A PROJECT REPORT ON

ERROR COMPENSATION IN CURRENT TRANSFORMER USING MATLAB

Project Report submitted in partial fulfillment of the degree of

BACHELOR OF ENGINEERING

BY

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Declaration

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

In today's modern world where the demand of the consumers for electricity requirement is going on day by day.

To achieve this ELECTRICAL POWER SYSTEM is the heart which continuously pumps the electricity from one end to other end by means of transmission and distribution system.

It is likely that when the demand of the consumers increases the probability of fault also increases & when the fault comes into picture it is necessary to clear the fault as early as possible. This can be achieved using various equipments eg:-C.B, relays, CT,PT etc..

In our project we have shown by means of MATLAB that how the error can be reduced in current transformer, which is the mode of providing the signal to the CB to trip.

We will be showing it by means of various graphs indicating various electrical parameters.

We hope that our project would be successful and it would be adopted as well in the power system network.

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CHAPTER 1

INTRODUCION

1.1 Current Transformer

A CT is an instrument transformer in which the secondary current is substantially proportional to primary current and differs in phase from it by ideally zero degree.

1.2 Need of Current Transformer:-

Instrument transformers means current transformer & voltage transformer are used in electrical power system for stepping down currents and voltages of the system for metering and protection purpose. Actually relays and meters used for protection and metering, are not designed for high currents and voltages.

High currents or voltages of electrical power system cannot be directly fed to relays and meters. CT steps down rated system current to 1 Amp or 5 Amp similarly voltage transformer steps down system voltages to 110 V. The relays and meters are generally designed for 1 Amp, 5 Amp and 110 V.

CHAPTER 2

THEORY RELATED TO CURRENT TRANSFORMER

A CT functions with the same basic working principle of electrical power transformer, as we discussed earlier, but here is some difference. If a electrical power transformer or other general purpose transformer, primary current varies with load or secondary current. In case of CT, primary current is the system current and this primary current or system current transforms to the CT secondary, hence secondary current or burden current depends upon primary current of the current transformer.

Are you confused? OK let us clear you.

In a power transformer, if load is disconnected, there will be only magnetizing current flows in the primary. The primary of the power transformer takes current from the source proportional to the load connected with secondary . But in case of CT, the primary is connected in series with power line. So current through its primary is nothing but the current flows through that power line. The primary current of the CT, hence does not depend upon whether the load or burden is connected to the secondary or not or what is the impedance value of burden. Generally CT has very few turns in primary where as secondary turns is large in number. Say N_p is number of turns in CT primary and I_p is the current through primary. Hence the primary AT is equal to N_pI_p AT.

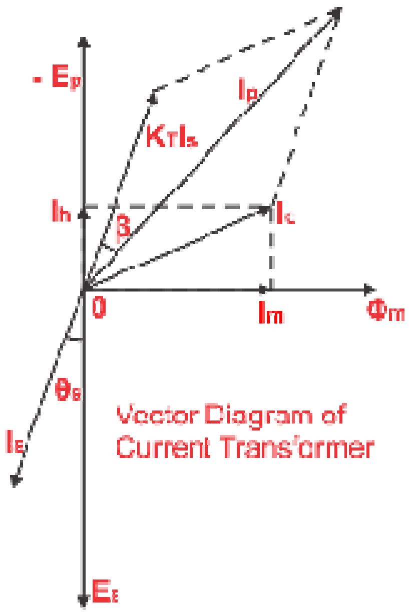
If number of turns in secondary and secondary current in that current transformer are N_s and I_s respectively then Secondary AT is equal to N_sI_s AT.

In an ideal CT the primary AT is exactly is equal in magnitude to secondary AT.

So from the above statement it is clear that if a CT has one turn in primary and 400 turns in secondary winding, if it has 400 A current in primary then it will have 1 A in secondary burden.

Thus the turn ratio of the CT is 400/1 A

2.1 PHASOR DIAGRAM OF CURRENT TRANSFORMER



Fig(a)

Let,

I_s - Secondary current

E_s - Secondary induced emf.

I_p - Primary current.

E_p - Primary induced emf.

K_T - Turns ratio = Numbers of secondary turns/number of primary turns.

I_0 - Excitation current.

I_m - Magnetizing component of I_0.

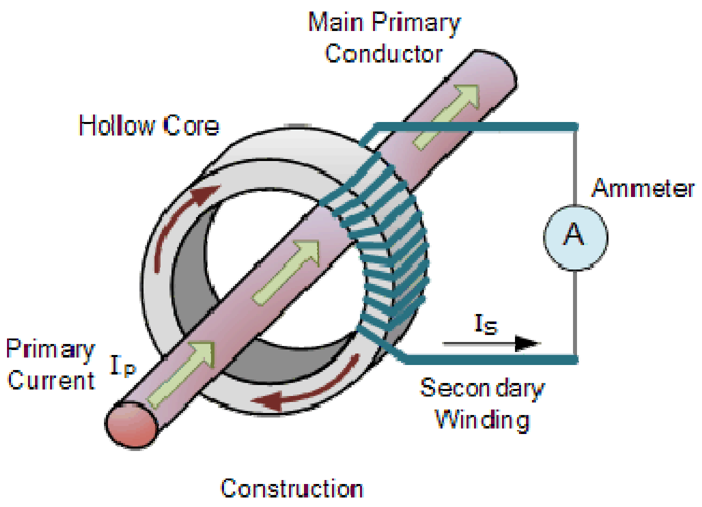
I_w - Core loss component of I_0.

