

POWER QUALITY ANALYSIS USING LabVIEW

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Abstract

In the present scenario the ever increasing existence of non linear loads and the increasing number of distributed generation power systems in electrical grids modify the characteristics of voltage and current waveforms in power systems, which differ from pure sinusoidal wave. The target of this paper is to design an accurate measurement system and display the system parameters under distorted system conditions. Harmonics, Sub Harmonics, and Inter Harmonics are measured and displayed using LabVIEW. The voltage and current are sensed using sensors for various loads, which are then interfaced with the PC using DAQ (Data Acquisition) card and displayed using LabVIEW. The Hardware implementation includes setting up of test systems such as diode bridge rectifier and thyristor based converter with various loads such as resistive, inductive and DC shunt motor. Experimental results obtained for various loads and source conditions are cross verified with theoretical analysis. The response obtained in hardware and simulation proves the effectiveness of the system.

Keywords: Data Acquisition, Power Quality, Harmonics, Sub harmonics and Inter harmonics

1. INTRODUCTION

Paragraph Over the recent years, there has been an increased emphasis and concern for the quality of power delivered. This concern for the quality of power has increased due to the considerable usage of non linear loads such as adjustable-speed drives, arc furnaces, switched mode power supplies, electronic ballasts etc. The harmonics created by these non-linear loads are non-sinusoidal in nature, which leads to poor power factor, low system efficiency and other power quality issues. Power quality is defined in the Institute of Electrical and Electronics Engineers IEEE standard terms as “the concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment.” Most of the important international standards define power quality as the physical characteristics of the electrical supply provided under normal operating conditions that do not disrupt or disturb the customer’s processes. Therefore, power quality problem exists if any voltage, current or frequency deviation results in failure or in bad operation of customer’s equipment. Normally problems like surges, poor voltage, frequency regulations, voltage switching transients, electrical noise, power loss and Electro-Magnetic Interference effects are frequently encountered in the load side. This leads to damage of capital-intensive appliances, safety concerns of the load, loss of reliability of the power electronic devices and a huge economic loss, which affects the power quality. The main causes of the poor power quality are Power supply failures, malfunctioning of power electronic equipments, over heating on the load side, loss of reliability, increase of losses in the system. Power quality parameters include real power, reactive power, apparent power, harmonics distortion, distortion power factor, displacement power factor, Crest factor and net source power factor.

Jing Chen, Tianhao Tang [4] had proposed use of LabVIEW software platform for power quality detection and interpreted system characteristics harmonic detection, voltage, current waveforms which includes their deviations.

Shahedul Haque Laskar [2] had surveyed different existing methods of power quality monitoring which is already in use which includes all existing technologies involved in the field of power quality monitoring.

H.E Wenhai[8] had developed a new noise test system which comprises the testing technology, the computer technology and the network technology based on virtual instrument technology. Using data acquired card (DAQ card) we can acquire and generate signals such as voltage, current, noise, temperature etc, so the total test system is more economical.

S. K Bath, Sanjay Kumra [1] had gathered information about system parameters which is then measured and simulated using LabVIEW as distorted power waveforms to know the amount of harmonics and distortion in the system, so that appropriate actions are taken to reduce development time and harmonics and to design higher quality products.

Qiu Tang, Zhaosheng Teng, Siyu Guo and Yaonan Wang [5] had designed a multifunctional Virtual monitoring system which monitors the power quality and then implemented in LabVIEW environment. The root mean square (RMS) value, the waveforms of current and voltage, current and voltage crest factor, the harmonic components, the total harmonic distortion (THD) waveforms of the voltage and current signals can be calculated and displayed in the system.

LabVIEW is a programming language used for acquiring signal, data presentation and measurement analysis. The LabVIEW platform provides models and specific tools to solve applications ranging from signal processing algorithms to voltage measurements, targeting number of platforms interfacing desktop and embedded devices. Virtual instruments represent a traditional hardware-centered system to software centered systems that exploit connectivity capabilities of workstations and desktop computers. Computing power display and productivity LabVIEW is easy to incorporate with the new LabVIEW applications into the existing systems without losing hardware information. NI LabVIEW software has more than 600-700 built functions for frequency analysis, signal synthesis, mathematical functions, probability and statistics, interpolation, curve fitting and many more.

2. SIMULATION RESULTS

Paragraph Measure and display the following system parameters under distorted system conditions (Harmonics, Sub Harmonics, and Inter Harmonics)- RMS Voltage V_{rms} , RMS Current I_{rms} , Total Harmonic Distortion (THD), Real Power, Reactive Power, Apparent Power, Distortion Power, Distortion Power Factor, Displacement Power Factor, Net Source Power Factor, Voltage Crest Factor, Current Crest Factor, I_{peak} and V_{peak} is the objective of the work.

The above system parameters are simulated using LabVIEW software under normal and distorted conditions. These parameters are simulated and cross verified analytically.

