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Modeling Of Factors Influencing Harmonic Distortion Based on Simulation Model of Personal Computer

Muhammad Shahzad Bajwa , Muhammad Usman Keerio

Department of Electrical Engineering, Quaid-e-Awam University of Engineering, Science and Technology Nawabshah
shahzadbajwa80@yahoo.com , usmankeerio@quest.edu.pk

Abstract: The penetration of harmonic distortion in electrical power system due to the extensive utilization of nonlinear electronic loads such as Personal Computer (PC) is the root cause of voltage and current distortion and also serious troubles for overall electrical power system. More or less every household consumer of electricity is faced variations in the system voltage, frequency, source impedance. To quantify the influence of above mentioned factors on harmonic distortion magnitudes in non linear loads accurately, we need to studies and implement various aspects together with the accurate simulation model of these nonlinear loads. Hence, the objectives of this paper is first to evaluate the efficiency of developed simulink model of personal computer for harmonic distortion investigation via comparing with experimental measurement and second is to investigate the influence of above mentioned factors individually and precisely on the total harmonic distortion by using that simulink model of personal computer. Validation of the PC simulink model is done by performing experimental study at Electrical Engineering Department QUEST Nawabshah and comparing the THD and other power quantities obtained from simulation using MATLAB with the values obtained by experimental measurement.

Keywords: Harmonic Distortion, Experimental study, Personal Computer (PC) , Simulink model , Curve Fitting.

I. INTRODUCTION

At the present time, power quality becomes important issue for utilities as well as for customers. As nonlinear load is increasing in electrical power system, require more analysis on the harms related with harmonic distortion in the electrical system. Harmonic distortion causing the quality of electrical system poor and the function of equipment connected to electrical system are affected [1-2]. When non linear electronic load is connected in AC electrical power distribution system the current waveform is distorted and distorted current flow back to input supply cause distortion in voltage waveform. Therefore power quality (PQ) problems produced cause enormous economic losses and fault occurrences in electrical power system [3-5].

Effects of harmonic distortion are increased recently because of power electronic load such as electronic fan regulator, printer, personnel computer etc. Harmonic distortion due to personal computer load get more attention as personal computers are the load that are commonly used in a concentrated group form [6].

As lot of works have been done to investigate and analyze the factors that can influence on the harmonic distortion phenomena due to nonlinear loads. In [7-8] attenuation factor is discussed which is the relations of voltage and current harmonic distortions caused by shared electrical system impedance and diversity factor which can be described as the partial cancellation can occur in harmonics order due to change of phase angle of voltage and current magnitudes. The influence of mixing or connected three phase loads with single phase load is described as the fifth and seventh order harmonic current are mostly in counterbalance caused reduction of total harmonic distortion (THD) [9].When many different types of single-phase nonlinear loads is connected with same source then also harmonic cancellation occurs as explained in [10]. Moreover simulation results presented in [11] shows background voltage distortion also influence on current harmonics and cannot be ignored while analyzing distortion due to non linear loads.

In order to quantify the quality of electrical power system due to the utilization of nonlinear loads exactly and precisely, many investigations require to be implemented together with the accurate modeling of these nonlinear loads. However, almost previously mentioned investigations [12-24] have not shown which type of simulation equivalent model employed for analyzing purposes. Hence, harmonics distortion quantification due to a particular factor is not fully assessed. As harmonic distortion mitigation filters, whether passive or active have the benefit of being retro-fit but the drawback is that only provide temporary solution. If further non linear load is added in electrical system or load having varying harmonic distortion profile with respect to operating duty cycle, then design assumptions will also be change.

Harmonic Distortion Indices

Harmonics in electrical power system are the sinusoidal waveforms with multiples of the fundamental (50 or 60Hz) as shown in Fig.1 [1].