Φ_m - Main flux.

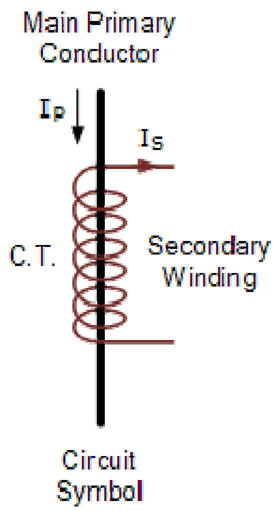
Let us take flux as reference. EMF E_s and E_p lags behind the flux by 90°. The magnitude of the passers E_s and E_p are proportional to secondary and primary turns. The excitation current I_o which is made up of two components I_m and I_w.

The secondary current I_0 lags behind the secondary induced emf E_s by an angle Φ_s. The secondary current is now transferred to the primary side by reversing I_s and multiplied by the turns ratio K_T. The total current flows through the primary I_p is then vector sum of K_T I_s and I_0.

2.2 WORKING OF CURRENT TRANSFORMER



Fig(b)



Fig(c)

Like any transformer, a current transformer has a primary winding, a core and a secondary winding, although some transformers, including current transformers, use an air core. In principal, the only difference between a current transformer and a voltage transformer (normal type) is that the former is fed with a 'constant' current while the latter is fed with a 'constant' voltage, where 'constant' has the strict circuit theory meaning.

The alternating current in the primary produces an alternating magnetic field in the core, which then induces an alternating current in the secondary. The primary circuit is largely unaffected by the insertion of the CT. Accurate current transformers need close coupling between the primary and secondary to ensure that the secondary current is proportional to the primary current over a wide current range. The current in the secondary is the current in the primary (assuming a single turn primary) divided by the number of turns of the secondary. In the illustration on the right, 'I' is the current in the primary, 'B' is the magnetic field, 'N' is the number of turns on the secondary, and 'A' is an AC ammeter.

The most basic current transformer comprises the secondary wound around the primary conductor, but typically current transformers consist of a silicon steel ring core wound with many turns of copper wire as shown in the right illustration. The conductor carrying the primary current is then passed through the ring; the CT's primary therefore consists of a single 'turn'. The primary 'winding' may be a permanent part of the current transformer, with a heavy copper bar to carry current through the core. Window-type current transformers (aka zero sequence current transformers, or ZSCT) are also common, which can have circuit cables run through the middle of an opening in the core to provide a single-turn primary winding. To assist accuracy, the primary conductor should be central in aperture.

CTs are specified by their current ratio from primary to secondary. The rated secondary current is normally standardized at 1 or 5 amperes. For example, a 4000:5 CT secondary winding will supply an output current of 5 amperes when the primary winding current is 4000 amperes. The secondary winding of a CT can have taps to provide a range of ratios, five taps being being common

CHAPTER 3

TERMS RELATED TO CURRENT TRANSFORMER

3.1 Rated Primary Current of Current Transformer:-

This is the value of rated primary current of current transformer on which the CT is designed to perform best. Hence rated primary current of current transformer is an optimum value of primary current at which, error of the CT are minimum and losses in the CT are also less, that means in few words, performance of the CT is best; with optimum heating of the transformer.

3.2 Rated Secondary Current of Current Transformer:-

Like rated primary current, this is the value of secondary current due to which errors in the CT are minimum. In other words, rated secondary current of current transformer is the value of secondary current on which the best performance of the CT is based.

3.3 Rated Burden of Current Transformer:-

Whatever is connected externally with the secondary of a current transformer is called burden of current transformer. In electrical power transformer the secondary is connected with load, but in case of current transformer, electrical consumer load is not connected to the secondary. In electrical power transformer we loaded the secondary of the transformer by connecting consumer's one by one to the secondary side. But in case of current transformer or other instrument transformer, we connect, metering instrument and protection relays to the secondary, which obviously behave like load of the instrument transformer but do not have any direct relation with the load of the electrical power system. That is why, all the instruments, wires etc connected with the secondary of the instrument transformer or IT is called burden rather load. In this way, we distinguish the secondary circuit of a current transformer or voltage transformer from other purpose electrical transformer.Although literally, load and burden carry nearly same meaning in english language. Rated burden of current transformer is the value of the burden to be connected with the secondary of CT including connecting load resistance expressed in VA or ohms on which accuracy requirement is based. Similarly rated burden of voltage transformer is the value of the burden to be connected with the secondary of Voltage Transformer including connecting load resistance expressed in VA or ohms on which accuracy requirement is based.

3.4 Rated Frequency of Current Transformer:-

The value of the system frequency on which the instrument transformer operates.

3.5 Accuracy Class of Current Transformer :-

There is always some difference in expected value and actual value of output of an instrument transformer current error and phase angle error count in CT, as because primary current of current transformer has to contribute the excitation component of CT core**.** Accuracy class of current transformer is the highest permissible percentage composite error at rated current. The standard accuracy classes of current transformer as per IS-2705 are 0.1, 0.2, 0.5, 1, 3 & 5 for metering CT.

