although, voltage distortion is recorded below the acceptable limit, but it is found above the recommended limit at the places of high current distortion, as it depends on the circuit impedance as well as harmonic generation characteristics. Significant distortion in the current is recorded at customer end with high percentage of 5th and 7th harmonic components. Though various optimization techniques are present, research is being done for the best eliminated results of THD.

REFERENCES

1. J. Arillaga, et al, "Power System Harmonics" ISBN 0-471-90640-9.
2. Copyright Hawaiian Electric Company, Inc. 2004 "A Harmonics primer".
3. IEEE Std 519-1992, IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.
4. IEEE Electrical Insulation Magazine," The Effect of Voltage Distortion on Ageing Acceleration of Insulation Systems under Partial Discharge Activity"
5. J.L.Hernandez , MA. Castro, J. Carpio and A. Colmenar, "Harmonics in power systems" in International Conference on Renewable Energies and Power Quality (ICREPQ'09).
6. EC & M magazine, edition 2012.
7. Square D "Product data bulletin" Power System Harmonics Causes and Effects of Variable Frequency Drives Relative to the IEEE 519-1992 Standard. Bulletin No. 8803PD9402 August, 1994 Raleigh, NC, U.S.A.
8. Allen-Bradley "Power system harmonics- A Reference Guide to Causes, Effects and Corrective Measures" in Rock well automation, A Reference Guide to Causes, Effects and Corrective Measures.
9. Lorenzo Cividino-Power products development manager "Power Factor, Harmonic Distortion Causes, Effects and Considerations", Telecommunications Energy Conference, 1992.INTELEC '92.14th International , 1992 , Page(s): 506 – 513.
10. Joseph.S, Sunbjak.JR,John s.Mcquililkin-Members IEEE," Harmonics - Causes, Effects, Measurements, and Analysis: An Update" IEEE transactions on applications, vol. 26. NO.6 November/December 1990.
11. M.I.Abu Bakar"Assessments for the Impact of Harmonic Current Distortion of Non Linear Load In Power System Harmonics", Transmission and Distribution Conference and Exposition: Latin America, 2008 IEEE/PES, 2008 , Page(s): 1 - 6.
12. David Kreiss "Increasing levels of non linear loads adds to harmonic woes" Vol. 1 No. 2 Summer 1995 A Quarterly publication of Dranetz Technologies,INC. Powercet corporation and Kreiss-Johnson Technologies.
13. Dr. R.K. Tripathi, Member, IEEE & Mr. Chandreshver Pratap Singh" Power Quality Control of Unregulated Non-linear Loads 978-1-4244-8542-0/10/$26.00 ©2010 IEEE
14. Gonzalo Sandoval,ARTECHE / INELAP S.A. de C.V." Power Factor in Electrical Power Systems with Non-Linear Loads"
15. Hossein Mokhtari Sharif University of Tech Tehran, "Nonlinear Loads Effect on Harmonic Distortion and Losses of Distribution Networks"Mohammad Jawad Ghorbani, Salar Atashpar, Arash Mehrafrooz Iran Energy Efficiency Organization (IEEO) Tehran, Iran
16. Anne Ko,Wunna Swe,Aung Zeya,"Analysis of Harmonic Distortion in Non-linear Loads"- The First International Conference on Interdisciplinary Research and Development, 31 May - 1 June 2011, Thailand

