

# Signal Analysis of Various Filters for Voltage and Current Level Measurement in Series or Parallel RLC Resonant circuits on Hyper Spectral Data Magnification

Dr.T.Arumuga Maria Devi, Mr.D.Muthukumar, Dr.P.Kumar

**Abstract**—Measurement is an act or the result of evaluation between the quantity and a predefined standard by means of Voltage/Current through HyperSpectral Analysis. Electrical measurements are the methods, devices and calculations used to measure electrical quantities. Measurement of electrical quantities may be done to measure electrical parameters of a system. Specifying a voltage measurement wants explicit or implicit specification of the points across which the voltage is measured. Whichever two points with the same potential may be connected by a conductor and no current will flow among them. Voltage and Current measurement or monitoring within electronic circuitry is a common requirement covering various types of applications. These may include anything from portable, handheld equipment through to automotive applications. The Current Measurement block is used to measure the instantaneous current flowing in any electrical block or connection line. The Voltage Measurement block measures the prompt voltage between two electric nodes. An electric current is a flow of electric charge. In electric circuits this charge is often carried by moving electrons in a wire. Electric current is measured using Series/Parallel RLC resonant circuits using MATLAB Simulink graphical representation. In the future work, the different level voltage circuits data will be tested with Hyperspectral data processing which is used to find out the accurate voltage magnification difference and analyze through signal processing.

**Keywords**— Electrical quality measurement, Current, Voltage, RLC resonant circuits, MATLAB/Simulink, Electric charge, graphical representation, Resistance.

## 1. INTRODUCTION

A RLC circuit is an electrical circuit [1] containing of a resistor, an inductor, and a capacitor, connected in series or in parallel. The circuit forms a harmonic oscillator for current and will resonate in a similar way as an LC circuit. Introducing the resistor (R) helps decay these oscillations. This effect of the resistor is called damping. The resistor also reduces the peak resonant frequency. A number of resistance is necessary in real circuits even if a resistor is not exactly included as a component. The ideal LC or RLC circuit [2] assumes zero resistance from the connecting conductors.

There are several applications for this circuit. They are used in various different types of oscillator circuits. An RLC circuit [3] can be used as a band-pass filter, band-stop filter, low-pass filter or high-pass filter. The tuning application, for instance, is an example of band-pass filtering. The RLC filter is defined as a second-order circuit, meaning that any voltage or current in the circuit can be defined by a second-order differential equation in circuit analysis. An essential property of this circuit is its capability to resonate at a specific frequency, the resonance frequency,  $f_0$ . Frequencies are measured in units of hertz. In this work, angular frequency,  $\omega_0$ , is used which is more mathematically convenient. This is measured in radians per second. They are related to each other by a simple proportion.

$$\omega_0 = 2\pi f_0 \dots\dots\dots (1)$$

Resonance is well-defined as the condition [4] in a circuit covering at least one inductor and one capacitor, when the supply voltage and the supply current are in phase. Thus, at resonance the equivalent impedance of the circuit is purely resistive. Meanwhile the supply voltage

and supply current are in phase, the power factor of a resonant circuit [5] is unity. At resonance the circuit impedance Z and the admittance Y are real quantities. Voltage magnification is reinforcement of an applied AC voltage due to resonance. There must be some capacitance and some inductance in a circuit that produces voltage magnification. The relation of voltage across L or C and the supply voltage is named the voltage magnification. That is,

Voltage magnification = voltage across L at resonance/supply voltage at resonance =  $V_{L0}/V$  Also,  
 Voltage magnification = voltage across C at resonance/supply voltage at resonance =  $V_{C0}/V$   
 At resonance,  $V = V_{R0}$  ..... (2)  
 $V_{L0}/V = V_{L0}/V_{R0} = X_{L0}I_0/RI_0 = X_{L0}/R = \omega_0L/R = Q_0$   
 $V_{C0}/V = V_{C0}/V_{R0} = X_{C0}I_0/RI_0 = X_{C0}/R = X_{L0}/R = \omega_0L/R = Q_0$