The accuracy class or simply class of measuring current transformer is 0.1, means the maximum permissible limit of error is 0.1%, more clearly, if we try to measure 100 A with a 0.1 class CT, the measured value may be either 100.1 or 99.9 A or anything in between these range.

The standard accuracy class for the protection current transformer, as per IS-2705 are 5 P, 10 P, 15 P.

Note:-Here in the protection current transformer, 5 P means 5%, 10 P means 10%, and 15 P means 15% error and ′P′ stands for protection.

3.6 Rated Short Circuit Current of a Current Transformer:-

In some abnormal condition like huge short circuit fault, the current transformer faces a huge current, flows through the CT primary. Although this fault current will not continue for long lime as because every fault in the system is cleared by electrical protection system within very short time. So current transformer should be designed in such a way that it can withstand this huge fault current at least for certain amount of time. It is unnecessary to design any equipment for withstanding short circuit current for long period of time since the short circuit fault is cleared by protection switch gear within fraction of second. For CT rated short circuit current of current transformer is defined as the rms value of primary current which the CT will withstand for a rated time with its secondary winding short circuited without suffering harmful effects.

3.7 Rated Voltage for Current Transformer(CT)

The RMS value of the voltage used to designate the CT for a particular highest system voltage is rated Voltage for current transformer. The voltage of electrical power system is increased if load of the system is reduced. As per standard, the system voltage can be raised up to 10% above the normal voltage during no load condition. So every electrical equipment is such designed so that it can withstand this highest voltage. As current transformer is an electrical equipment, it should also be designed to withstand highest system voltage.

3.8 Instrument Security Factor

ISF or instrument security factor of current transformer is defined as the ratio of instrument limit primary current to the rated primary current. The instrument limit primary current of metering CT is the value primary current beyond which CT core becomes saturated.

3.9 Accuracy Limit Factor

For protection current transformer, the ratio of accuracy limit primary current to the rated primary current is called accuracy limit factor of current transformer.

3.10 Knee Point Voltage of Current Transformer

Knee point voltage of current transformer is significance of saturation level of a current transformer core mainly used for protection purposes. The sinusoidal voltage of rated frequency is applied to the secondary terminals of CT, with other winding being open circuited which increased by10%, cause the exiting current to increase by 50%.

3.11 Current Error (Ratio Error)

The percentage error in the magnitude of the secondary current is defined by the following formula

Ratio error = $(K_n I_s - I_p)/ I_p \times 100\%$

I_p, I_s = primary and secondary winding currents respectively,

K_n = turns ratio

3.12 Turns Ratio :-

$$T.R. = n = \frac{N_P}{N_S} = \frac{I_S}{I_P}$$

$$\text{secondary current, } I_S = I_P\left(\frac{N_P}{N_S}\right)$$

CHAPTER 4

TYPES OF CURRENT TRANSFORMER

4.1 Measuring current transformers

These current transformers are used along with the measuring devices for the measurement of current, energy and power.

4.2 Protective current transformers

These current transformers are used along with the protection equipments such as trip coils, relays etc.

Based on the function & construction it can be classified in to as follows:

4.2.1 Bar Type: This type of current transformer consists of a bar of suitable size and material forming an integral part of the transformer.

4.2.2 Wound Type: This type of CTs have a primary winding of more than one full turn wound over the core.

4.2.3 Window Type: CTs of this type have no primary winding. The secondary wind of the CT is placed around the current flowing conductor. The magnetic electric field created by current flowing through the conductor induces current in the secondary winding which is used for measurement.

Fig(d):Bar Type Fig(e):Wound Type Fig(f):Window Type

CHAPTER 5

ERRORS IN CURRENT TRANSFORMER

5.1 Cause of error:-

The total primary current is not actually transformed in CT. One part of the primary current is consumed for core excitation and remaining is actually transformers with turns ratio of CT so there is error in current transformer means there are both ratio error in current transformer as well as a phase angle error in current transformer.

8.4 Types of errors:-

8.4.1 Ratio error

The ratio error which is defined as

$$\text{Ratio error} = \frac{\text{Actual ratio} - \text{Ideal ratio}}{\text{Ideal ratio}}$$

is approximately given by

$$\boxed{\text{Ratio error} \approx \frac{I_e}{nI_s}}$$

as shown in Figure A.3.

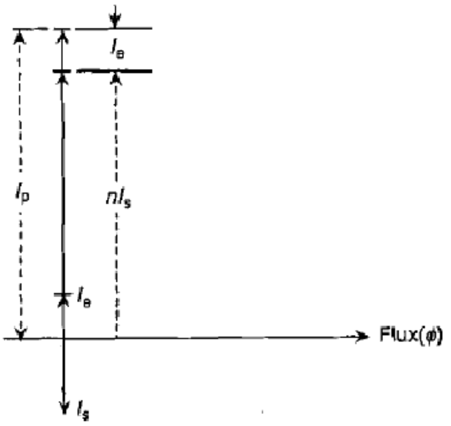


Figure . Approximate method of expressing ratio error.