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17. Dranetz"Power line harmonic problems-causes and cures" 1994
18. S.Kim,P.Enjeti,D.Rendusara,I.J. Pitel "A new method to improve THD and reduce harmonics generated by a three phase diode rectifier type utility interface", Industry Applications Society Annual Meeting, 1994., Conference Record of the 1994 IEEE, 1994 , Page(s): 1071 - 1077 vol.2.
19. Sangsun Kim, Member, IEEE, Maja Harfman Todorovic, Student Member, IEEE, and Prasad N. Enjeti, Fellow, IEEE" Three-Phase Active Harmonic Rectifier (AHR) to Improve Utility Input Current THD in Telecommunication Power Distribution System" IEEE transactions on industry applications , vol .39 , No5,September/October 2003.
20. Hussain S. Athab, IEEE Member, P. K. Shadhu Khan, senior IEEE Member" A Cost Effective Method of Reducing Total Harmonic Distortion (THD) in Single-Phase Boost Rectifier",Power Electronics and Drive Systems, 2007. PEDS'07. 7th International Conference, Page(s): 669 – 674, 2007.
21. Predrag Pejovic´ and ˇ Zarko Janda"An Improved Current Injection Network for Three-Phase High-Power-Factor Rectifiers that Apply the Third Harmonic Current Injection" IEEE transactions on industrial electronics,vol.47,no.2, April 2000."
22. V. Cuk, J.F.G. Cobben, W.L. Kling, and R.B. Timens" An Analysis of Diversity Factors applied to Harmonic Emission Limits for Energy Saving Lamps", Harmonics and Quality of Power (ICHQP), 2010 14th International Conference, 2010, Pages:1-6.
23. M.C. Falvo, Member, IEEE, U. Grasselli, Member, IEEE, R. Lamedica, Member, IEEE, and A.Prudenzi, Member, IEEE" Harmonics monitoring survey on office LV Appliances" 2000.
24. H. Sharma, Member, IEEE, W. G. Sunderman, Member, IEEE, and A. Gaikwad, Member, IEEE Harmonic Impacts of Widespread Use of CFL Lamps on Distribution Systems"1991.
25. Khodijah Mohamed, Hussain Shareef , Azah Mohamed, "Analysis of Harmonic Emmision from Dimmable Compact Fluorescent Lamps" 2011 International Conference on Electrical Engineering and Informatics 17-19 July 2011, Bandung, Indonesia.
26. I. F. Gonos, M. B. Kostic, M. B. Kostic," Harmonic Distortion in Electric Power Systems
27. Introduced by Compact Fluorescent Lamps",Electric Power Engineering, 1999. PowerTech Budapest 99.International Conference 1999.
28. Gluskin, E Emanuel Gluskin,Department of Electrical and Computer Engineerhg Ben-Gurion University of the Negev"High harmonic currents in flouescent lamp circuits", Industry Applications Society Annual Meeting, 1988., Conference Record of the 1988 IEEE , 1988 , Page(s): 1852 - 1854 vol.
29. Ashok D. Pateliya, Manish N. Sinha"Simulation of Harmonics Producing Loads in Power System Network" in National Conference on Recent Trends in Engineering & Technology. 13-14 May 2011.
30. J. Sousa, M.T. Correia de Barros,M. Covas ,A.Simões" Harmonics and Flicker Analysis in Arc Furnace Power Systems".
31. Rahmat Allah Hooshmand* and Mahdi Torabian Esfahani"Optimal Design of TCR/FC in Electric Arc Furnaces for Power Quality Improvement in Power Systems" in Leonardo Electronic Journal of Practices and Technologies,ISSN 1583-1078 Issue 15, July-December 2009 p. 31-50.
32. Dr. W. Z. Gandhare and D. D. Lulekar, Govt. College of Engineering, Aurangabad (Maharashtra), India" Analyzing Electric Power Quality in Arc Furnaces", International Conference of Renewable Energy and Power Quality, March 2007.
33. Wang Yongning, Li Heming, Xu Boqiang, Member, IEEE, Sun Lilhg, Student Member, IEEE" in2004 International Conference on Power System Technology - Powercon 2004 Singapore, 21-24 November 2004.
34. N. Browne, Member, IEEE, S. Perera, Member, IEEE, P.F Ribeiro, Fellow, IEEE."Harmonic Levels and Television Events",Power Engineering Society General Meeting, 2007. IEEE, 2007, Page(s): 1 – 6.
35. Grady, W.M.; Mansoor, A.; Fuchs, E.F.; Verde, P.; Doyle M, Harmonic Levels and Television Events "Estimating the Net Harmonic Currents Produced by Selected Distributed Single-Phase Loads: Computers, Televisions, and Incandescent Light Dimmers", Power Engineering Society Winter Meeting, 2002. IEEE Volume: 2, Year: 2002, Page(s): 1090 - 1094 vol.2 Cited by: 5.
36. T. Inouye, D.Eng., and T. Tarui, D.Eng." Detailed analysis of 3rd-harmonic tuning of television horizontal-deflection circuit", Electrical Engineers, Proceedings of the Institution of Vol: 118, Issue:6, 1971, Pages: 756-757.
37. E.F.Fuchs, D.J.Joesler, K.P.Kovacs" Sensitivity of electrical appliances to harmonics and fractional harmonics of the power system's voltage.part ii: television sets, induction watthour meters and universal machines" in IEEE transactions on power delivery, vol. pwrd-2, no. 2, April 1987.
38. Rana A. Jabbar, Muhammad Junaid, M. Ali Masood and Khalid Saeed Akhtar Rachna College of Engineering & Technology, Gujranwala, Pakistan" Impacts of Harmonics caused by Personal Computers on Distribution Transformers,Electrical Engineering, 2009. ICEE '09. Third International Conference on 2009, pages 1-6.
39. V.Tipsuwanporn, Member, IEEE, W.Thueksathit, and W.Sawaengsinkasikit"Harmonics, reduction system using active filter based on computer unit" in 2005 IEEE/PES transmission and distribution conference and exhibition: Asia, Pacific Dalian, China.
40. Philip J. Moore, Senior Member, IEEE, and Iliana E. Portugués" The Influence of Personal Computer Processing Modes on Line Current Harmonics" in IEEE transactions on power delivery, vol. 18, no. 4, october 2003.
41. A. Mansoor, W. M. Grady, P. T. Staats, R. S. Thallam, M. T. Doyle, M. J. Samotyj "Predicting the Net Harmonic Currents Produced by Large Numbers of Distributed Single-phase Computer Loads" in IEEE Transactions on Power Delivery, Vol. 10, No. 4, October 1995.
42. H.O.Aintablian and H.W.Hil1, Jr" Harmonic Currents Generated by Personal Computers and their Effects on the Distribution System Neutral Current", Industry Applications Society Annual Meeting, 1993, Conference Record IEEE, oct 1993, 1483 - 1489 vol.2.
43. Dalil Paraiso, Éloi Ngandui, Martin de Montigny, Pierre Sicard" Characterization of Neutral and Line Current Harmonics in Three-Phase Computer Power Systems" Industrial Electronics Society, 2005.IECON 2005. 31st Annual Conference of IEEE, 2005

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