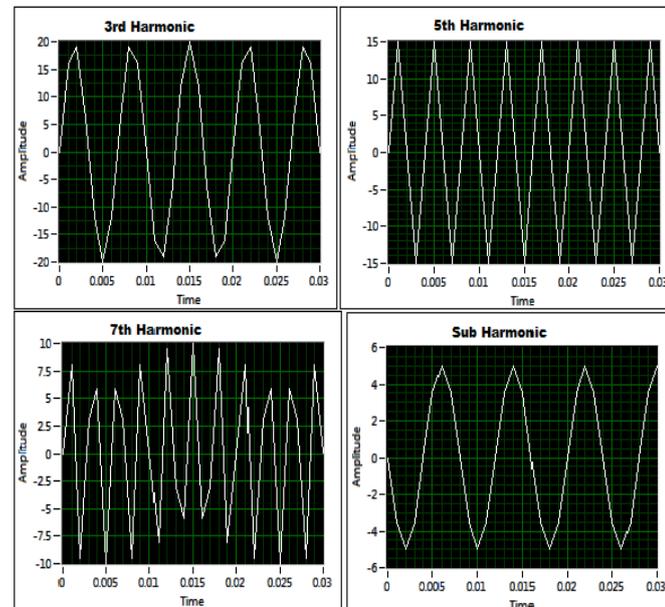


Fig -1: Harmonic Currents

Consider the nonlinear system which takes source currents consisting of following harmonics

Third Harmonic $I_2 = 20\sin(6\pi ft)$, $f=150\text{Hz}$,

Fifth Harmonic $I_3 = 15\sin(10\pi ft)$, $f=250\text{Hz}$,

Seventh Harmonic $I_4 = 10\sin(14\pi ft)$, $f=350\text{Hz}$,

Sub Harmonic $I_5 = 5\sin(5\pi ft)$, $f=125\text{Hz}$

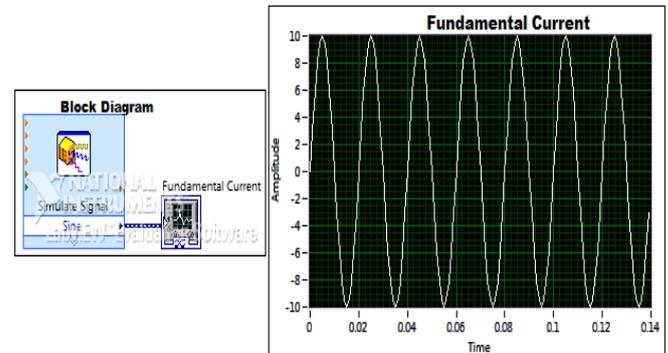


Fig -2: Fundamental Current

The above figure include, Fundamental Current $i=10\sin(\omega t)$, Frequency = 50Hz, Samples=1000/s, No of samples=140 Time Period =20m/s

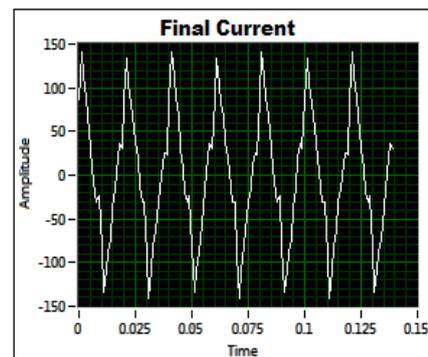


Fig -3: Total Instantaneous Current

$$\text{Total instantaneous Current} = i_1 + i_2 + i_3 + i_4 + i_5 = 100\sin(100\pi t - 60^\circ) + 20\sin(300\pi t) + 15\sin(500\pi t) + 10\sin(700\pi t) + 5\sin(250\pi t) \quad (1)$$

Three Test Cases are taken where case (1) includes no phase difference between source current and source voltage, case (2) includes source current lags source voltage by 30 degrees and (3) source current leads source voltage by 60 degrees. For each case the results obtained for the above system parameters are cross verified mathematically. The simulated results and mathematically obtained are tabulated below for each case.

Case (1):

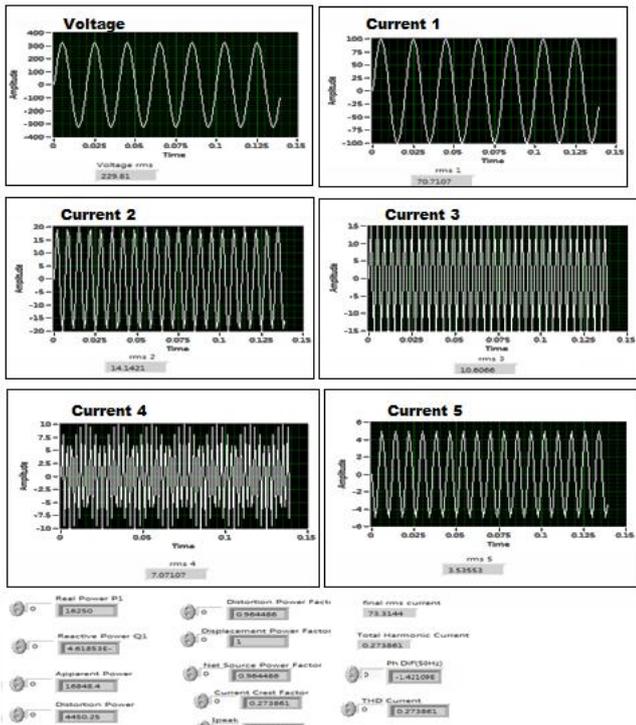


Fig-4. Case (1) :Simulated Output- Voltage and Currents are inphase

Case (2):