Fig(g)

5.2.2 Phase angle error:-

The *phase angle error* is defined as the *angular difference between the secondary current phasor reversed and the primary current phasor*. If the reversed current phasor leads the primary current phasor then the phase angle error is defined as positive otherwise it is taken as negative. As shown in Figure A.4, the phase angle error is given approximately by

$$\text{Phase angle error} \approx \frac{I_m}{nI_s}$$

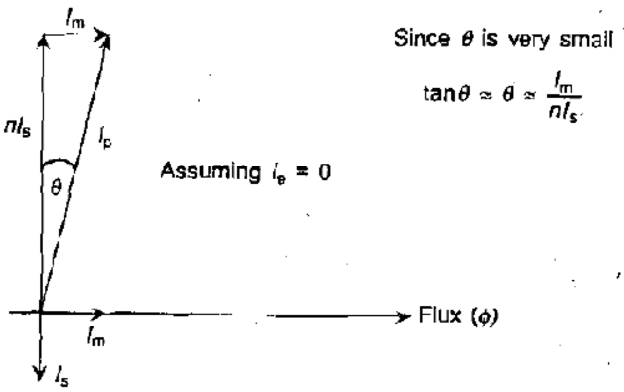


Figure A.4 Approximate method of expressing phase angle error.

Fig(h)

CHAPTER 6

THEORETICAL METHODS TO REDUCE ERRORS

It is desirable to reduce these errors, for better performance. For achieving minimum error in current transformer, one can follow the following,

- Using a core of high permeability and low hysteresis loss magnetic materials.
- Keeping the rated burden to the nearer value of the actual burden.
- Ensuring minimum length of flux path and increasing cross-sectional area of the core, minimizing joint of the core.
- Lowering the secondary internal impedance.

CHAPTER 7

INTROUCTION TO MATLAB

MATLAB is widely used in all areas of applied mathematics, in education and research at universities, and in the industry. MATLAB stands for MATrix LABoratory and the software is built up around vectors and matrices. This makes the software particularly useful for linear algebra but MATLAB is also a great tool for solving algebraic and differential equations and for numerical integration. MATLAB has powerful graphic tools and can produce nice pictures in both 2D and 3D. It is also a programming language, and is one of the easiest programming languages for writing mathematical programs. MATLAB also has some tool boxes useful for signal processing, image processing, optimization, etc.

MATLAB was first adopted by researchers and practitioners in control engineering, Little's specialty, but quickly spread to many other domains. It is now also used in education, in particular the teaching of linear algebra, numerical analysis, and is popular amongst scientists involved in image processing.

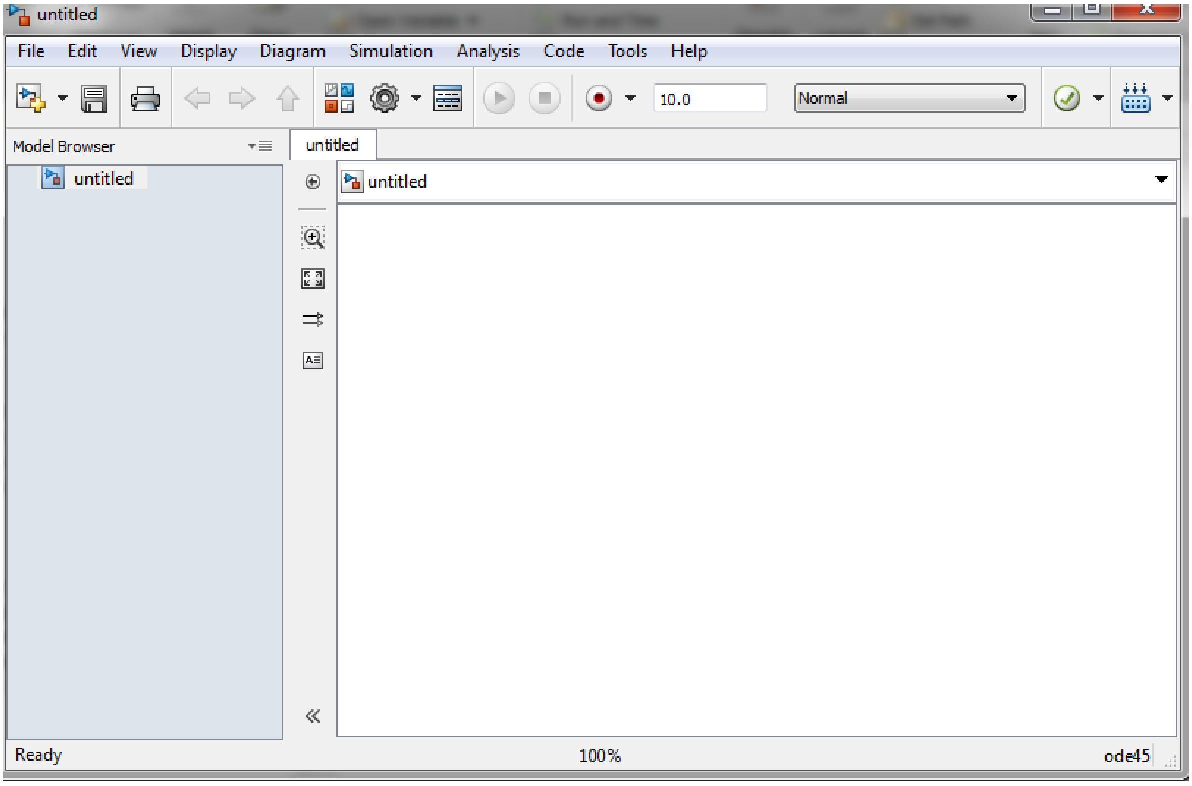
Our project is related with the simulation part so we shall discuss about it.