Hence, for a series resonant circuit the factor  $Q_0$  is a measure of the voltage magnification. For a series RLC circuit Quality of Service (QOS) can be establishing in terms of R, L and C as follow:

$$QOS = \omega_0L/R = 1/\sqrt{LC} \times L/R \times 1/R \sqrt{L/C} \dots\dots\dots (3)$$

The outcome of voltage magnification in series resonant circuit requirement is considered in the selection of circuit components. Current Magnification is at resonance in a parallel circuit, the branch current may be several times greater than the supply current.

Current magnification =  $I_C/I$   
 $= I_L \sin \Phi_L / I_L \cos \Phi_L = \tan \Phi_L = \omega_0L/R$

= Q-factor of the circuit at resonance =  $Q_0$ ..... (4)  
 Thus, Q-factor [6] is a measure of current magnification in a parallel resonant circuit.

*Hyperspectral data analysis:*

Hyperspectral images give ample spectral information to identify and distinguish spectrally similar Circuit data for more accurate and detailed information extraction. Widespread range of advanced classification methods are available based on spectral information and spatial information[7]. To improve classification accuracy it is essential to identify and decrease uncertainties in image processing chain. Due to continuity of bands and narrow sampling bandwidth it becomes possible to put on several mathematical methods, such as derivative analysis and continuum removal [8] which are pre-requisite for spectral feature recovery and characterization. Main challenges in Hyperspectral data processing[9] include noise reduction, recovery of subtle absorption features, spectral matching analysis, classification and creation of library spectra that can guide spectral classification. Hyperspectral data is frequently stated many ways to better describe the mathematical handling of the data; generally as a vector of pixels when referring to the data in a space or a matrix of pixels when referring to data as an image. Hyperspectral data examined like an image will be well-defined as a matrix  $M_{m \times n \times p}$  of dimension  $m \times n \times p$  where  $m$  is defined as the number of rows in the image,  $n$  is defined as the number of columns in the image, and  $p$  is defined as the number of bands in the image. Hence, a single element of such an image will be accessed using  $M_{i,j,k}$  and a single pixel of an image will be accessed using  $M_{i,j}$ . Hyperspectral data formed as a vector of vectors (i.e. 2D matrix) is defined as  $M_{(m \cdot n) \times p}$  of dimension  $(m \cdot n) \times p$ . Single element is read using  $M_{i,j}$  and a single pixel is accessed using  $M_{:j}$ . Notice the multi-element notation is consistent with MATLAB this is purposeful.

The list below provides a summary of the notation convention used throughout this code.

- M Data matrix. Defined as an image of spectral signatures or vectors:
- $M_{m \times n \times p}$ . Or, defined as a long vector of spectral signatures:
- $M_{(m \cdot n) \times p}$ .
- N The total number of pixels. For example  $N = m \cdot n$ .
- m Number of rows in the image. n Number of columns in the image. p Number of bands.

**II. ELECTRICAL CIRCUIT ANALYSIS IN MATLAB SIMULINK TO FIND THE VOLTAGE AND CURRENT LEVEL CHANGES**

Computer Simulation acts a vital role in the analysis and design of power electronic circuits and systems. The simulation not only validates the system's operation but also permits optimization of the system's performance by iteration of its parameters. Furthermore control and circuit parameters, the signal parameter variation can be studied. Hence, valuable time is saved in design and development of a product. Simulation software's are used to calculate the circuit waveforms, the steady state and

dynamic performance of the systems, and the ratings of the various components used in the circuit.

Simulink is a powerful graphical user-interface to MATLAB [10] which lets dynamic systems to be defined in an easy block diagram form. A library of function blocks, such as sources, sinks, discrete, linear, non-linear and connections can be used in the simulation. Simulink is a block diagram environment for multi domain simulation and Model-Based Design. It provides system-level design, simulation, automatic code generation, and continuous test and verification of embedded systems. Simulink provides a graphical editor, customizable block libraries, and solvers for modeling and simulating dynamic systems. It is combined with MATLAB [11], allowing to incorporate MATLAB algorithms into models and export simulation results to MATLAB for further analysis.