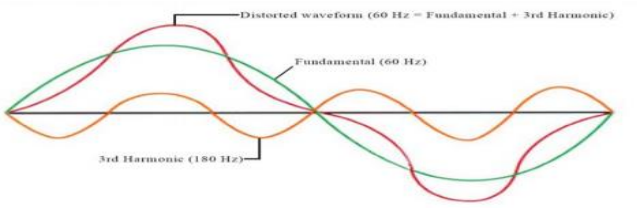

Figure 1. Sinusoidal waveform with 3rd harmonic

The total effect of multiple harmonics in voltage and current waveforms are expressed as total harmonic distortion (THD) as in expression 1.

$$THD_i = \frac{\sqrt{\sum_{n=2}^{\infty} I_{rms,n}^2}}{I_{rms}} \quad (1)$$

Where

$$I_{rms} = \sqrt{\sum_{n=1}^{\infty} I_{rms,n}^2}$$

Similarly for THD_v replace I with V.

This research paper is structured as section I presents the effect of non-linear power electronic load on power quality and harmonic distortion indices , Section II showing comparision of results from experimental measurement and simulation model of equivalent PC circuit model. Section III presents modeling of factors influencing total harmonic distortion , Finally, Section IV concludes the paper.

II. COMPARISION OF EXPERIMENTAL AND SIMULATION OF EQUIVALENT PC MODEL MEASUREMENT RESULTS

A. Experimental Harmonic Distortion Measurement due to PC

Experimental harmonic distortion measurement is performed to confirm the level of distorted current and voltage waveforms during the operation of personal computer by Power Quality Analyzer instrument in Electrical Engineering Department QUEST Nawabshah.

PC Configuration:
ATX type power supply 220V, LED-17 Inch, Processor: Intel (R) Core (TM) i7, 3.4GHz (4cpus), RAM of 2048MB, Rated Power range from 140w to 200w.

Figure 2. View of Personal Computer and Power Quality Analyzer used in experimental measurement

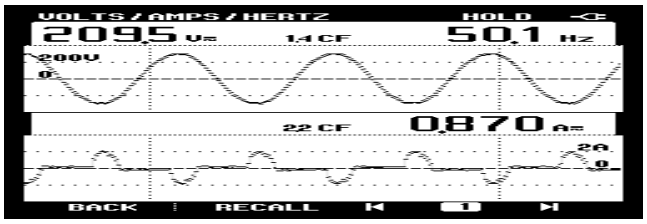

Figure 3. Voltage And Current Waveforms

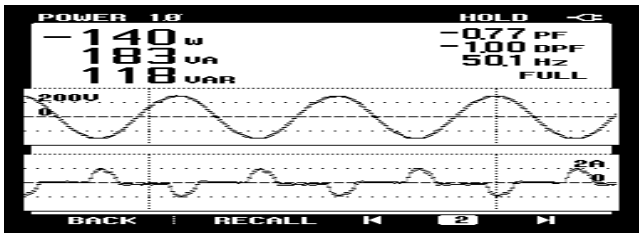

Figure 4. Power Quantities

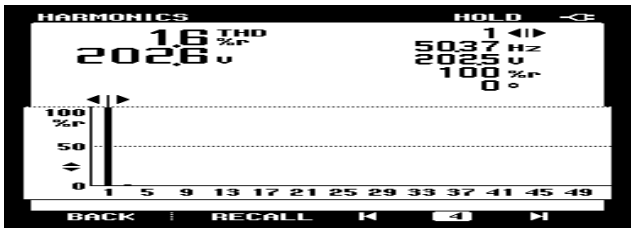

Figure 5. THD_v value

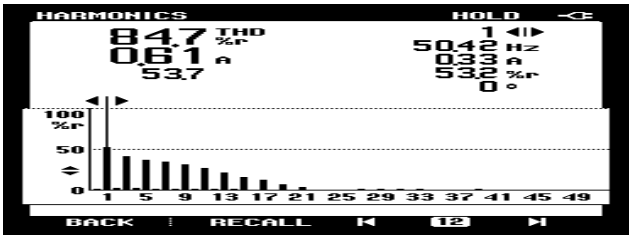

Figure 6. THD_i value

B. Simulation Harmonic Distortion Measurement Of Equivalent SMPS of PC

In this research work personal computer is used as a non linear load. Switch Mode Power Supply (SMPS) are vital part of personal computer , however it produce harmonic distortion and can be equivalently represented model of PC load as shown in Fig. 7