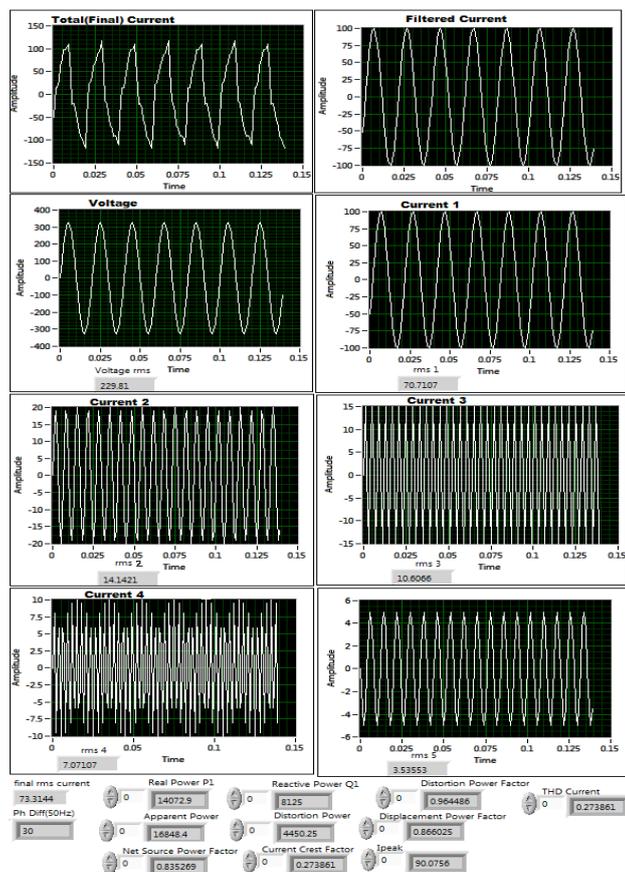


Fig-5. Case 2(i)- Simulated Output when Current Lags Voltage by 30°

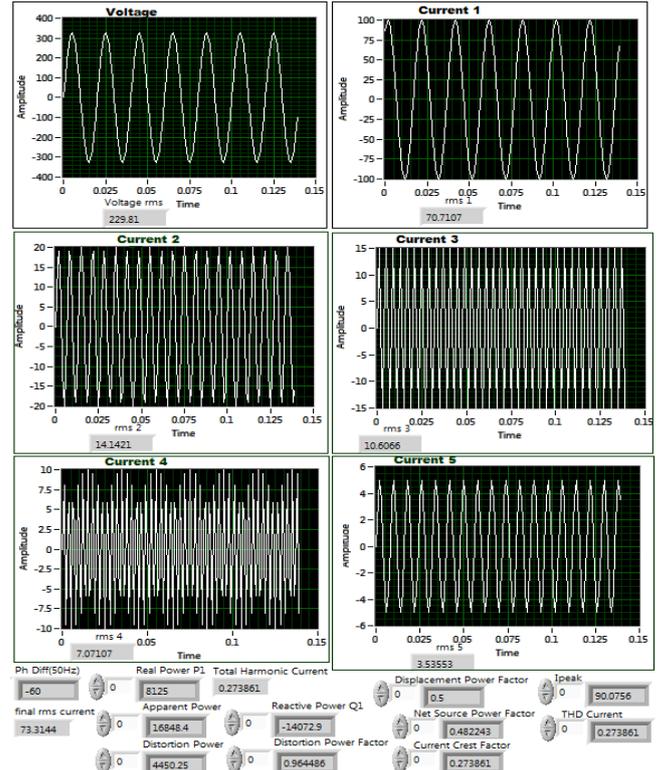


Fig-6. Case 2(ii)-Simulated Output when Current Leads Voltage by 60°

Case (3)

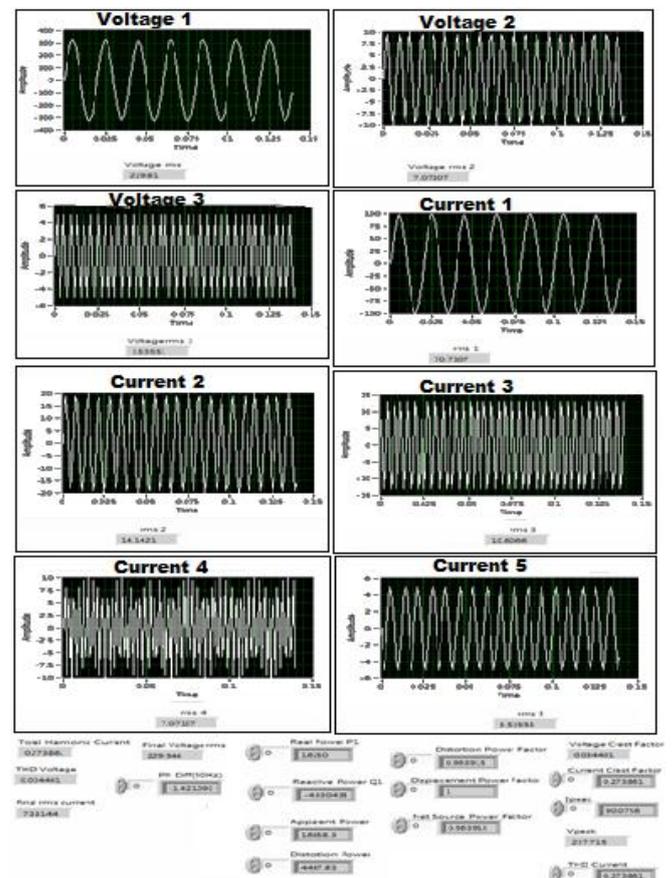


Fig-7. Case (3)-Simulated Output- Introducing Distortion in Voltage Waveforms

Table -1: Comparison of Simulated Results with results after Theoretical Verification