*A) Sim Power System*

SimPower Systems models can be used to develop control systems and test system-level performance. It can parameterize models using MATLAB variables and expressions, and design control systems for electrical power system in Simulink. SimPower Systems offers component libraries and analysis tools for modelling and simulating electrical power systems. The libraries contain models of electrical power components, including three-phase machines, electric drives, and components for applications such as flexible AC transmission systems.

*B) Measuring Voltages and Currents*

When measure a current using a Current Measurement block, the positive direction of current is indicated on the block icon such as positive current flowing from + terminal to -terminal. Also, when measure a voltage using a Voltage Measurement block, the measured voltage is the voltage of the + terminal with respect to the -terminal. The electrical state variables are the Simulink states of diagram related to the capacitor and inductor devices of the SimPower Systems blocks. Inductors and capacitors elements are found in the RLC-branch type blocks such as the Series RLC Branch block. The electrical state variables consist of the inductor current sand the capacitor voltages.

*C) Filtering Data using Signal Processing Toolbox*

Signal Processing Toolbox provides industry-standard algorithms for analog and digital signal processing (DSP). Using this toolbox to visualize signals in time and frequency domains, compute FFTs for spectral analysis, design FIR and IIR filters, and implement convolution, modulation, resampling, and other signal processing techniques. The command, `sptool`, opens SPTool, a suite of four tools: Signal Browser, Filter Design and Analysis Tool, FVTool, and Spectrum Viewer. These tools provide access to many of the signal, filter, and spectral analysis functions in the toolbox.

The Signal Browser (Fig.1), allows to view, measure, and analyze the time-domain information of one or more signals. The Filter Design and Analysis Tool permits to design and edit FIR and IIR filters. The Filter Visualization Tool (Fig.2) allows viewing the characteristics of a designed or imported filter, including its magnitude response, phase response, group delay, and phase delay, pole-zero plot, impulse response, and step

response. The Spectrum Viewer (Fig.3) lets analyzing frequency-domain data graphically using a variety of methods of spectral density estimation [14].

