MEASUREMENT OF IMPEDANCE USING STOCHASTIC GRADIENT SEARCH ALGORITHM

Thesis submitted in partial fulfilment of the requirements for the degree of

MASTER of ELECTRICAL ENGINEERING

By

JOY BANERJEE

REGISTRATION NO. - 128911 of 2014-15

ROLL NO. - M4ELE1618

Under the guidance of

Prof. MITA DUTTA

Asst. Prof. GAUTAM SARKAR

ELECTRICAL ENGINEERING DEPARTMENT

FACULTY COUNCIL OF ENGINEERING & TECHNOLOGY

JADAVPUR UNIVERSITY

KOLKATA-700032, INDIA

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JADAVPUR UNIVERSITY

FACULTY COUNCIL OF ENGINEERING & TECHNOLOGY

ELECTRICAL ENGINEERING DEPARTMENT

KOLKATA-700032, INDIA

CERTIFICATE OF RECOMMENDATION

I hereby recommend that the thesis prepared under my supervision and guidance by **Joy Banerjee** entitled **"MEASUREMENT OF IMPEDANCE USING STOCHASTIC GRADIENT SEARCH ALGORITHM"** be accepted in partial fulfillment of the requirements for award of the degree of

"**MASTER OF ELECTRICAL ENGINEERING**" at **JADAVPUR UNIVERSITY**.

The project, in my opinion, is worthy of acceptance.

SUPERVISOR

Prof. MITA DUTTA
Professor
Electrical Engineering Department
Jadavpur University
Kolkata – 700032, India

Asst. Prof. GAUTAM SARKAR
Assistant Professor
Electrical Engineering Department
Jadavpur University
Kolkata – 700032, India

COUNTERSIGNED

Prof. SWAPAN KUMAR GOSWAMI
Head of the Department
Electrical Engineering Department
Jadavpur University
Kolkata – 700032, India

Prof. SIVAJI BANDYOPADHYAY
Dean, FET
Jadavpur University
Kolkata – 700032, India

JADAVPUR UNIVERSITY

FACULTY COUNCIL OF ENGINEERING & TECHNOLOGY

ELECTRICAL ENGINEERING DEPARTMENT

KOLKATA-700032, INDIA

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NAME:	JOY BANERJEE
REGISTRATION NO.:	128911 of 2014-15
ROLL NO.:	M4ELE1618
THESIS TITLE:	MEASUREMENT OF IMPEDANCE USING STOCHASTIC GRADIENT SEARCH ALGORITHM

DATE :

PLACE: KOLKATA

(JOY BANERJEE)

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DATE:

PLACE: Kolkata

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(JOY BANERJEE)

CONTENTS

Chapter 1

INTRODUCTION

Measurement of unknown impedance of electrical equipment is very important part regarding to the studies of electrical engineering. In electrical equipment it is necessary to calculate various parameters such as resistance, capacitance, inductance of that particular electrical equipment. The values of these parameters can be obtained by employing a balancing theory between that equipment, with respect to a reference one. The values of parameters of the reference equipments are known and the unknown parameters are obtained by the balancing technique.

Common technique to calculate the unknown values of electrical parameters with respect to a known or reference parameter is by creating a bridge circuit. This technique is a conventional one and used in many practical purposes to calculate unknown impedance value.

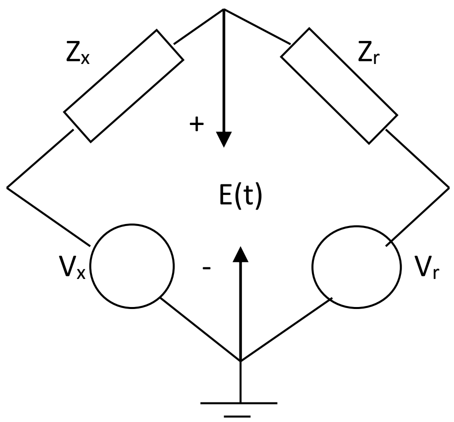


Fig 1. Conventional ac bridge

In Fig 1 V_x is variable voltage source, V_r is reference voltage source, Z_x is unknown impedance and Z_r is a known reference impedance.

The error voltage is given by,

$$E(t) = V_x(t)*(R/(R+Z_x)) – V_r(t)*(Z_x/(R+Z_x)) \quad ....(Eq\ 1.1)$$

The bridge is balanced when the error voltage E(t) = 0.

Hence, from Eq 1.1

$$V_x(t)*(R/(R+Z_x)) – V_r(t)*(Z_x/(R+Z_x)) = 0$$

The value of unknown impedance(Z_x) is obtained by,

$$Z_x = (V_x(t)/V_r(t)) * Z_r \quad ....(Eq\ 1.2)$$

The drawbacks of conventional ac bridges are lying under the fact that they are handled manually. So there should be some error due to human intervention and the balancing process is slower.

Automatic ac bridges are very much handy, useful ,faster in operation than the conventional ac bridges. There are wide range of application of automatic ac bridges like measurement of input impedence of an amplifier, impedance of a speaker, Iron core inductance measurement and measurement of negative impedance. The main function of digital ac bridge is to operate on an efficient balancing algorithm which gives good end results.

Automatic ac bridges work both as analog and digital one depending on the types of input signal. In case of digital ac bridge the variable input V_x and the reference input V_r are software synthesized voltage sources. The unknown and reference impedances are remain same as that in the conventional ac bridge.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Automatic ac bridges have a wide range of application area for its efficiency and reliability. Increasing efficiency and convergence of the algorithm it used helps to originate various paths of new application resources.

The measurement of capacitance with the help of De-sauty bridge pattern, the output voltage of the bridge is nonlinear function of sensor response. The balancing of this capacitive bridge circuit is problemistic due to capacitance effect of the bridge and its surroudings. This drawback can be eliminated if automatic balancing method is used.

Conventional software operated ac bridges have a limitation in their ability to track time varying parameters. But the digital ac bridge which has the features of balancing by means of LMS adaptive algorithm, obviates this limitation and provide a simple and effective method of tracking time varying impedances.