7.1 SIMULINK IN MATLAB

Simulink, developed by MathWorks, is a graphical programming environment for modeling, simulating and analyzing multidomain dynamic systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it. Simulink is widely used in automatic control and digital signal processing for multidomain simulation andModel-Based Design.

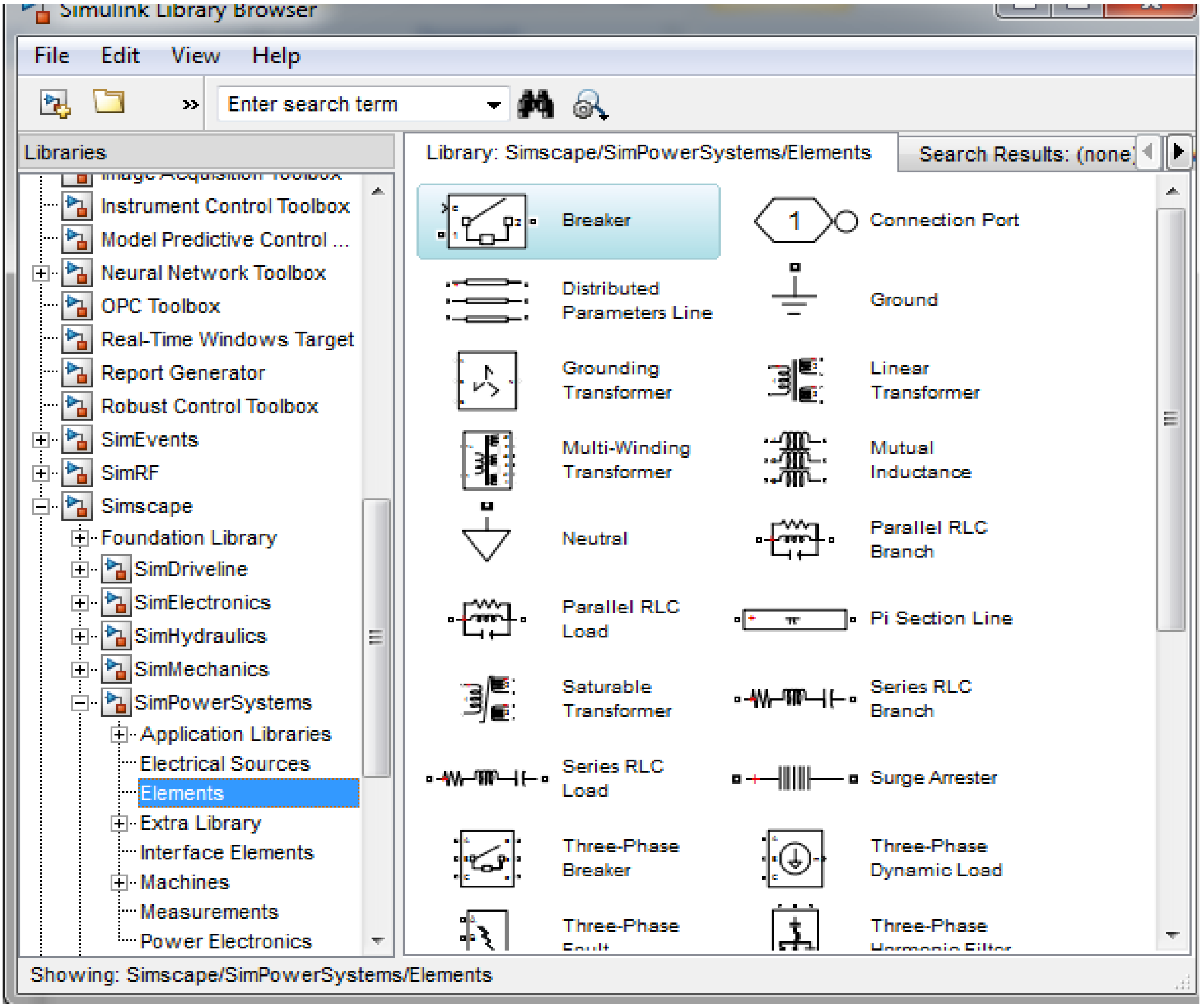
- **Simulink mainly consists of :-**

7.1.1 **Simulink model:-**Here the actual circuitt whose output is to be observed is made using simulink library



Fig(i) Simulink model

7.1.2 Simulink library:-From the library various equipments are selected using which the required ckt is made.



Fig(j) Simulink library browser

CHAPTER 8

OUR PROJECT DESCRIPTION

We have used the simulink model in MATLAB for the error compensation purpose, we have used the following models in MATLAB.