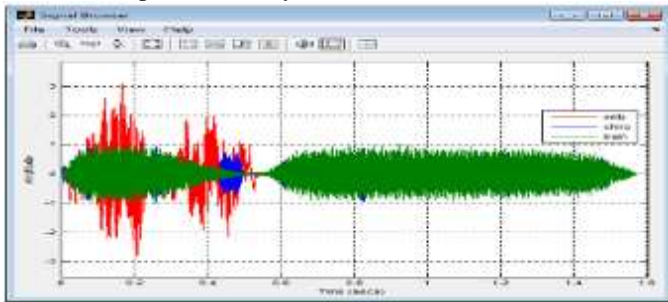


Fig.1 Signal Browser

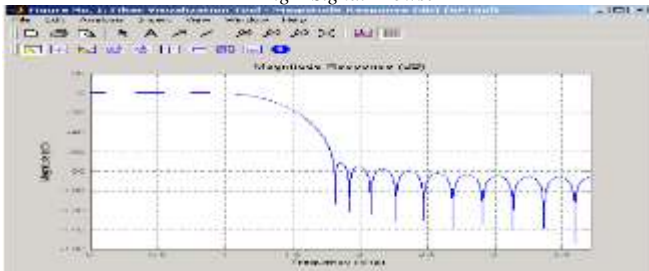


Fig.2 Filter Visualization Tool

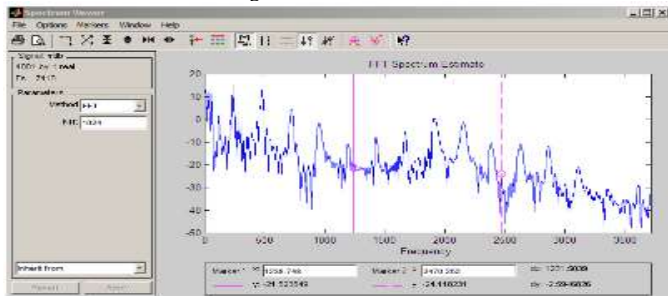


Fig.3 Spectrum Viewer

### III. DIFFERENT VOLTAGE AND CURRENT LEVELS – INPUT/OUTPUT BASED CIRCUIT ASSESSMENT

Current and voltage are dual essential quantities in electricity. Voltage is the cause and current is the effect. The voltage between two points is equal to the electrical potential difference among those points. It is really the electromotive force (emf), responsible for the movement of electrons (electric current) over a circuit. A flow of electrons forced into motion by voltage is current. A voltage source has two points that have dissimilarity in electrical potential. When there is a closed loop path between these two points, it is called a circuit and current can flow. Voltages add up for components connected in series. Currents are the same through all components attached in series. Currents add up for components connected in parallel. Voltages are the same through all components attached in parallel. In actual power system process, different categories and types of loads such as; residential, industrial and commercial loads might be present. The nature of these types of loads is such that their active and reactive power is dependent on the voltage and frequency of the system. Additionally, load characteristics have significant effects on the load flow solutions and convergence ability. Common characteristic of the exponential load models can be given as:

$$P = P_o \left( \frac{V}{V_o} \right)^{np}, Q = Q_o \left( \frac{V}{V_o} \right)^{nq} \dots\dots\dots (5)$$

Where np and nq stand for load exponents, Po and Qo stand for the values[12] of the active and reactive powers at the nominal voltages. V and Vo stand for load bus voltage and load nominal voltage, correspondingly.

Voltage  $V = I \times R = P / I = \sqrt{(P \times R)}$  in volts V  
 Current  $I = V / R = P / V = \sqrt{(P / R)}$  in amperes A  
 Resistance  $R = V / I = P / I^2 = V^2 / P$  in ohms  $\Omega$   
 Power  $P = V \times I = R \times I^2 = V^2 / R$  in watts W ..... (6)

Load Component	Voltage KVA	Current	Resistance (Ohms)	Power (Watts)
GENERATOR-1	500	415	1.2048	207500
GENERATOR-2	250	415	0.60240	103750
HT LINE	11	433	0.02540	4763
EB FACTORY	22	440	0.0500	9680
EB DOMESTIC	11	230	0.0478	2530
SMALL INDUSTRIES	11	415	0.0265	4565

Table-1 shows Different Load components and its equivalent voltage, current Resistance and Power value.

Power systems deliver energy to loads that perform a function. These loads range from household appliances to industrial machinery. Most loads expect a certain voltage and, a certain frequency and number of phases. As per analysis, calculated data from Table-1 helps to making sure that the voltage, frequency and amount of power supplied to the loads is in line with expectations for the respective load components.

Based on 230V input the following resultant values are calculated:

#### A. Series Resonant circuit [14]

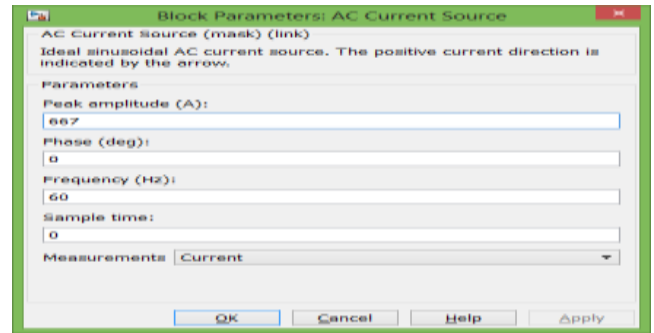
$$V=230\Omega, R=30\text{ohm}, L=60\text{mH}, C=6.8\mu\text{F}$$