2.2 Review of Automatic Digital ac Bridges

2.2.1 Software Operated Digital ac Bridges

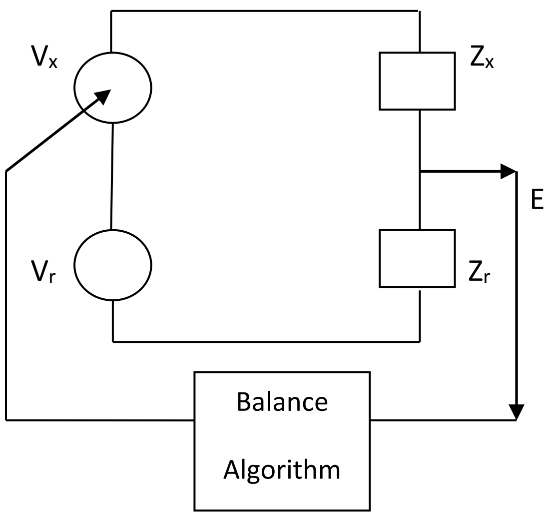


Fig 2.2.1 Software operated digital ac bridge

Fig. 1 shows the principle of a software operated digital ac bridge. The bridge is formed by two symmetrical sine wave generators (V_x, V_r) and by the impedances (Z_x, Z_r) to be compared. In the balanced bridge, the unknown impedance is measured in terms of the ratio of the two voltages and the absolute value of the reference impedance. In an idealized case, without considering stray impedances, the balance condition is

$$V_x / V_r = Z_x / Z_r \qquad \text{....(Eq 2.2.1)}$$

where V_x and V_r are the rms values of variable and reference voltage sources, respectively. Z_x is the unknown impedance, and Z_r is the reference impedance. The error voltage E (Fig. 1) is given by

$$E = (V_x Z_r - V_r Z_x)/(Z_x + Z_r) \qquad \text{....(Eq 2.2.2)}$$

AC bridges are conventionally balanced by successive adjustments of one or several parameters, each adjustment tending to decrease the out-of-balance voltage. The number of steps required to balance the bridge indicates the convergence rate which depends on the bridge components and their configuration.

The software operated digital ac bridge is balanced by controlling the complex voltage V_x , in phase and amplitude according to a simplified version of LMS adaptive algorithm. This digital ac bridge which has the features of balancing by means of LMS adaptive algorithm, provides a simple and effective method of tracking time varying impedances.

2.2.2 Automatic balancing of linear ac bridge circuits for capacitive sensor

Capacitive sensors are measured by De-sauty bridge configuration. But due to the capacitive effect of the bridge and the surroundings the bridge output becomes a nonlinear function of the sensor response. To overcome this problem digital control signals are introduced into the circuit to ensure the balance.

This is done by feedback of the bridge unbalance voltage into one of the bridge branches. The balancing procedure can be repeated periodically, provided that the bridge is unloaded, to reduce drifts and offsets in the sensor and/or in the electronics.

The bridge circuit is typically a De-sauty type but modified with two op-amps and one multiplier. The multiplier controls the variable signal U_c to balance the bridge. The only task for this device is to regulate the amplitude in an electronic way by a control signal. U_c is chosen in such a way that the bridge output U_{dc} is zero.

The variation in capacitance ΔC generates a voltage at A_1 which in turn a current in A_2.

Therefore the output is,

$$U_{dc}(\Delta C) = (C_0 + \Delta C - C_1 * R_2 * U_c/(R_1*10)) * w * 2R_1 * R_f * A/(\pi * R_2) \quad \text{....(Eq 2.2.3)}$$

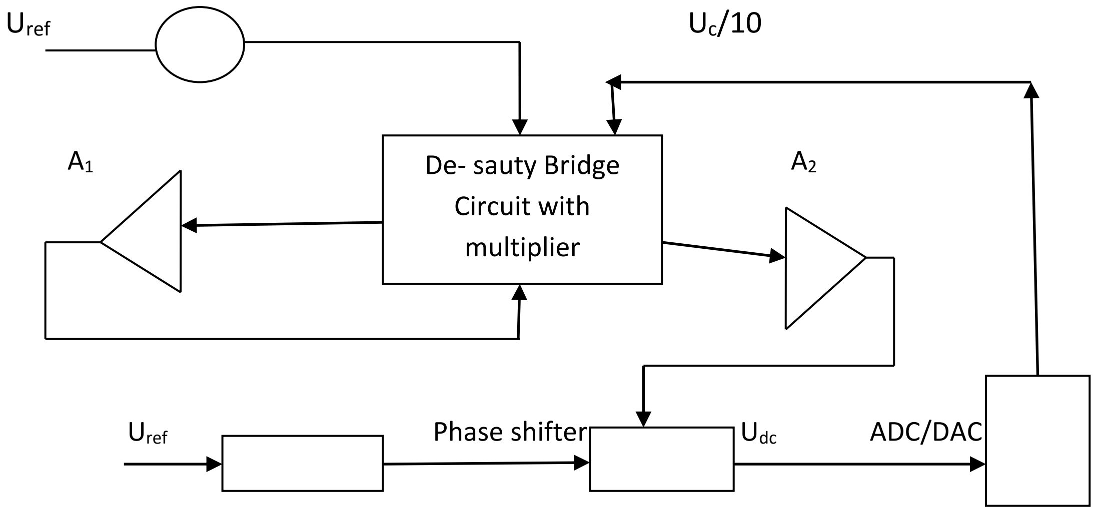


Fig 2.2.2 Block of Capacitive Sensor Bridge

Ensure that the bridge is unloaded, $\Delta C = 0$ in (Eq 2.2.3). Measure the bridge unbalance and by use of (Eq 2.2.3) compute the needed feedback signal U_c, to obtain zero bridge output. Make a new measurement of the bridge output. If it is zero the bridge is balanced, if not, repeat the procedure until the bridge output is zero. In (Eq 2.2.3) the drifts and offsets are not considered because they are difficult to model.

The balancing algorithm is,

$$U_c(k+1) = U_c(k) - \{U_{dc}[U_c(k)]/ U'_{dc}[U_c(k)]\} \quad \text{....(Eq 2.2.4)}$$

where, $U_{dc}[U_c(k)] = - C_1 w * R_f * (2A)/(10\pi)$ ....(Eq 2.2.5)

2.2.3 Non-iterative Digital ac bridge balance

This automatic digital ac bridge balance technique is fast and suitable for high-frequency phase and impedance measurement. Digital ac bridges are balanced by least-mean-square algorithms in the feedback path. This traditional heuristic method is less efficient to converge to the balance point of the digital ac bridge unless certain parameters are appropriately selected.