8.1 Error compensation without compensation.

8.2 Error compensation using passive components.

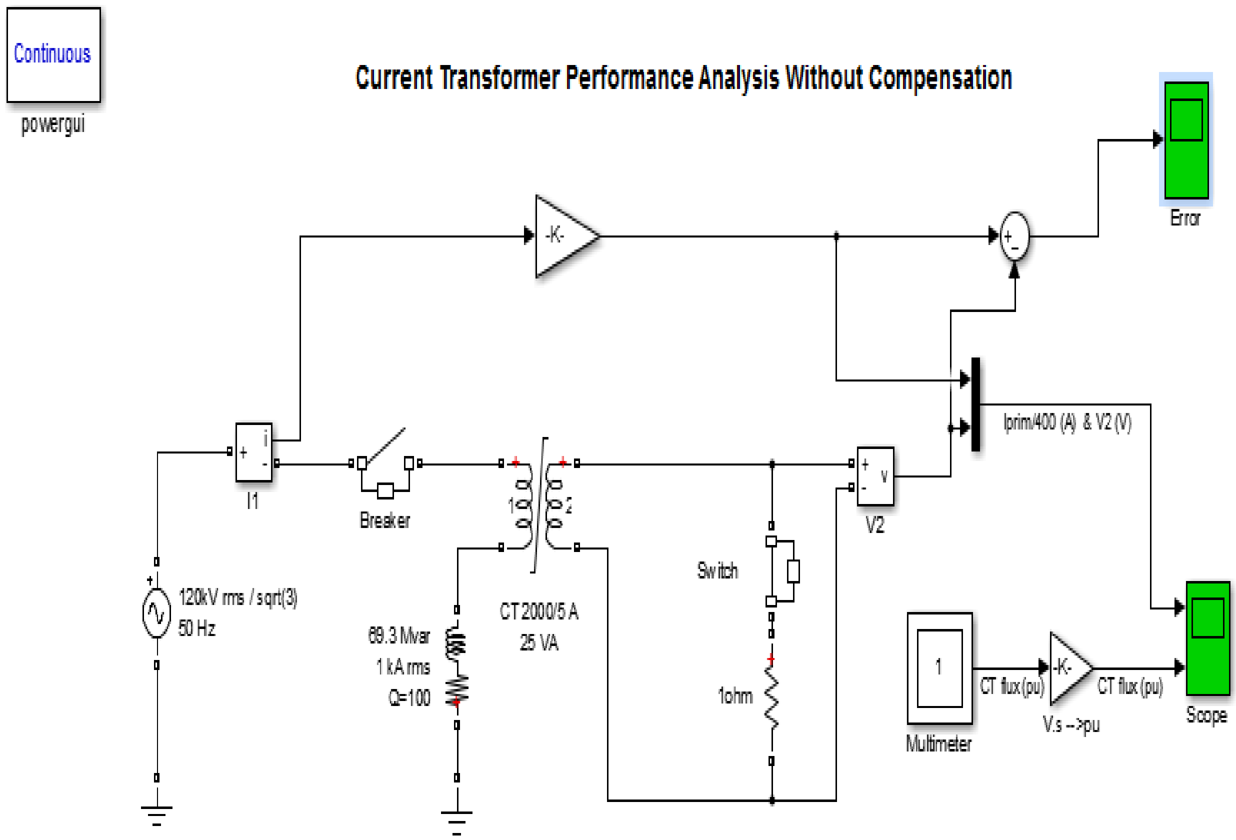
8.3 Error compensation using active components.

Each model will be shown by its equivalent circuit diagrams , waveforms.

Each model will have some advantages over the other & we will observe from the waveforms that active compensation will be the best one.

8.1 Error compensation without compensation

8.1.1 Circuit Diagram:-



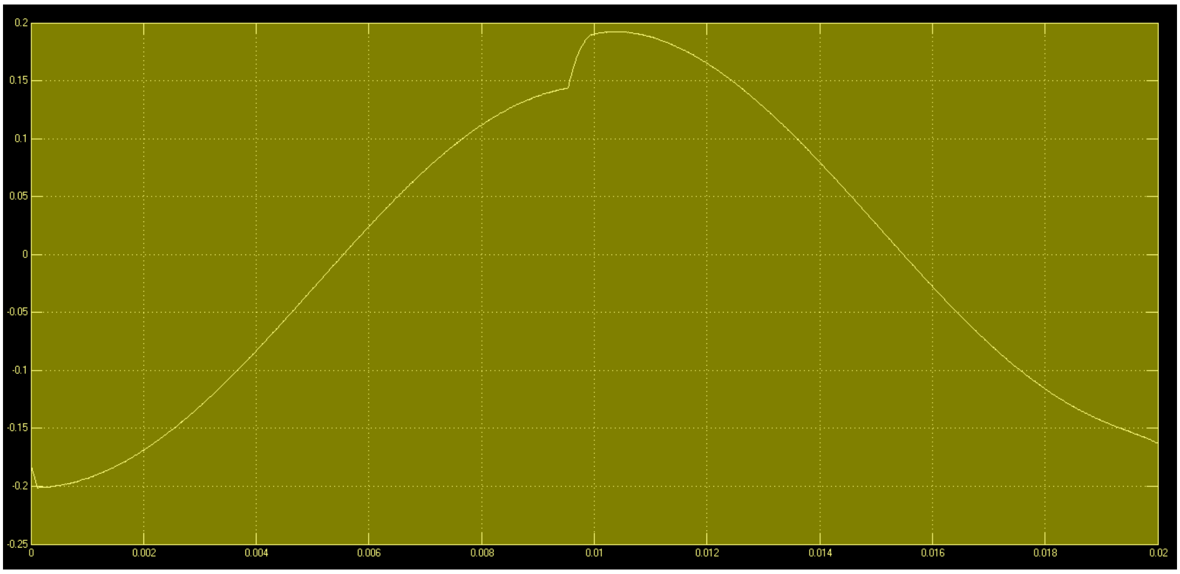
Fig(k)