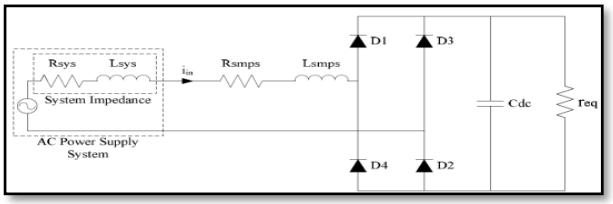

Figure 7. Equivalent Circuit Model of PC

The magnitudes of parameters used for simulink model are seen in Table.I and developed simulink model of equivalent circuit of PC in MATLAB/Simulink as shown in Fig.8.

TABLE.I. PARAMETERS FOR SIMULATED EQUIVALENT CIRCUIT MODEL OF PC

Index	Vs (v)	F (Hz)	R_{SYS} (Ω)	L_{SYS} (mH)	C_{dc} (uF)	R (Ω)
Magnitudes	209.5	50	0.1	1	100	312

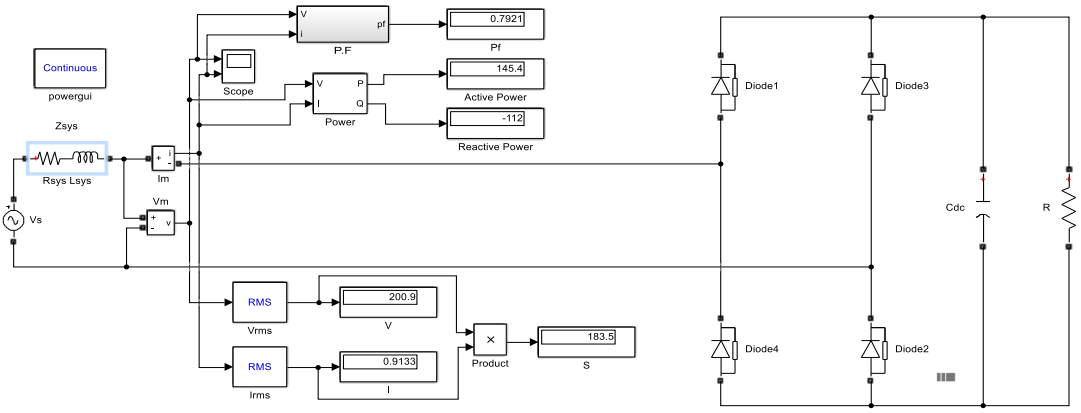

Figure 8. Simulation of equivalent circuit model of PC

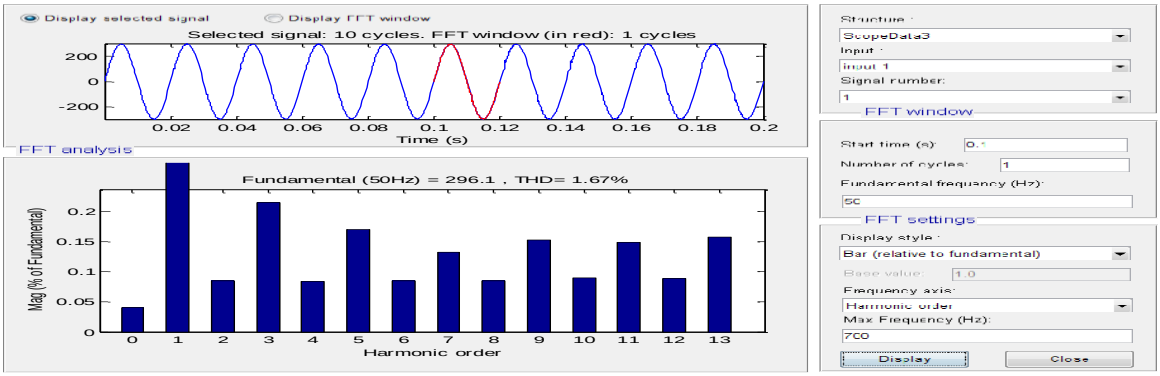

Figure 9. FFT of input supply voltage

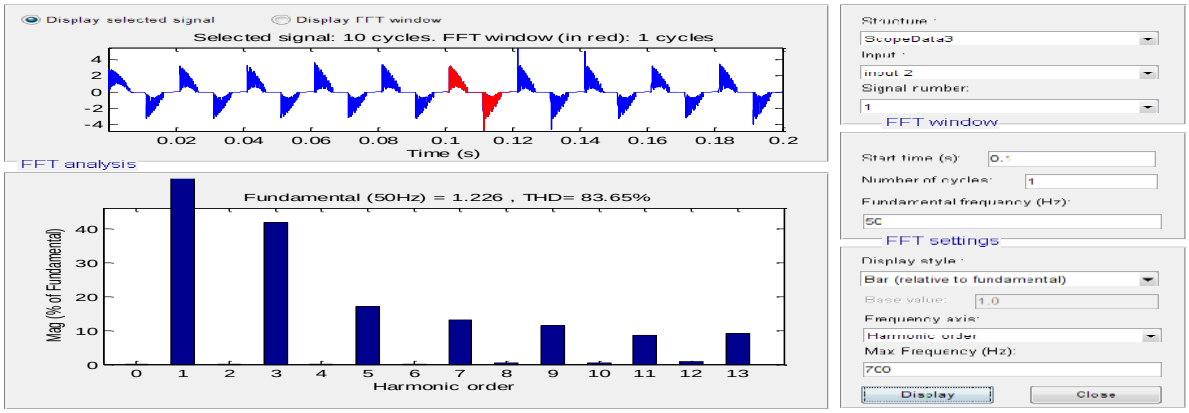

Figure 10. FFT of input supply current

TABLE.II. PARAMETERS FOR SIMULATED EQUIVALENT CIRCUIT MODEL OF PC

Index	Input Voltage (Volt)	Input Current (Ampere)	Active Power (Watt)	Reactive Power (Var)	Apparent power (VA)	Power Factor	THDv (%)	THD_i (%)
Experimental Measurements	209.5	0.870	140	118	183	0.77	1.6	84.7
Simulation Model Measurements	200.9	0.913	145.4	112	183.5	0.79	1.67	83.6

This research work compares simulations results with experimental measurements conducted on a PC load. Table. II listed experimental and simulation model results and shows almost both give same results, it means simulation model of equivalent SMPS of PC can be used to predict the behavior of actual PC under changing of above mentioned parameters.

III. MODELING OF FACTORS INFLUENCING TOTAL HARMONIC DISTORTION

In electrical power system the parameters as supply voltage, supply frequency and source impedance vary all the time. This research paper showing the effect of each one separately on the behavior of harmonic generation by varying in permissible limit. This section presents mathematical relationship of harmonics produced due to personal computer by different parameters.

A. Supply Voltage Variation

Almost every household consumer of electricity are faced variations in the supply voltage such as under voltage and over voltages for many reasons. In order to evaluate the influence of voltage variation on the harmonic distortion produced due to PC the supply voltage magnitudes vary in steps of 6V, ±5% of the 220V supply. Hence, THD_v and THD_i were obtained as shown in table.III.