The digital ac bridge has reliability, accuracy over a conventional ac bridge, and high flexibility to connect to automated systems. The heart of the automatic ac bridge is a digital signal generator. In an adaptive digital ac bridge, balancing is achieved by means of an artificial neural network based on a stochastic gradient search algorithm. Automatic balancing of the bridge circuit for capacitance sensors uses an analog phase-sensitive detector and a phase shifter, therefore, the circuit becomes cumbersome and prone to drift.

Based on simple trigonometric formulas and the basic bridge-balance principle, a new non-iterative method has been implemented to balance the bridge. Fig. 2.2.3 shows a typical digital ac bridge, which is excited by two sinusoidal voltages $V_r(t) = A \sin(2\pi f_0 t)$ and $V_x(t) = B \sin(2\pi f_0 t \pm \psi)$ of the same frequency f_0 but different amplitudes; in addition, a phase difference ψ is maintained between the two. The E(t) in Fig. 2.2.3 represents the instantaneous error voltage output of the bridge, where $Z_r = |Z_r|$ with phase φ_r is the reference arm impedance, and $Z_x = |Z_x|$ with phase φ_x is the measurement arm impedance of the bridge. Digital ac bridge balance can be expressed as two conditions.

1) The ratio of magnitudes of Z_x and Z_r should be equal to the ratio of peak amplitudes of V_x and V_r.

2) The phase-angle difference between Z_x and Z_r should be equal to the phase difference between V_x and V_r.

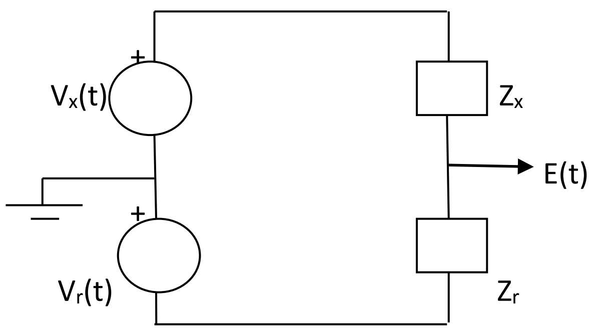


Fig 2.2.3 Typical Digital ac bridge

Therefore, we can mathematically express the aforementioned conditions as follows:

$$k = | Z_x | / | Z_r | = B/A \qquad \text{....(Eq 2.2.6)}$$

$$\psi = \varphi_x - \varphi_r \qquad \text{....(Eq 2.2.7)}$$

Where k is amplitude correction factor and ψ is phase correction factor.

When both $V_r(t)$ and $V_x(t)$ are present the peak error voltage is

$E'_{rx}(t) = 2\, E'_r\ \sin((\varphi_x - \varphi_r)/2)$ ....(Eq 2.2.8)

Where E'_r is the peak error voltage when only $V_r(t)$ is present.

So from Eq 2.2.8 the phase balance expression is

$\psi = \varphi_x - \varphi_r = \pm 2\ \sin^{-1}(E'_{rx}/2\, E'_r)$ ....(Eq 2.2.9)

Chapter 3

AUTOMATIC AC BRIDGE

3.1 Introduction

Automation of ac bridges is very much important for real time implementation and calculating errors by computers. As computers can only handle digital data so digitization of each bridge parameters are necessary. In order to employ digital computers for balancing of ac bridges, an approach on the basis of discrete signal is quite pertinent.

The present chapter is devoted to this aspect of ac bridge balance. The proposed digital ac bridge is suitable for operation on instantaneous basis and hence is also suitable for tracking time varying impedances.

3.2 Stochastic Gradient Search Algorithm

3.2.1 Least Mean Square(LMS) Algorithm(Discrete Realization)

The LMS or least-mean-square algorithm searches for minimum mean square error value through steepest-descent method. In general the mean square error surface is a multidimensional paraboloid. For the case of only two weights, the nature of the paraboloid is shown in Fig 3.1 .This is essentially applicable for discrete variables also.

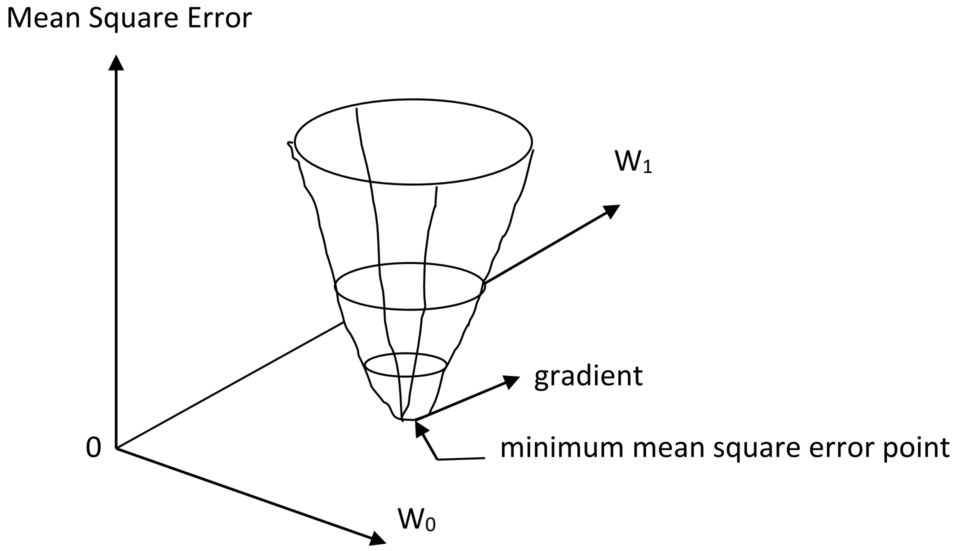


Fig 3.1 Mean Square Error Surface

The goal of the adaptation process is to reach the bottom of the paraboloid bowl. The 'next' filter weight vector is equal to the 'present' weight vector W_k plus a change proportional to the negative of the gradient Δ_k of the mean square error surface i.e.

$$W_{(k+1)} = W_k + \mu(-\Delta_k) \qquad \text{....(Eq 3.1)}$$

Where μ is the factor that controls stability an rate of convergence.