8.1.2 Components used:-

- AC vtg source(120KV)
- Continous power gui
- Circuit breaker
- Current transformer(2000/5A,25VA)
- Ammeter
- Voltmeter
- Gain
- Summer
- Multiplexer
- Scope(for viewing error and measurement of current and voltage)
- Multimeter

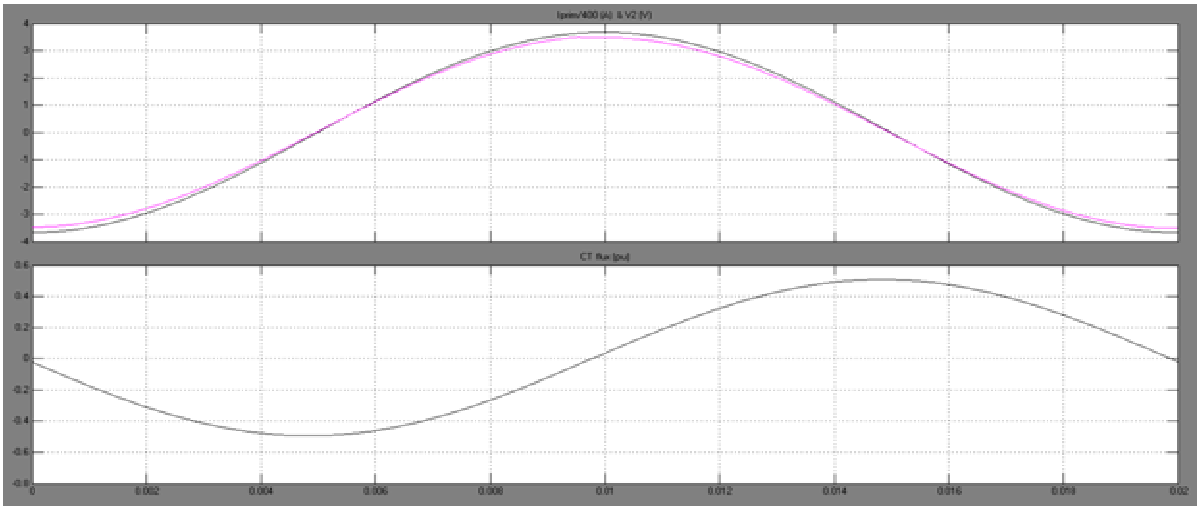
8.1.3 Waveforms:-

8.1.3.1 Error introduced



Fig(l)