TABLE.III. SIMULATION RESULTS OF VOLTAGE VARIATION

S.No	Voltage Variation (v)	THD_v (%)	THD_i (%)
1	206	1.32	75.29
2	213	1.61	82.65
3	220	1.43	78.63
4	227	1.30	74.59
5	234	1.95	91.50

For engineering applications, it is convenient method to show the THD_v and THD_i function with respect to supply voltage variation with mathematical expressions. For this purpose curve fitting toolbox of MATLAB is used.

Fig.11 and Fig.12 are obtained using curve fitting tool of MATLAB while mathematical relationship b/w THD_v and THD_i and the supply voltage are expressed in equations (2) and (3) respectively.

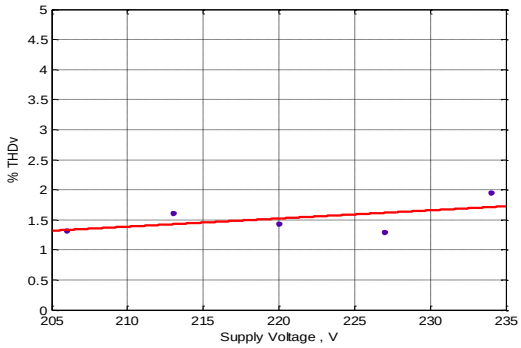

Figure 11. THD_v versus supply voltage variation

It can be seen from Fig.11 that supply voltage variation has a small influence on THD_v while increasing supply voltage from 220v cause increment in THD_i as shown in Fig.12 .

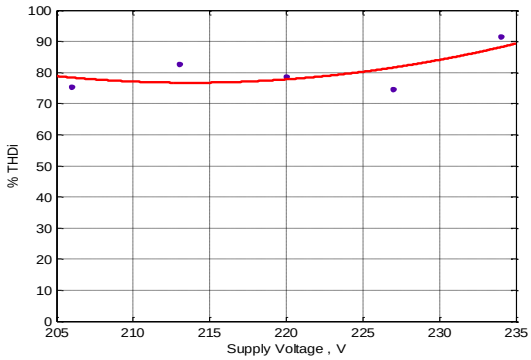

Figure 12. THD_i versus supply voltage variation

$$THD_v = 0.01357V - 1.464 \quad (2)$$

$$THD_i = 0.02781V^2 - 11.89V + 1347 \quad (3)$$

The significance of developing mathematical expression is that the THD can be determine at some other new value of supply voltage. e.g if supply voltage is 230v is put in equation number (3) and (4), the predicted THD_V and THD_i value is 1.65% and 83.44 % respectively.

B. Supply Frequency Variation

Disconnecting or removing large portion of loads from electrical power system and fault occurrences on transmission cause supply frequency change. The supply frequency changes from 49.50 to 50.50Hz meansns ±1% variations in frequency are occur and tolerable. Hence THD_V and THD_i were obtained as shown in table.IV.

TABLE.IV. SIMULATION RESULTS OF FREQUENCY VARIATION

S.No	Frequency Variation (Hz)	THD_v (%)	THD_i (%)
1	49.50	2.23	77.54
2	49.75	1.68	78.42
3	50	1.43	78.63
4	50.25	1.66	75.29
5	50.50	2.78	90.14

Similarly Fig.13 and Fig.14 are obtained using curve fitting tool of MATLAB while mathematical relationship b/w THD_v and THD_i and the supply frequency are expressed in equations 4 and 5 respectively.