The LMS algorithm estimates an instantaneous gradient in a crude but efficient manner. By assuming Widrow-Hoff LMS algorithm e_k^2, the square of single error sample, is an estimate of the mean square error $E[e_k^2]$, i.e.

$$E[e_k^2] \sim e_k^2 \qquad \text{....(Eq 3.2)}$$

By differentiating e_k^2 w.r.t W, the estimated gradient at the k-th instant

$$\Delta_k = d\, e_k^2 / dW_k = 2e_k (d\, e_k / dW_k) \quad \text{....(Eq 3.3)}$$

From Eq 3.2

$$d\, e_k / dW_k = -R_k \quad \text{....(Eq 3.4)}$$

since p_k and R_k are independent of W_k

where Here p_k is the primary input samples at the k-th instant. The reference input at the k-th instant is R_k, adaptive weight W_k

so,

$$\Delta_k = -2\, e_k R_k \quad \text{....(Eq 3.5)}$$

Using this relation of the estimated gradient in Eq 3.3 yields the following relation

$$W_{(k+1)} = W_k + \mu(-\Delta_k)$$

$$= W_k + 2\, \mu\, e_k R_k \quad \text{....(Eq 3.6)}$$

Advantages :

1. Low computational complexity
2. Simple to implement
3. Allow real time operation
4. Does not need autocorrelation and cross-correlation of signals

3.2.2 Principle of Operation of the proposed automatic digital ac bridge

The automatic digital ac bridge proposed here is represented in the Fig 3.2. One part of the bridge has two arms consist of two sets of sampled data from two symmetrical sine wave (V_x, V_r) where both of them have a different amplitude with a phase shift and the other part has two arms of impedances(Z_x, Z_r) one is reference(Z_r) and the other is unknown(Z_x). In the balanced condition, the unknown impedance is measured in terms of the ratio of the two instantaneous voltages and the absolute value of the reference impedance.

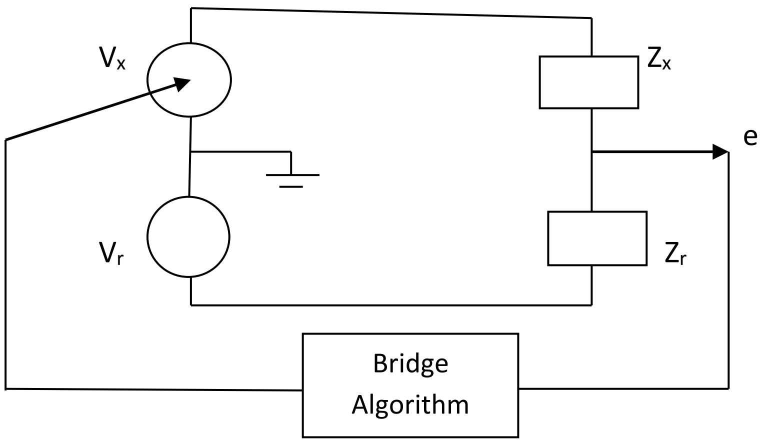


Fig 3.2 Digital ac bridge circuit

In an idealized case, without considering stray impedances, the balance condition is

$$V_x / V_r = Z_x / Z_r \quad ....(\text{Eq } 3.7)$$

where V_x and V_r are the instantaneous values of variable and reference voltage sources, respectively. Z_x is the unknown impedance, and Z_r is the reference impedance. The error voltage e (Fig 3.2) is given by

$$e = (V_x*Z_r - V_r*Z_x)/(Z_x+Z_r) \qquad ....(Eq\ 3.8)$$

AC bridges are conventionally balanced by successive adjustments of one or several parameters, each adjustment tending to decrease the out-of-balance voltage. The number of steps required to balance the bridge indicates the convergence rate which depends on the bridge components and their configuration.

This automatic ac bridge is widely used to measure the value of unknown impedance. In case of measurement of impedance of various electrical equipments like, resistors they have a very small reactive part unless they are wire wound and inductors and capacitors have both resistive and reactive part. At a given frequency, impedance can be written in either polar or rectangular form as,

$$Z = |Z|<\theta = R + j X \qquad ....(Eq\ 3.9)$$

Where Z is impedance in ohms, $|Z|$ is magnitude of Z at an angle θ. R is resistive part of Z and X is reactive of Z.

Now, $|Z| = (R^2 + X^2)$ and $\theta = \tan^{-1}(X/R)$ ....(Eq 3.10)

The unknown impedance can be modeled by a series combination of R and X.

In Fig 3.2 a LMS bridge circuit is shown. The input signals of this bridge are all sampled signals. Reference voltage source V_r is of constant amplitude A and zero phase shift. However, V_x has a variable amplitude and phase shift. They can be written as follows:

$$V_r = A \sin(w_o\, kt) \quad \text{for } k=0,1,2,\ldots\ldots. \qquad ....(Eq\ 3.11)$$

$$V_x = B \sin(w_o\, kt + \Phi) \quad \text{for } k=0,1,2,\ldots\ldots. \qquad ....(Eq\ 3.12)$$

The parameters B and ϕ are controlled to balance the bridge. V_r and V_x are generated via D/A (digital to analog) converters from the microprocessor. Voltage e is read into the microprocessor with an A/D (analog to digital) converter. Other elements of the bridge are the unknown impedance Z_x and the reference impedance taken as purely resistive $Z_r = R_m$. When the bridge is balanced (voltage e = 0) the unknown impedance is given by

$$Z_x = R_m (B/A) <\Phi \quad \text{at frequency } w_o \quad \text{....(Eq 3.13)}$$

Expressing V_x in terms of in-phase and quadrature components yields:

$$V_x = B \cos\Phi \sin(w_o kt) + B \sin\Phi \cos(w_o kt) = W_1 A \sin(w_o kt) + W_2 A \cos(w_o kt) \quad \text{....(Eq 3.14)}$$

Where $W_1 = (B/A) \cos\Phi$ and $W_2 = (B/A) \sin\Phi$ are the weights in-phase and quadrature components respectively. With B and Φ expressed in terms of W_1 and W_2 Eq 3.13 can be written as

$$Z_x = R_m W_1 + j R_m W_2 \quad \text{at balance} \quad \text{....(Eq 3.15)}$$

The terms $R_m W_1$ and $R_m W_2$ are the real and imaginary parts of Z_x. To balance the bridge, one starts with initial values of W_1 and W_2 and iteratively modifies these to force e to zero. One method of doing this, the LMS algorithm, requires that the error be found at each new sample and updated values of W_1 and W_2 be calculated that hopefully force e to zero over time. The LMS algorithm does that well but we won't go into how it does it right now.