Formulas	Result
$f_r = \frac{1}{2\pi\sqrt{LC}}$	249.189Hz
$X_L = 2\pi fL$	93.9420 $\Omega$
$X_c = \frac{1}{2\pi fC}$	468 $\Omega$
$I = \frac{V}{R}$	7.666mA
$V_c = (X_c)(I_T)$ $V_L = (X_{L_c})(I_T)$	720.15V
$Q = \frac{X_L}{r_s}$	3.1314
Bandwidth $\square f = f_2 - f_1 = \frac{f_r}{Q}$	79.5775Hz
Frequency Points $f_L=f_r-1/2 \text{ BW}$ $f_H=f_r+1/2 \text{ BW}$	209.400Hz 288.97Hz
$Z = \sqrt{R^2 + (X_L - X_C)^2}$	450.166 $\Omega$

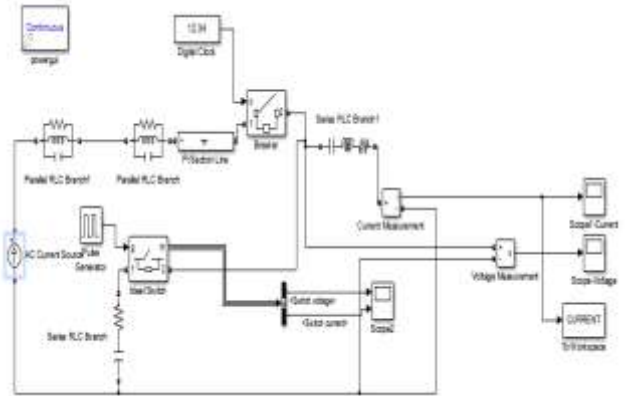
B. Parallel Resonant circuit

$$V=230\Omega, R=30\text{ohm}, L=60\text{mH}, C=6.8\mu\text{F}$$

Formulas	Result
$f_r = \frac{1}{2\pi\sqrt{LC}}$	249.189Hz
$X_L = 2\pi fL$	93.9420Ω
$X_C = \frac{1}{2\pi fC}$	468Ω
$I_c = \frac{V_A}{X_C}$	451.4mA
$I_L = \frac{V_A}{X_L}$	2448.31mA
$Q = \frac{X_L}{r_s}$	100.04
$Z_{eq} = QX_L$	9.3979Ω
$I_T = \frac{V_A}{Z_{eq}}$	24.473μA
$\Delta f = f_2 - f_1 = \frac{f_r}{Q}$	2.4908kHz
$f_2 = f_r + \frac{\Delta f}{2}$	250.43mHz
$f_1 = f_r - \frac{\Delta f}{2}$	247.94mHz



(c)

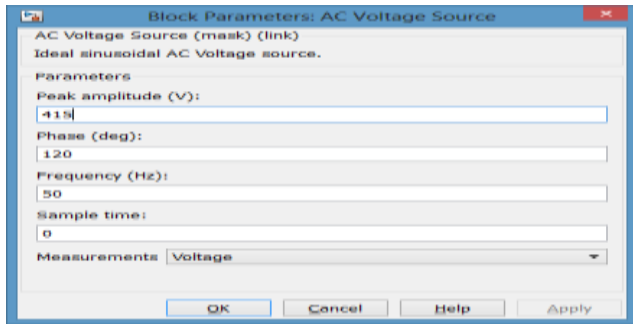


(d)

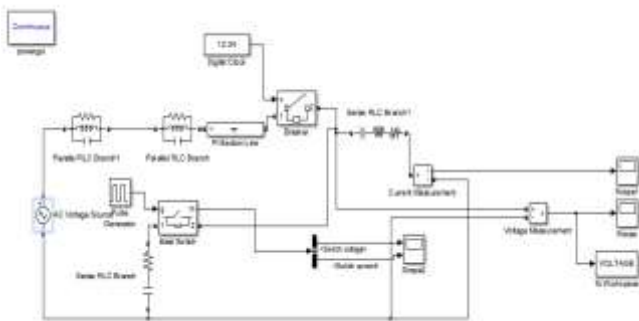
Fig 1. MATLAB-Simulink Circuit Design

- (a) Block Parameters: AC Voltage Source.
- (b) RLC Series and Parallel circuits to 415V AC input.
- (c) Block Parameters: AC Current Source
- (d) RLC Series and Parallel circuits to 667A AC input