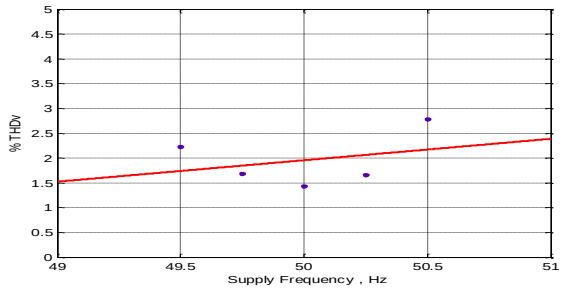

Figure 13. THD_v versus supply frequency variation

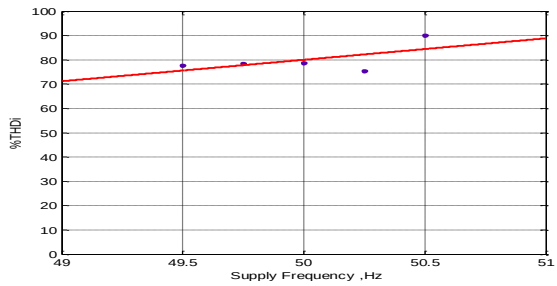

Figure 14. THD_i versus supply frequency variation

$$THD_v = 0.432F - 19.64 \quad (4)$$

$$THD_i = 8.828F - 361.4 \quad (5)$$

The change in supply frequency from under to over frequency has approximately no greater influence on the generated harmonics.

C. Source Impedance Variation

Source impedance magnitudes are different for every consumer depending on loading on electrical system and the distance of their particular load from the utility transformers and distribution cabinets.

When R_{sys} and L_{sys} values are set within permissible limit then source impedance values obtained as from 0.25Ω to 0.94Ω.Therefore THD_v and THD_i were obtained at these values of source impedance as shown in table.V.

TABLE.V. SIMULATION RESULTS OF SOURCE IMPEDANCE VARIATION

S.No	Source Impedance Variation (Ω)	THD_v (%)	THD_i (%)
1	0.25	1.70	77.55
2	0.32	2.05	79.30
3	0.48	2.63	81.38
4	0.55	2.89	82.79
5	0.63	3.14	82.86
6	0.79	3.56	84.00
7	0.94	3.99	84.58

Similarly Fig.15 and Fig.16 are obtained using curve fitting tool of MATLAB while mathematical relationship b/w THD_v and THD_i and the source impedance are expressed in equations 6 and 7 respectively.

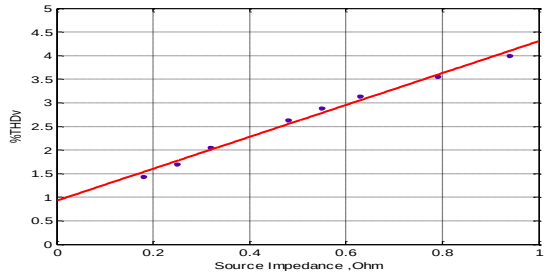

Figure 15. THD_v versus source impedance variation

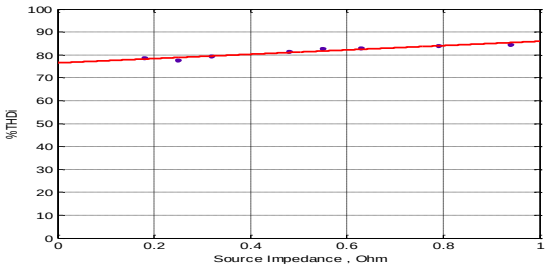

Figure 16. THD_i versus source impedance variation

$$THD_v = 3.376Z + 0.926 \quad (6)$$

$$THD_i = 9.428Z + 76.51 \quad (7)$$

From Fig.16 it is clear that increasing of source impedance in permissible range having small influence on THD_i while Fig.15 shows increasing source impedance greatly increased THD_v.

D. Source Impedance angle Variation

According to the location of consumer inside a building construction and the joints or connections of conductors inside electrical installation are primarily resistive. Therefore source impedance angle that is determined by inverse tangent ratio of (X/R) values might be dissimilar for different electrical sockets. Hence, a different set of X/R ratio angles carried out rather than source impedance magnitudes.

When R_{sys} and L_{sys} are set within permissible limit then the source impedance angle obtained are as from 8.9^0 to 80.9°. THD_v and THD_i were obtained at these values of source impedance angle as shown in table.VI.