Here V_r and V_x are sampled with sampling frequency 1/ T, where T is the sampling as well as the iteration interval, and where $W_o = (2\pi/ nT)$ is the angular frequency of V_x and V_r . The in-phase and quadrature voltages V_{xi} and V_{xq} , respectively, combine to give the complex voltage V_x . Z_x and Z_r are the unknown and reference impedances, respectively. The LMS adaptive algorithm minimizes the mean square error $E [e^2_k]$ by recursively altering W_{xik} and W_{xqk}, where these latter, respectively, represent the k-th iterative weights attached to the in-phase and quadrature components of the voltage V_{xk} , and e_k is the instantaneous out-of-balance voltage of the bridge at the k-th iteration. The LMS algorithm yields the "next," i.e., (k + 1)-th weights as follows:

$$W_{xi(k+1)} = W_{xik} – 2ue_k A \sin(w_o kt) \quad \text{for } k=0,1,2,\ldots\ldots. \quad \text{....(Eq 3.16)}$$

$$W_{xq(k+1)} = W_{xqk} – 2ue_k A \sin(w_o kt) \quad \text{for } k=0,1,2,\ldots\ldots. \quad \text{....(Eq 3.17)}$$

The parameter u is the convergence factor which controls the stability and adaptation rate.

So after each iteration

$$V_{x(k+1)} = V_{xi(k+1)} + V_{xq(k+1)} \quad \text{for } k=0,1,2,\ldots\ldots.. \quad \text{....(Eq 3.18)}$$

And

$$V_{r(k+1)} = A \sin(w_o kt) \quad \text{for } k=0,1,2,\ldots\ldots \qquad \ldots.(\text{Eq } 3.19)$$

The instantaneous in-phase and quadrature voltages

$$V_{xi(k+1)} = W_{xi(k+1)} \; A \sin(w_o kt) \quad \text{for } k=0,1,2,\ldots\ldots \qquad \ldots.(\text{Eq } 3.20)$$

$$V_{xi(k+1)} = W_{xi(k+1)} \; A \cos(w_o kt) \quad \text{for } k=0,1,2,\ldots\ldots \qquad \ldots.(\text{Eq } 3.20)$$

Adaptation rate can be controlled by adjustment of the convergence factor u which should be greater than zero but less than the reciprocal of the largest eigenvalue of the autocorrelation matrix of the in-phase and quadrature bridge excitation voltages V_{xi} and V_{xq}.

Advantage :

The advantage of this bridge is stated from Eq 3.15 that, at balance the real and imaginary part of Z_x depend only on the weight and R_m and there is no requirement to know the amplitude A.

Disadvantage :

Since the LMS algorithm requires that calculations occur at each new sample of e, we have only one sample period to find new values of W_1 and W_2. In addition, the sampling of e and the outputs V_r and V_x must be synchronized. Note too that since the sources V_r and V_x are generated digitally they must be calculated for each new point on the sine waves. Finally, we see that the unknown, Z_x is floating above ground, which is not desirable.

Chapter 4

Real Time Implementation Of Automatic digital ac Bridge

4.1 Introduction

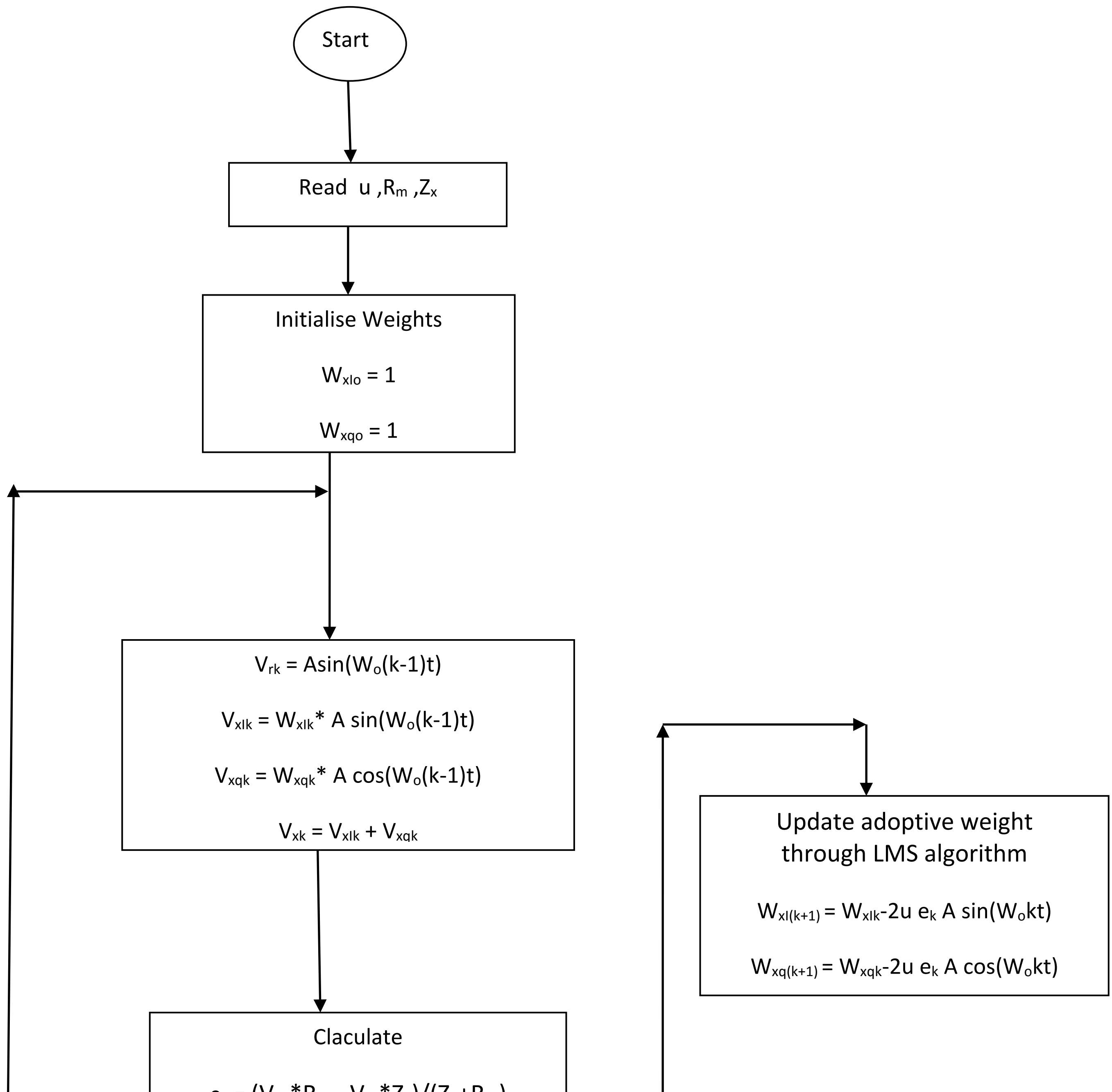
The real time implementation of Automatic digital ac bridge is done in a MATLAB program. The gradient search algorithm considered for this purpose is chosen to be Least Mean Squares (LMS) algorithm.