Fig. 1 shows Block parameters for AC Voltage/Current source as a input for circuits. In our analysis we get sample for 415V, 667V AC in Series and Parallel RLC circuits. Using Scope tool in MATLAB Simulink to view the signal data.



(a)



(b)

IV. ALGORITHM

The proposed algorithm for the system simulation is given below: [14]

- Step 1. Using AC Voltage/Current source to give the different load as input to start the circuit.
- Step 2. Connect Series and Parallel RLC branch to follow the load in circuit.
- Step 3. If necessary using Pi Section Line, Circuit breaker and Digital clock tool to valuate intermediate load flow.
- Step 4. Using scope tools (one for current and another for voltage) to measure the value to evaluate visualization signal data in between execute simulation program.
- Step 5. In last using workspace tool to store signal data value in difference frequency level into vector array. This vector array used to signal analysis.
- Step 6. Also using workspace vector array to apply the different filter to compute FFT for spectral analysis.
- Step 7. The same process applies for different voltage/current load to analyze signal data with different time series.
- Step 8. Stop.



V. EXPERIMENTAL RESULTS

A. Different Voltage and Current level assessment [14]



(a)

Figure.1.a., 415V Voltage - Signal Scope view in different time frequencies [14]



(a)

Figure.2.a, 433V Voltage - Signal Scope view in different time frequencies



Figure.3 Workspace vector array data

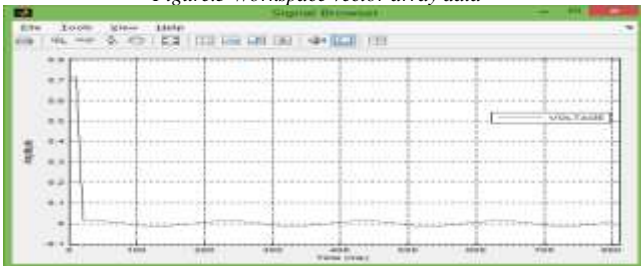


Figure.4 Signal Browser ( 415V) based on VOLTAGE vector array

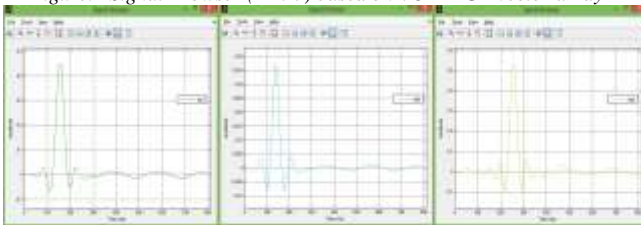


Figure..5 Signal browser shows different signal level with diff. Time series.