TABLE.VI. SIMULATION RESULTS OF SOURCE IMPEDANCE ANGLE VARIATION

S.No	Source Impedance Angle (X/R) Ratio (Degree)	THD_v (%)	THD_i (%)
1	8.9	0.73	58.26
2	17.4	0.89	62.62
3	27.6	1.22	71.84
4	38.1	1.22	72.18
5	43.2	0.95	71.99
6	59.9	1.39	75.23
7	78.01	2.63	81.38
8	80.9	3.14	82.86

Similarly Fig.17 and Fig.18 are obtained using curve fitting tool of MATLAB while mathematical relationship b/w THD_v and THD_i and the source impedance angle are expressed in equations 8 and 9 respectively.

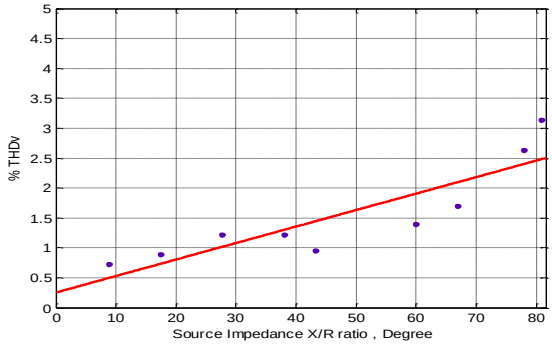

Figure.17. THD_v versus source impedance angle variation

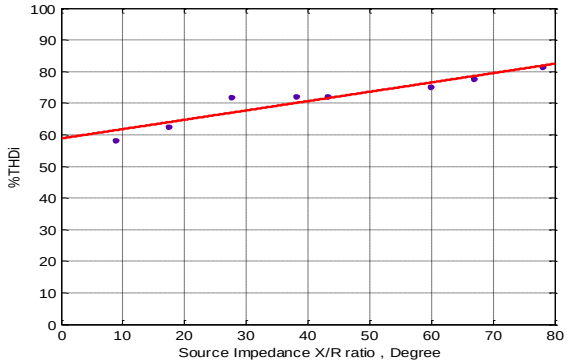

Figure.18. THD_i versus source impedance angle variation

$$THD_v = 0.02755(X/R)+0.2528 \quad (8)$$

$$THD_i = 0.2953(X/R)+ 58.85 \quad (9)$$

Fig.17 and Fig.18 shows that THD_v and THD_i values are increasing by increasing (X/R) ratio angle.

The experimental measurements and simulation model presented in this work and mathematical expressions from (2) to (9) help researchers and engineers to estimate harmonic distortion level precisely.

IV. CONCLUSION

Harmonic distortion is the major issue related to power quality of electrical power system. Nonlinear electronic load such as personal computer connected in electrical power distribution system produced significant amount of distortion that are not acceptable to limit specified by international standards. Accurate modeling of harmonic distortion generating devices and system parameters helps to quantify exactly their influence on harmonic distortion phenomena.

Experimental measurements along with simulation results of harmonic distortion due to personal computer load are presented and as simulink model of equivalent circuit model of personal computer have close results of harmonic distortion and power quantities to experimental measurements, therefore that simulink model be able to be used to predict the harmonics distortion due to actual personal computer by varying certain factors within practical limit. Therefore this work provides insight the behavior of harmonic distortion due to personal computer.

By Curve fitting technique the users or researcher can quantify and evaluate factors influencing harmonics distortion due to personal computer interms of mathematical expression. The scope of this work is that before installing filters to reduce harmonic distortion and increase efficiency of electrical power system as well as non linear load, we must know correct and precise harmonic distortion generating phenomena with respect to different factors.

This scheme offer an expansion for further explores new kind of non linear load connected collectively. It is also suggested that if certain parameters influence in any non linear load are not possible in actual hardware arrangement, then equivalently proper simulink model can be used for harmonic distortion assessment.

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