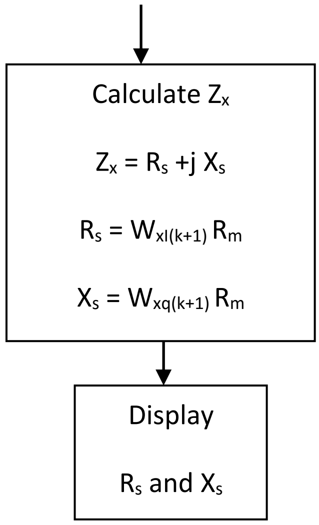
Widrow-Hoff LMS method is implemented and simulated in MATLAB for comparison of accuracy and convergence using data sampled from a MATLAB program. So the operation is done with the help of software synthesized sampled data.

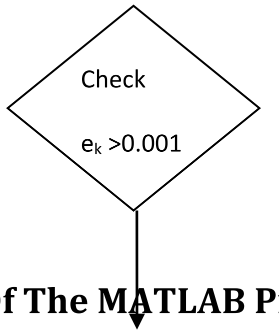
Many different cases of unknown impedances, whose values can precisely measured on a commercial LCR bridge are tested here.

The generated software synthesized sine wave has a sampling frequency of 44100 samples per second and a sinusoidal frequency of 1225 Hz is used as the test signal. The 11025 numbers of data samples are taken in consideration which provides 0.25 seconds of data.