	System Parameters	Simulated Results	Results after Verification
	RMS Voltage	229.81	229.80 V
	RMS Current for Fundamental	70.7107	70.71 A
	RMS Current for 3 rd Harmonic	14.1421	14.14 A
	RMS Current for 5 th Harmonic	10.6066	10.60 A
	RMS Current for 7 th Harmonic	7.07107	7.07 A
	RMS Current for Sub-Harmonic	3.53553	3.53 A
CASE(1) V and I in phase ($\phi=0$)	THD Voltage	0 V	0 V
	THD Current	0.27386A	0.27 A
	Real Power	16250 W	16.249 KW
	Reactive Power	0 KVAR	0 KVAR
	Apparent Power	16848.4VA	16.938KVA
	Distortion Power	4440.25VAD	4812 VAD
	Distortion Power Factor	0.964	0.96
	Displacement Power Factor	1	1
	Net Source Power Factor	0.964	0.96
	Voltage Crest Factor	0	0
	Current Crest Factor	0.2738	0.27
	Ipeak	80A	89.94A
Case (2) I lags V by 30°	Vpeak	229.804V	229.80V
	THD Voltage	0V	0V
	THD Current	0.2738A	0.27A
	Real Power	16250W	16.072 KW
	Reactive Power	8.12KVAR	8.124KVAR
	Apparent Power	16848.4 VA	16.938KVA
	Distortion Power	4450.125 VAD	4812 VAD
	Distortion Power Factor	0.964	0.96
	Displacement Power Factor	1	0.86
	Net Source Power Factor	0.964	0.82
	Voltage Crest Factor	0	0
	Current Crest	0.273	0.27

	Factor		
	Ipeak	90.07A	89.94A
	Vpeak	229.81V	229.80V
Case (2) I leads V by 60°	THD Voltage	0V	0V
	THD Current	0.2738A	0.27A
	Real Power	18223W	18.124 KW
	Reactive Power	0KVAR	0KVAR
	Apparent Power	16848.4 VA	16.938KVA
	Distortion Power	4450.125 VAD	4579 VAD
	Distortion Power Factor	0.964	0.96
	Displacement Power Factor	0.5	0.86
	Net Source Power Factor	0.964	0.82
	Voltage Crest Factor	0	0
	Current Crest Factor	0.273	0.27
		Ipeak	90.07A
	Vpeak	229.81V	229.80V
Case(3)	THD Voltage	0.03V	0.034V
	THD Current	0.2738A	0.27A
	Real Power	16250W	16.249 KW
	Reactive Power	0KVAR	0KVAR
	Apparent Power	16050.3 VA	16.856KVA
	Distortion Power	4487.83 VAD	4812 VAD
	Distortion Power Factor	0.936	0.9639
	Displacement Power Factor	1	1
	Net Source Power Factor	0.96	0.96
	Voltage Crest Factor	0.034	0.034
	Current Crest Factor	0.273	0.27
		Ipeak	90.07A
	Vpeak	229.81V	237.61V

2. HARDWARE IMPLEMENTATION

Test System I is selected as 3 ϕ , 400V, 50Hz sinusoidal supply connected to 3 ϕ diode bridge rectifier feeding

- i. Resistive Load
- ii. RL Load
- iii. DC Shunt Motor

Test System II is selected as 3 ϕ , 400V, 50Hz sinusoidal supply connected to 3 ϕ thyristor converter feeding