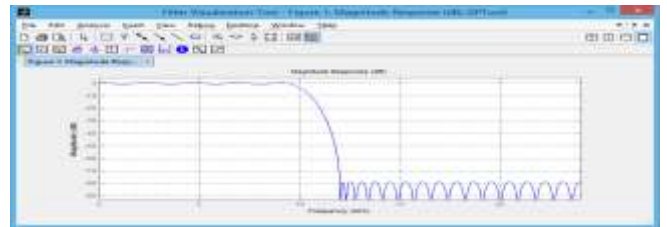


Figure..6 Low Pass filter

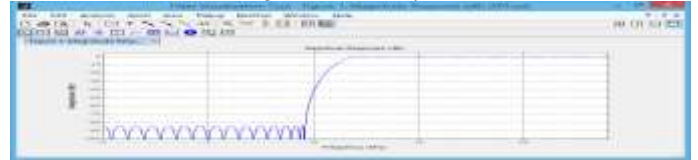


Figure.7 High Pass filter

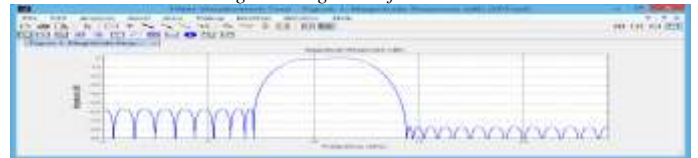


Figure.8 Bandpass Filter

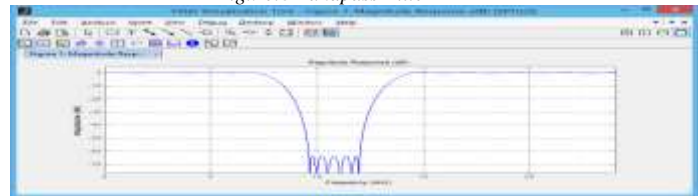


Figure.9 Bandstop filter

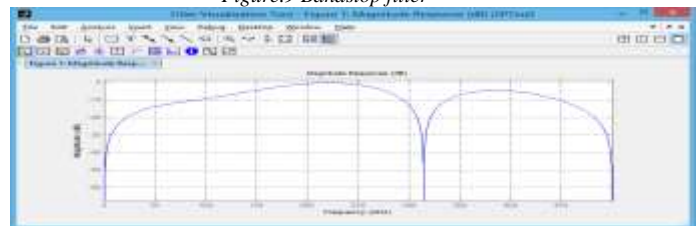


Figure.10 Differentiator

[14] Graphical representation of Voltage and Current Measurements in Series/Parallel RLC Resonant circuits Fig. 1 to 10 are analysed with MATLAB Simulink Visualization software and apply different filter to preview the signal analysis. It shows various signal level with different voltage parameters. The Signal Browser in SPTool uses the longest time length of all the input signals signal display selected in the Signals list box for the time range (Fig 1,a,1,b shows 415V voltage and current signal, Fig.2.a,2.b shows 433V voltage and current signal). Figure 3 shows different time frequency voltage data from workspace vector array. Figure 4 and Figure 5 shows signal levels with different time series which is corresponding to workspace vector array. Figure 6 to 10 shows output from Filter Design Analyze tool which depicts the characteristics of a various designed filter, including its magnitude response, phase response, group delay, phase delay, impulse response, and step response based on data imported from workspace vector array. In our future work the different level voltage circuits data will be tested with Hyperspectral data processing [13] [14] to find out the accurate voltage magnification difference and analyze through signal processing.

## VI CONCLUSION

The present voltage and current level analytical study had been shown that the statistical behavior of a circuit from the different voltage and current level at difference time series information. Also analyze the different spectrum viewer information. Circuit simulation results clearly demonstrate that the representation to visualize signals in time and frequency domains, compute FFTs for spectral analysis, design FIR and IIR filters, and implement convolution, modulation, resampling, and other signal processing techniques.

## VII FUTURE SCOPE

With the RLC series and parallel circuits, able to show that using MATLAB to analyze these circuits saves time and provides exact results with minimal prerequisite knowledge of programming. And by using Simulink, able to analyze the circuit using its transfer function representation. Solved the circuits, using the MATLAB symbolic solver for analytical solutions, using the block diagram programming language-Simulink. With less effort, these techniques allow researchers to solve engineering problems with an excellent graphical picture of the result. The purpose of comparing simulation result with different voltage/current level to ensure that the numerical approximation gives an acceptable result using the analytical signal data. In the future work the different level voltage circuits data will be tested with [14] Hyperspectral data processing to find out the accurate voltage magnification difference and analyze through signal processing. In future, these voltage/current measurement can be applicable to ultraspectral data processing by means of different types of filters classification for our proposed work of graphical representation in series/parallel circuits with heavy load magnification conditions through Hyperspectral Data Analysis.

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