4.2 Flow Chart of the LMS Algorithm







4.3 Output Of The MATLAB Program

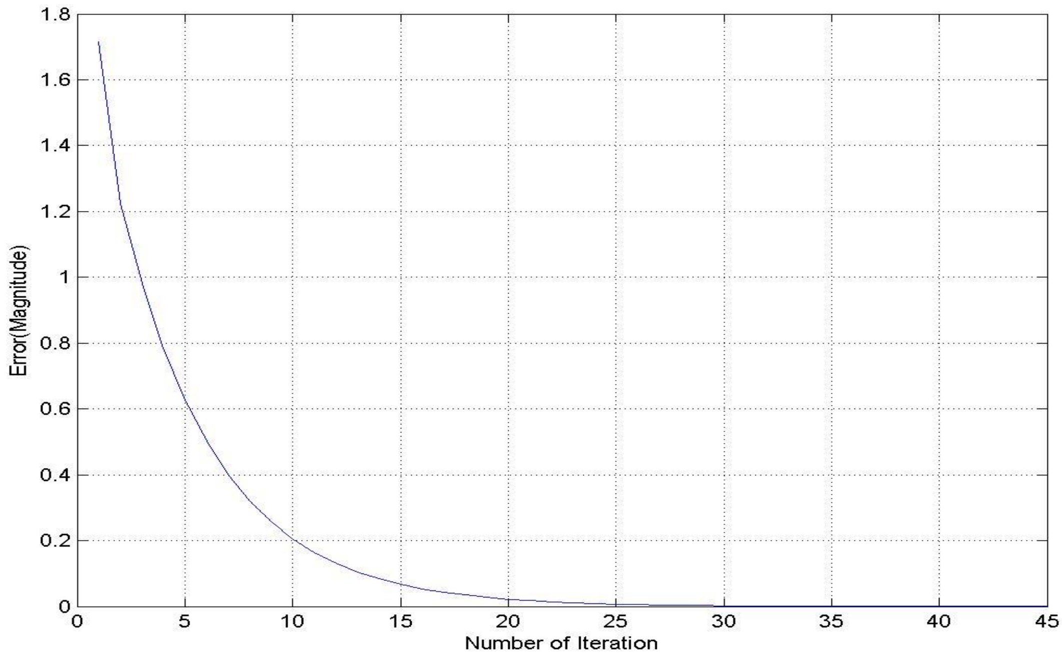


Fig 4.3.1 Error for Z_x = 15 ohm

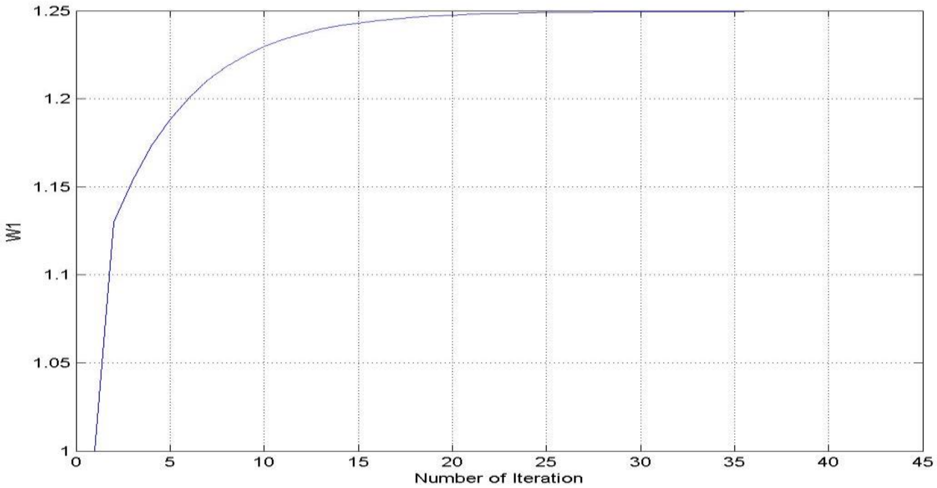


Fig 4.3.2 W1 w.r.t iteration

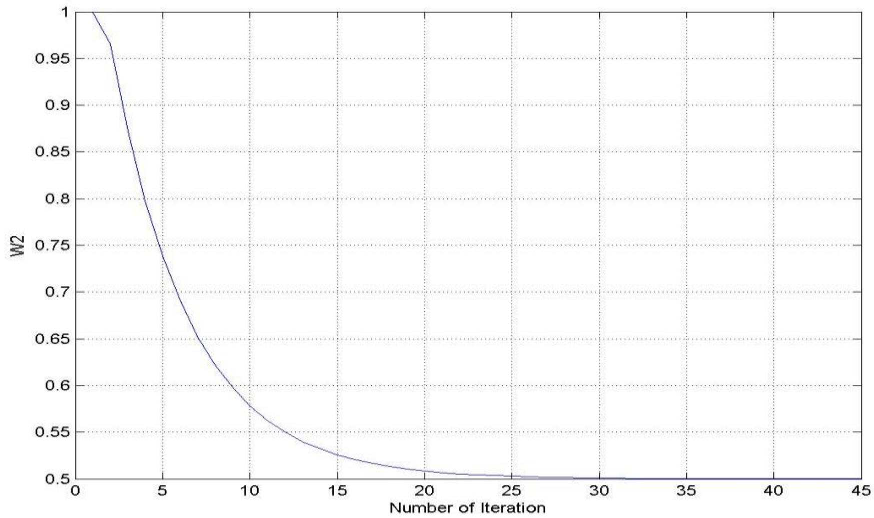


Fig 4.3.3 W2 w.r.t iteration

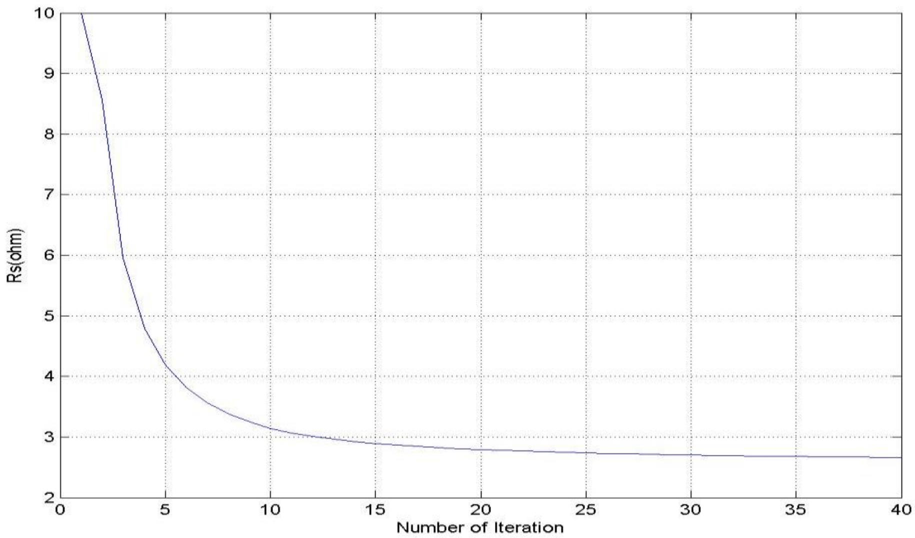


Fig 4.3.4 Rs w.r.t iteration when number of samples is 11025

According to the transient and convergent behavior of the adaptive line enhancer the eigen values of V_{xi} and V_{xq} can be expressed as

$$\Lambda_1, \Lambda_2 = (A^2/2)*[1+\cos(\omega_0 T)] \quad ....(Eq\ 4.5.1)$$

where A is the amplitude of the sinusoid. Then the largest eigen value Λ_{max} is given as

$$\Lambda_{max} = (A^2/2)*[1+\cos(2\pi/n)] \quad \text{for } n>=4 \quad ....(Eq\ 4.5.2)$$

The variation of Λ_{max} for different values of n can be explained below.

$$0 < u < 1/ \Lambda_{max} \quad ....(Eq\ 4.5.3)$$

The instantaneous errors decays with the number of iteration and their graphical relation may be called the "learning Curve" of the bridge. The envelope of this curve is exponential in nature and its time constant τ is given by,

$$\tau = 1/(2*u*\Lambda_{av}) \qquad \text{....(Eq 4.5.4)}$$

where

$$\Lambda_{av} = (\Lambda_1 + \Lambda_2)/2 = A^2/2 \qquad \text{....(Eq 4.5.5)}$$

According to this formula we have taken the amplitude of sinusoid as A = 5 and n = 16 our calculation is as shown:

$A = 5$ and $n=16$

$$\Lambda_{max} = (5^2/2) * (1 + \cos(2\pi/16))$$

$$= 24.045$$

So the value of u must be represented as

$$0 < u < 1/ \Lambda_{max} \quad \text{or}$$

$$0 < u < 0.04158$$

4.4 Results Of the LMS Adaptive Algorithm

Here we run the MATLAB program for different values of A. The values of A is defined by the bit adjustments to introduce different number of samples.

We take four different values of A according to the block consideration and run the program and find out the results of different values of bridge parameters.

The average values of different results are as shown:

For Rm=10 ohm

Zx (Unknown Impedance ohm)	**Xs (Unknown Reactance ohm)**	**Rs (Unknown Resistance ohm)**	**Q (Iteration Number)**
15	5.011	12.2471	42
16	5.014	12.9970	43
18	5.020	13.9969	43
20	5.025	14.9967	44

Table 4.4.1

Overview Of Results

The results of the given tables shown that the values of unknown impedance Z_x varies for taking different number of sample values taken in consideration. For larger number of sample values taken to calculate the error estimation gives good end result and thus specifying the criteria of LMS algorithm.

As shown in the table 4.8.2 i.e. the results for taking sample values after 64 interval with a random variation gives a wide range of values for Z_x thus giving the variation in values of L1 and C1. The main reason behind this the number of samples taken is quiet small so the difference of result is large.

Beside this the table 4.8.5 shows different results for taking sample values after every 8 interval with a random variation. As in this case our concern is depends upon a large number of sets of values so the result of Z_x and hence the values of L1 and C1 are pretty close.

This phenomenon can be verified for the rest of the tables with the increasing number of sample values taken for calculation.

Chapter 5

FUTURE SCOPE

The aspects of automatic ac bridge is applicable to many practical purposes. There are very few techniques to balance an ac bridge in many conventional ways. But balancing ac bridge by this method is very cheap.

The previously done operations on the ac bridge is developing a balancing algorithm and measure impedance of any unknown equipment by a small computer hardware.

Here our basic concern is to develop a MATLAB program for the operation of the ac bridge perfectly and very less iteration. Here we are using two software synthesized voltages for the operation of the bridge balancing algorithm. Apply LMS algorithm to balance the bridge.

Here we are using μ as a constant that controls the speed and stability of the algorithm and modifying the two variable weights W_1 and W_2 to balance the bridge.