- i. Resistive Load
- ii. RL Load

Block Diagram

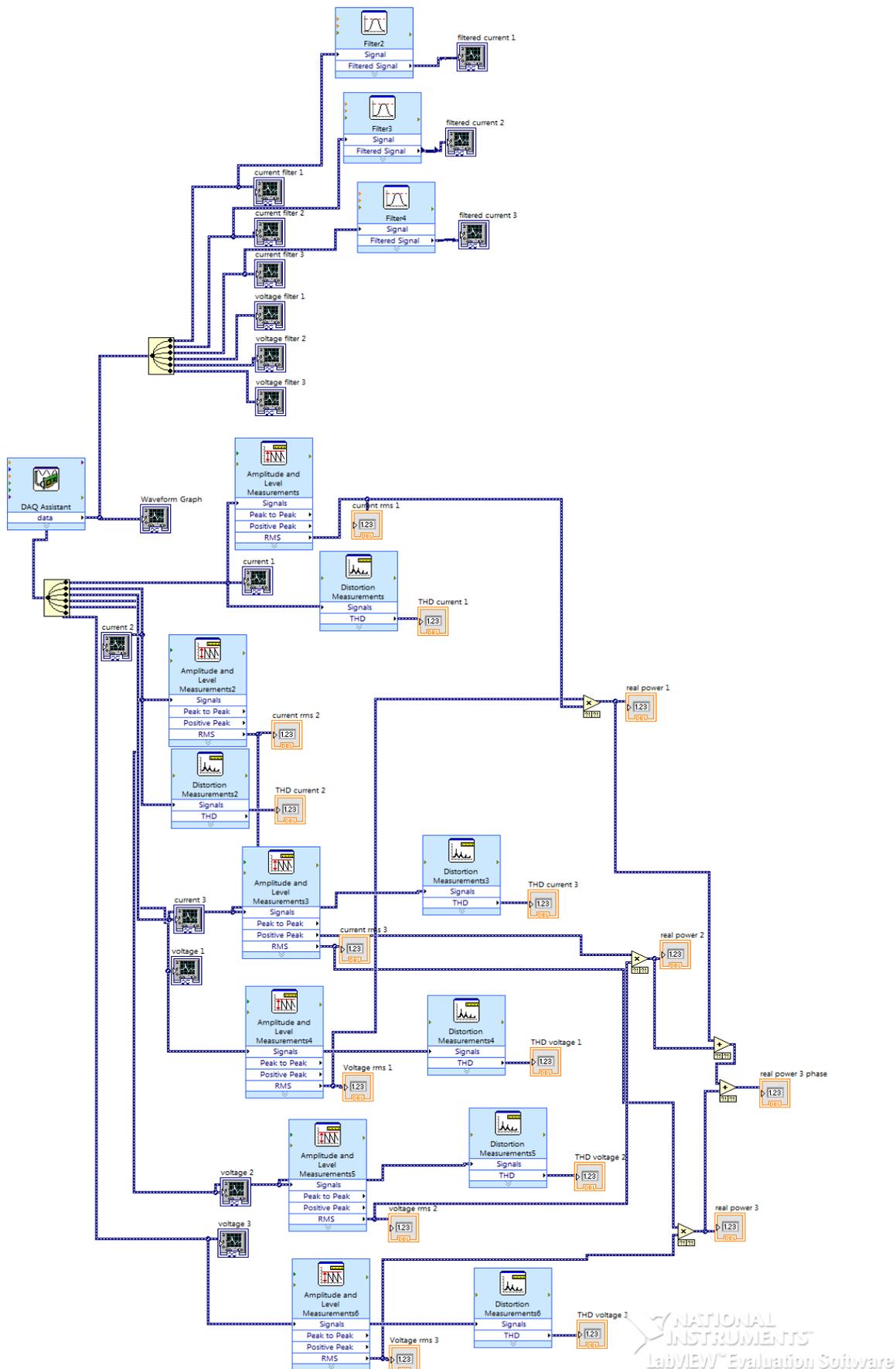


Fig-8. Block Diagram for Test Cases 1 and 2

2.1 Test System 1

The connection diagram for test System I is selected as 3 ϕ , 400V, 50Hz sinusoidal supply connected to 3 ϕ diode bridge rectifier feeding various loads is shown in Fig 9.