Note that according to the LMS algorithm I have calculated the Autocorrelation of sample data inputs and Cross-correlation of the desired samples and the sample data inputs. These two expected values of the desired samples and data samples inputs give one optimal weight factor W* which is basically denoted as Z in the MATLAB program in Chapter 4.

Further prospects of this program can be done by adjusting this optimal weight factor Z in accordance with the variable weights taken in consideration for the system.

Another future scope of this thesis is by making real time analysis by making one MATLAB model with the real time inputs convert them to digital by ADC then apply the MATLAB program for those digitized data and calculate error apply this to DAC and hence update variable voltage. By this iterative method the error voltage is tends to zero and the program gives a good estimation of real time data.

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Appendix

Matlab Program For LMS Algorithm

Main MATLAB Program

```
% file : lms.m
```

```
clc
q=1;
u=.01;
M=0;
T=0;
R=0;
L=0;
V=0;
W=0;
G=0;
A=0;
d=0;
x=0;
p=0;
h=0;
s=0;
n=0;
Rm=0;
Zx=0;
Rs=0;
Xs=0;
W1=0;
W2=0;
Ph=0;
E=0;
N=11025;
f=1225;
FS=44100;
n=0:N-1;
d=5*sin(2*pi*f*n/FS);
x=2*sin(2*pi*f*n/FS+(pi/3));
p=5*cos(2*pi*f*n/FS);

A=N/1;
for j=1:A
    U=round(rand(1));

    h(j)=d(j*1);
    s(j)=x(j*1);
    n(j)=p(j*1);
end

a=x';
b=d';
Q=xcorr(a);
P=xcorr(b,a);
Z=pinv(Q)*P;

for j=1:A
    Rm(j)=10;
    W1(j)=1;
    W2(j)=1;
    Zx(j)=15;

    Ph(j)=atand(W2(j)/W1(j));
    Ph(j)=Ph(j)*(pi/180);
    Rs(j)=W1(j)*Rm(j);
    Xs(j)=W2(j)*Rm(j);
end
```

```
for j=1:A
    E(j)=(s(j)*Rm(j)/(Rm(j)+Zx(j)))-(h(j)*Zx(j)/(Rm(j)+Zx(j)));
end

for j=1:A
    e(j)=E(j)^2;
end

[k] = myavg(E,A);
[t] = myavg1(W1,A);
[r] = myavg1(W2,A);
[l] = myavg1(Zx,A);
[v] = myavg1(Rs,A);
[w] = myavg1(Xs,A);
[g] = myavg(e,A);
[o] = myavg1(Ph,A);

M(q,:)=k;
T(q,:)=t;
R(q,:)=r;
L(q,:)=l;
V(q,:)=v;
W(q,:)=w;
G(q,:)=g;
H(q,:)=o;

while (k>0.0001)
    for j=1:A
        W1(j)=W1(j)-2*u*E(j)*h(j);
        W2(j)=W2(j)-2*u*E(j)*n(j);
    end
    for j=1:A

        Ph(j)=atand(W2(j)/W1(j));
        Ph(j)=Ph(j)*(pi/180);
        Rs(j)=W1(j)*Rm(j);
        Xs(j)=W2(j)*Rm(j);
        s(j)=W1(j)*h(j)+W2(j)*n(j);
    end
    for j=1:A
        E(j)=(s(j)*Rm(j)/(Rm(j)+Zx(j)))-(h(j)*Zx(j)/(Rm(j)+Zx(j)));
    end
    for j=1:A
        e(j)=E(j)^2;
    end

    a=x';
    b=d';
    Q=xcorr(a);
    P=xcorr(b,a);
    Z=pinv(Q)*P;
    k
    [k] = myavg(E,A);
    [t] = myavg1(W1,A);
    [r] = myavg1(W2,A);
    [l] = myavg1(Zx,A);
    [v] = myavg1(Rs,A);
```

```
    [w] = myavg1(Xs,A);
    [g] = myavg(e,A);
    [o] = myavg1(Ph,A);
    q=q+1;
    M(q,:)=k;
    T(q,:)=t;
    R(q,:)=r;
    L(q,:)=l;
    V(q,:)=v;
    W(q,:)=w;
    G(q,:)=g;
    H(q,:)=o;
end

fprintf('Number Of Iteration: ');
fprintf('%12f\n',q);




s
plot(M);
grid;
xlabel('Number of Iteration');
ylabel('Error(Magnitude)');

L
V
W
L1=w/(pi*1225);
C1=1/(2*pi*1225*w);

fprintf('The value of Inductance : ');
fprintf('%12f\n',L1);

fprintf('The value of Capacitance : ');
fprintf('%12f\n',C1);

fileID = fopen('Error(64).doc','w');
fprintf(fileID,'%12s\n','Error');
fprintf(fileID,'  %12.8f  ',E);
fclose(fileID);
fileID = fopen('Rs(64).doc','w');
fprintf(fileID,'%12s\n','Rs');
fprintf(fileID,' %12.8f ',Rs);
fclose(fileID);
fileID = fopen('Xs(64).doc','w');
fprintf(fileID,'%12s\n','Xs');
fprintf(fileID,'%12.8f ',Xs);
fclose(fileID);

fileID = fopen('Zx(64).doc','w');
fprintf(fileID,'%12s\n','Zx');
fprintf(fileID,'%12.8f ',Zx);
fclose(fileID);

fileID = fopen('W1(64).doc','w');
fprintf(fileID,'%12s\n','W1');
fprintf(fileID,'%12.8f ',W1);
```

```
fclose(fileID);

fileID = fopen('W2(64).doc','w');
fprintf(fileID,'%12s\n','W2');
fprintf(fileID,'%12.8f ',W2);
fclose(fileID);

fileID = fopen('s(64).doc','w');
fprintf(fileID,'%12s\n','s');
fprintf(fileID,'%12.8f ',s);
fclose(fileID);
```

Program For Calculating normal averages

```
function [a] = myavg1(b,A)
for i=1:A
    if b(i)<0
        b(i)=(+1)*b(i);
    else
        b(i)=b(i);
    end
```

```
end
a=mean(b);
end
```

This is useful for calculating the averages of Zx , Rs ,Xs and other important output of the bridge parameter.

Program For Calculating modal averages

```
function [a] = myavg(b,A)
for i=1:A
    if b(i)<0
        b(i)=-b(i);
    else
        b(i)=b(i);
    end
end
a=mean(b);
end
```