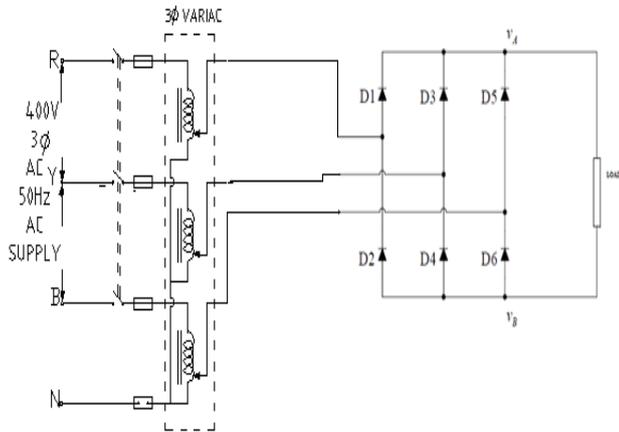


Fig-9. Equivalent Circuit for 3 ϕ Diode Bridge Rectifier with loads

2.1.1 Simulated Result-3 ϕ Diode Bridge Rectifier Feeding

2.1.1.1 Resistive Load

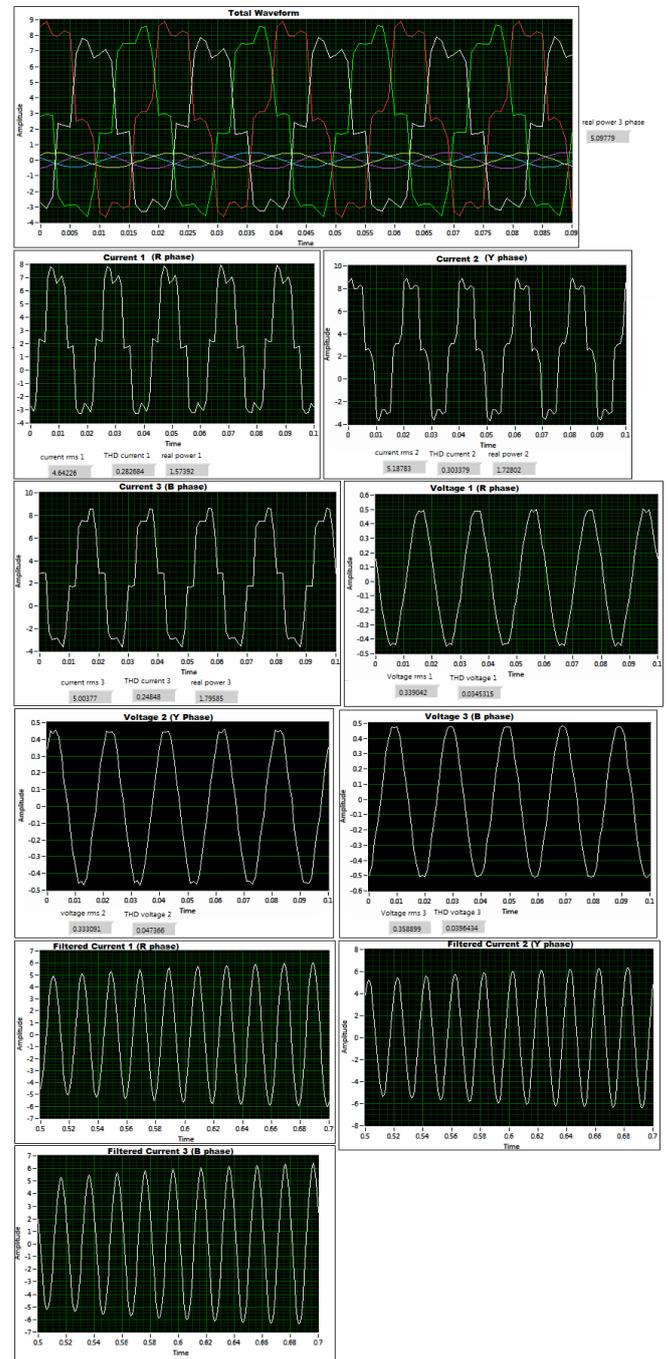


Fig-10 Simulated Output- 3 ϕ Diode Bridge Rectifier feeding Resistive Load

The results obtained after simulation for test system (I) for 3 ϕ diode bridge rectifier feeding resistive load is shown below in Table 2. Here a resistor value of 100ohm 5A is used which resist the RMS currents up to 5A. The THD values of voltages are found to be lesser than that of currents as no harmonics are induced in voltage waveforms. Fig 10 displays the simulated output obtained using LabVIEW.

Table 2: Simulated Results of obtained for 3 ϕ Diode Bridge Rectifier feeding Resistive Load

	System Parameters	Simulated Results
R Phase	Voltage RMS	0.3390 V
	Current RMS	4.6422 A
	THD Current	0.2826 A
	THD Voltage	0.0345 V
	Real Power	1.5739 W
Y Phase	Voltage RMS	0.330 V
	Current RMS	5.1878 A
	THD Current	0.3033 A
	THD Voltage	0.0473 V
	Real Power	1.7280 W
B Phase	Voltage RMS	0.3588 V
	Current RMS	5.0037 A
	THD Current	0.2484 A
	THD Voltage	0.039 V
	Real Power	1.7958 W
TOTAL REAL POWER		5.0977 W

2.1.1.2 RL Load

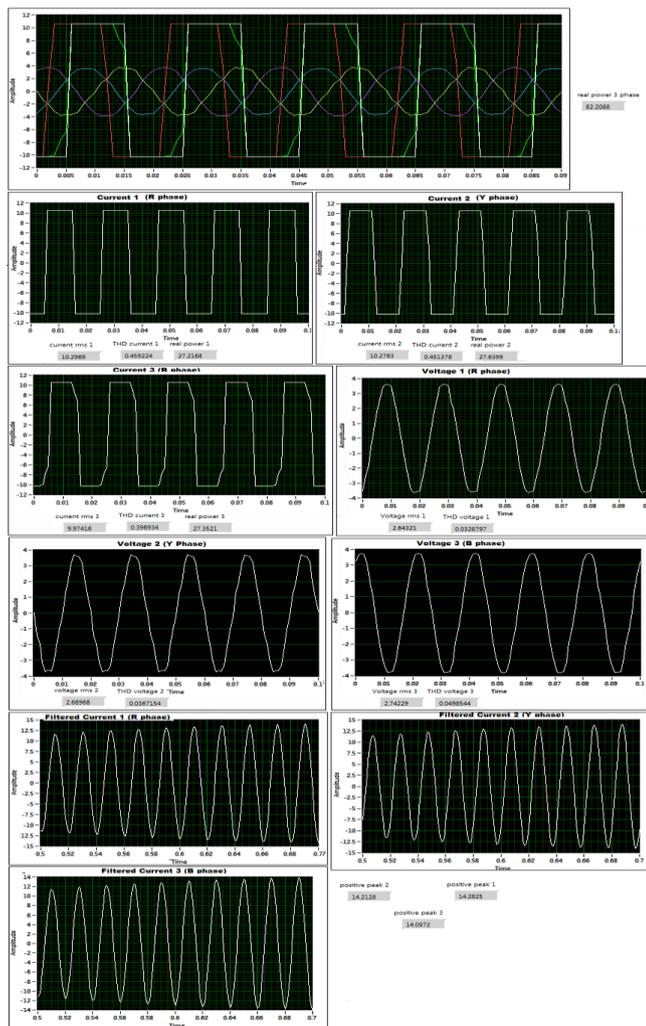


Fig-11 Simulated Output- 3 ϕ Diode Bridge Rectifier feeding RL Load

Fig 11 displays the simulated output of 3 ϕ Diode Bridge Rectifier feeding RL Load Here the values of Resistor and Inductor are selected as R=100ohm, 5A L=390mH. The results obtained after simulation for test system(I) for 3 ϕ diode bridge rectifier feeding DC shunt motor load is shown below in Table 3. Here an inductor value of 390mH is used. As charging and discharging is involved in inductor the time constant will be more for a RL load.

Table 3: Simulated Results for 3 ϕ Diode Bridge Rectifier feeding RL Load

	System Parameters	Simulated Results
R Phase	Voltage RMS	2.6432 V
	Current RMS	10.2069 A
	THD Current	0.4592 A
	THD Voltage	0.032 V
	Real Power	27.2168 W
Y Phase	Voltage RMS	2.6896 V
	Current RMS	10.2763 A
	THD Current	0.4513 A
	THD Voltage	0.0367 V
	Real Power	27.6398 W
B Phase	Voltage RMS	2.7422 V
	Current RMS	9.9741 A
	THD Current	0.3969 A
	THD Voltage	0.0498 V
	Real Power	27.3921 W
TOTAL REAL POWER		82.2487 W

2.1.1.3 DC Shunt Motor

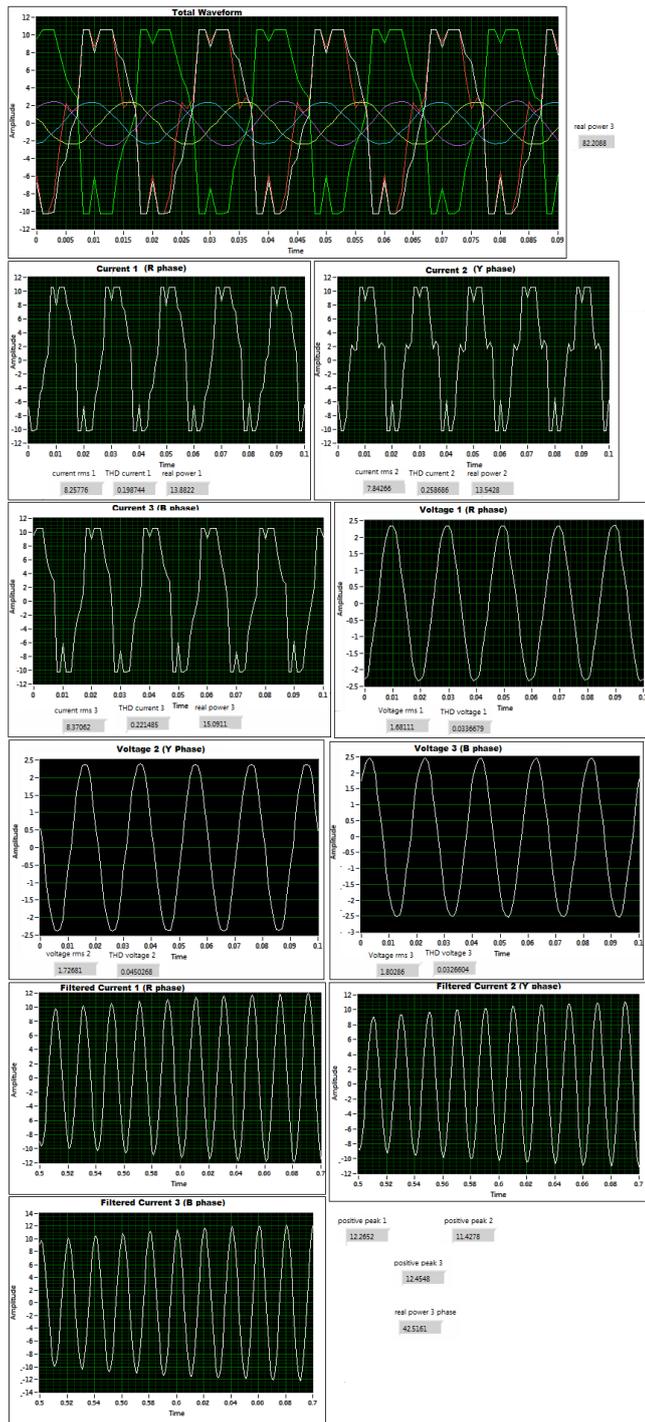


Fig-12 Simulated Output- 3ϕ Diode Bridge Rectifier feeding DC Shunt Motor

The results obtained after simulation for test system (I) for 3ϕ diode bridge rectifier feeding DC shunt motor load is shown below in Table 4. The simulated output of 3ϕ diode bridge rectifier feeding DC shunt motor load is displayed in Fig 12. The output of the diode bridge rectifier is connected to the armature of the DC shunt motor. The DC supply is given to the shunt motor. The speed can be controlled by armature voltage controller.

Table 4: Simulated Results 3ϕ Diode Bridge Rectifier feeding DC Shunt Motor

	System Parameters	Simulated Results
R Phase	Voltage RMS	1.6811 V
	Current RMS	8.2577 A
	THD Current	0.1987 A
	THD Voltage	0.022 V
Y Phase	Real Power	13.88 W
	Voltage RMS	1.7268 V
	Current RMS	7.8426 A
	THD Current	0.2586 A
B Phase	THD Voltage	0.045 V
	Real Power	13.5428 W
	Voltage RMS	1.8028 V
	Current RMS	8.3706 A
TOTAL REAL POWER	THD Current	0.2214 A
	THD Voltage	0.0326 V
	Real Power	15.0911 W
TOTAL REAL POWER		42.5161 W

2.2 Test System II

Connection Diagram

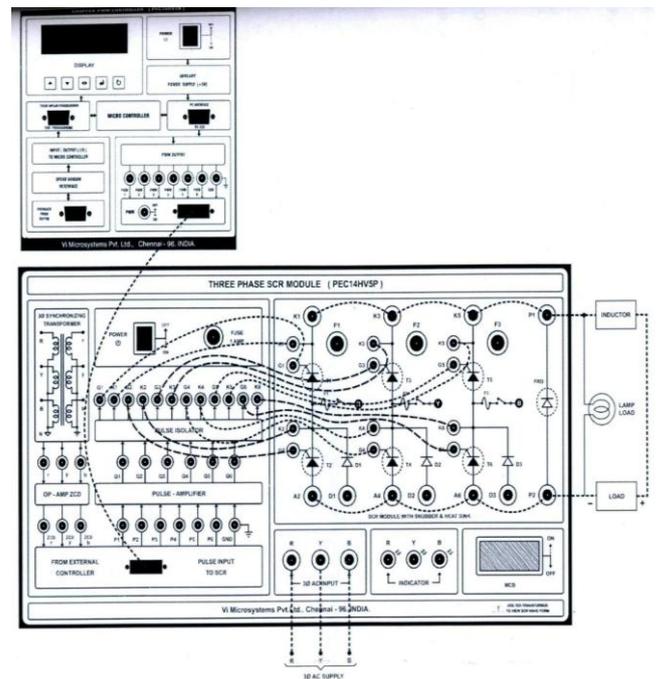


Fig-13 Connection Diagram- Test system II

2.2.1 Simulated Result-3ϕ Thyristor Converter Feeding Resistive Load

Test System II is selected as 3ϕ, 400V, 50Hz sinusoidal supply connected to 3ϕ thyristor converter feeding Resistive Load of 230ohm, 1.7Ampere is shown in Fig.14.

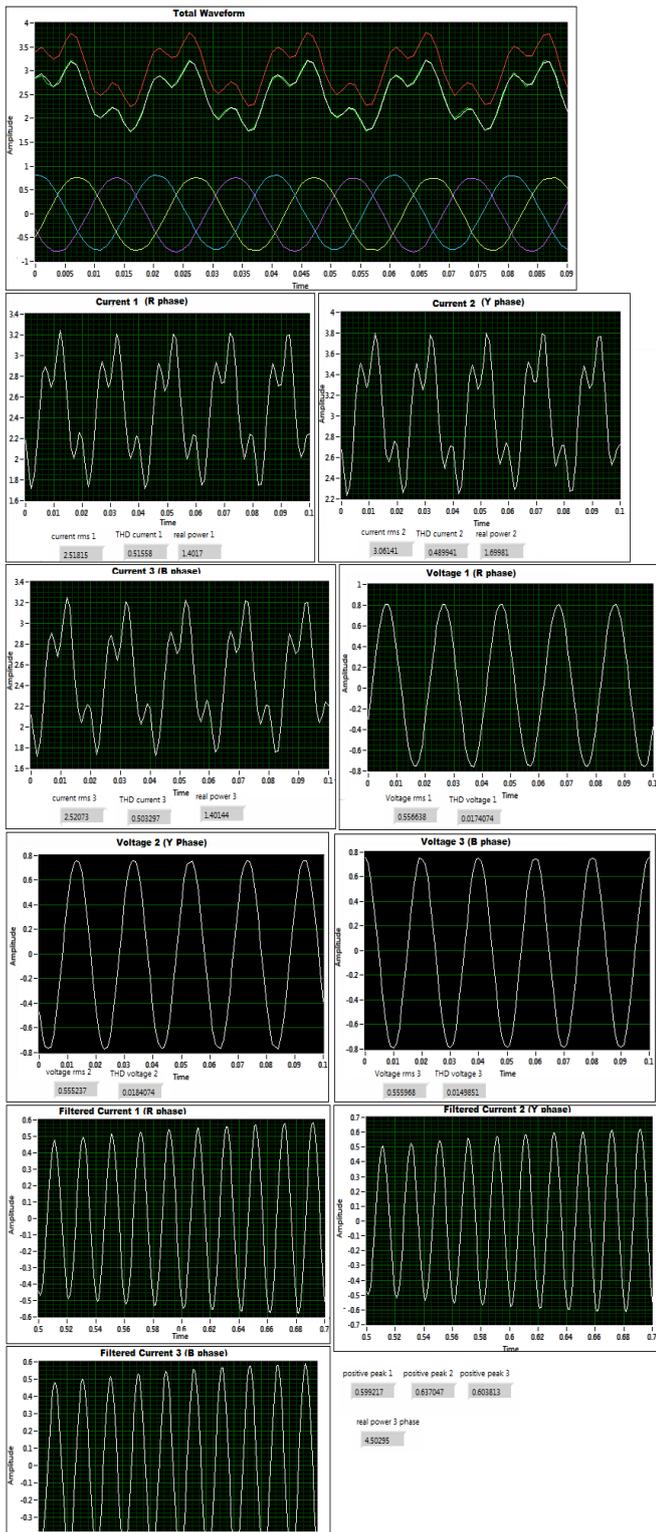


Fig-14 Simulated Output- 3 ϕ Thyristor Converter feeding Resistive Load

The results obtained after simulation for test system(II) for 3 ϕ Thyristor Converter feeding Resistive Load is shown below in Table 5. The SCR's are triggered at $\alpha=45^\circ$ and it allows the current to flow through the circuit in forward-biased condition and reversed- biased condition. The resistive load used here resists the current up to 3A.

Table 5: Simulated Results- 3 ϕ Thyristor Converter feeding Resistive Load

	System Parameters	Simulated Results
R Phase	Voltage RMS	0.5566 V
	Current RMS	2.5181 A
	THD Current	0.5155 A
	THD Voltage	0.0174 V
	Real Power	1.4017 W
Y Phase	Voltage RMS	0.5552 V
	Current RMS	3.061 A
	THD Current	0.4899 A
	THD Voltage	0.0184 V
B Phase	Voltage RMS	0.5559 V
	Current RMS	2.5207 A
	THD Current	0.503 A
	THD Voltage	0.0149 V
TOTAL REAL POWER		4.5029 W

3. CONCLUSION AND FUTURE WORK

Non-linear loads introduce harmonics that has many undesirable effects such as increased losses, thermal stress and reduced lifetime of the equipment on the power system. Hence power quality analysis / monitoring should be done in any system to avoid undesirable effects due to harmonics and also avoid some of the factors such as electromagnetic compatibility, voltage sag, flickers, transients, notching and interruptions. A background study of the graphical programming tool LabVIEW on power quality analysis is done. LabVIEW program for power quality analysis is formulated and its performance is verified with non-linear loads- 3 ϕ Diode Bridge Rectifier fed R-load, 3 ϕ Diode Bridge Rectifier fed DC shunt motor and 3 ϕ Diode Bridge Rectifier fed RL-load and 3 ϕ Thyristor converter fed R Load. The obtained results were verified with theoretical calculations.

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