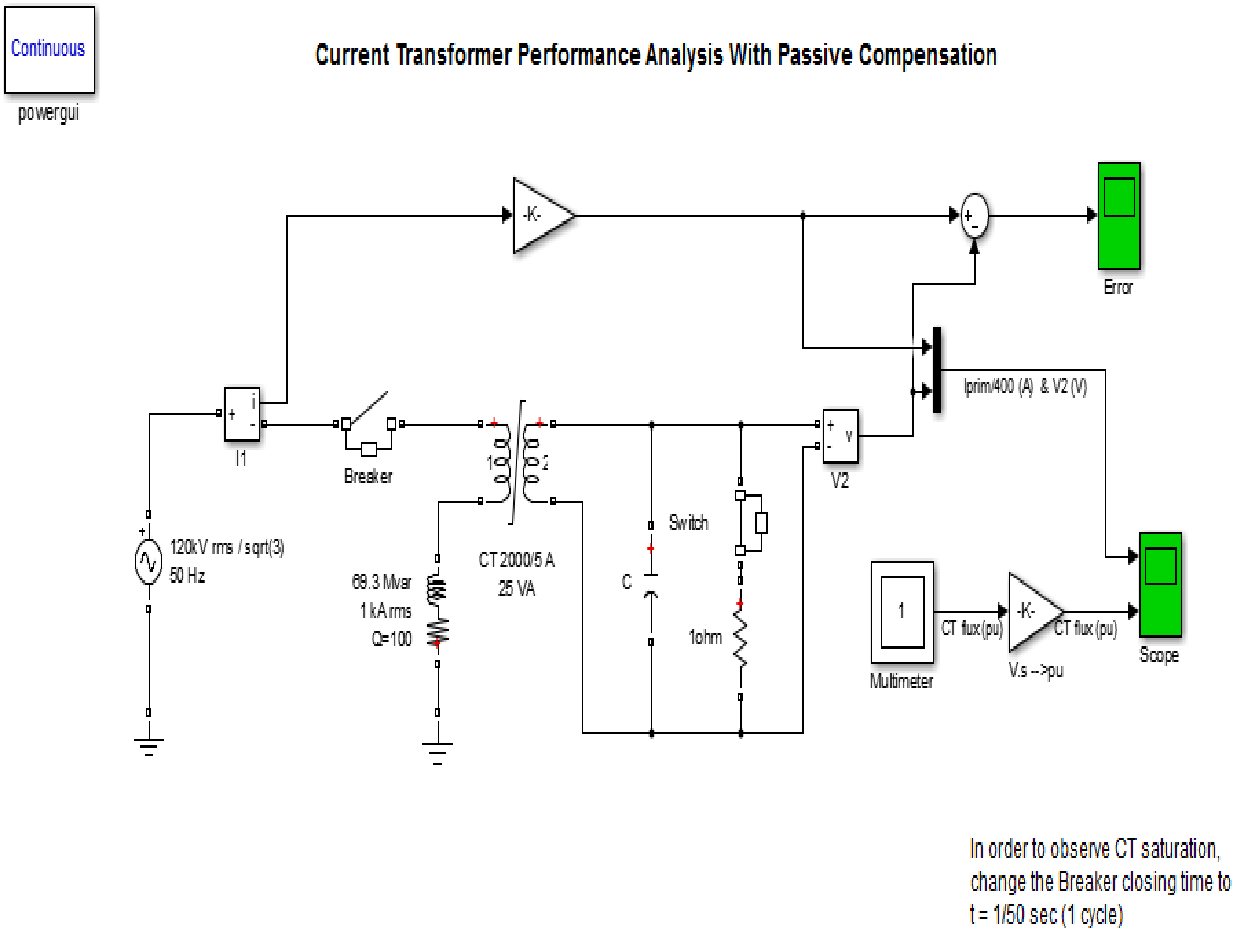
8.1.3.2 Voltage, current and CT flux :-



Fig(m)

8.2 Error compensation with passive compensation:-

8.2.1 Circuit Diagram:-



Fig(n)

8.2.2 Components used:-

- AC vtg source(120KV)
- Continous power gui
- Circuit breaker
- Current transformer(2000/5A,25VA)
- Capacitor as a passive compensating element
- Ammeter
- Voltmeter
- Gain
- Summer
- Multiplexer
- Scope(for viewing error and measurement of current and voltage)
- Multimeter

8.2.3 Advantages Of Passive Compensation:-

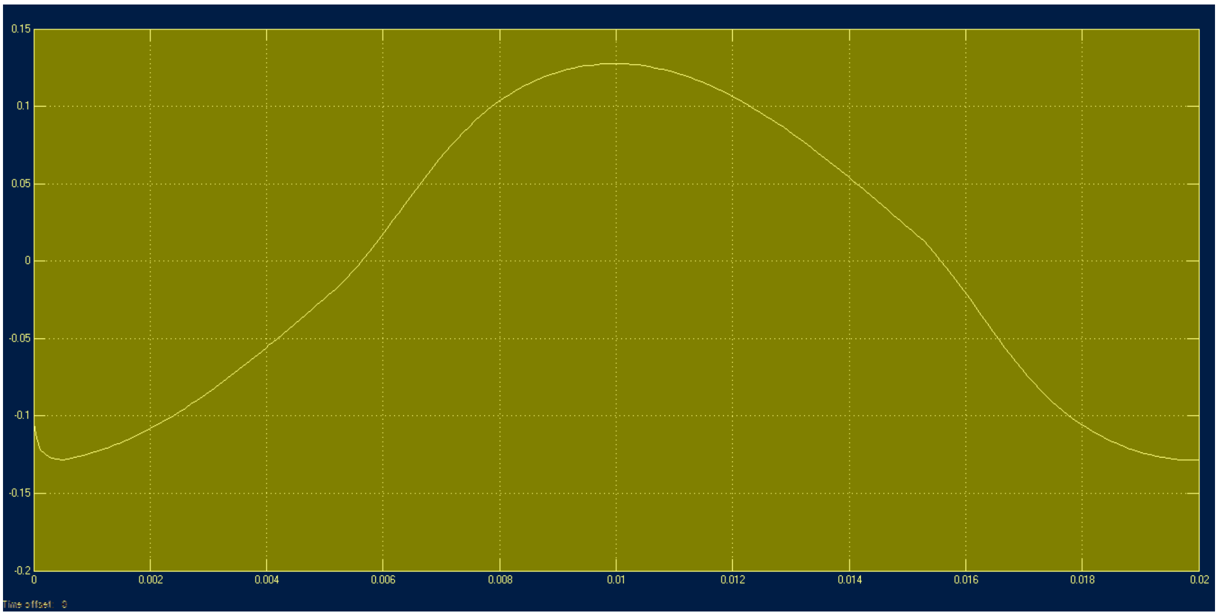
- More stable then active components
- Passive filters scale better to large signals (tens of amps, hundreds of volts), where active devices are often impractical
- No bandwidth limitation

8.2.4 Disadvantages Of Passive Compensation:-

- Humming noise affects the performance
- Presence of harmonics
- Low tolerance inductor which are very expensive
- generally not amenable to miniaturization
- Resonance affects the performance

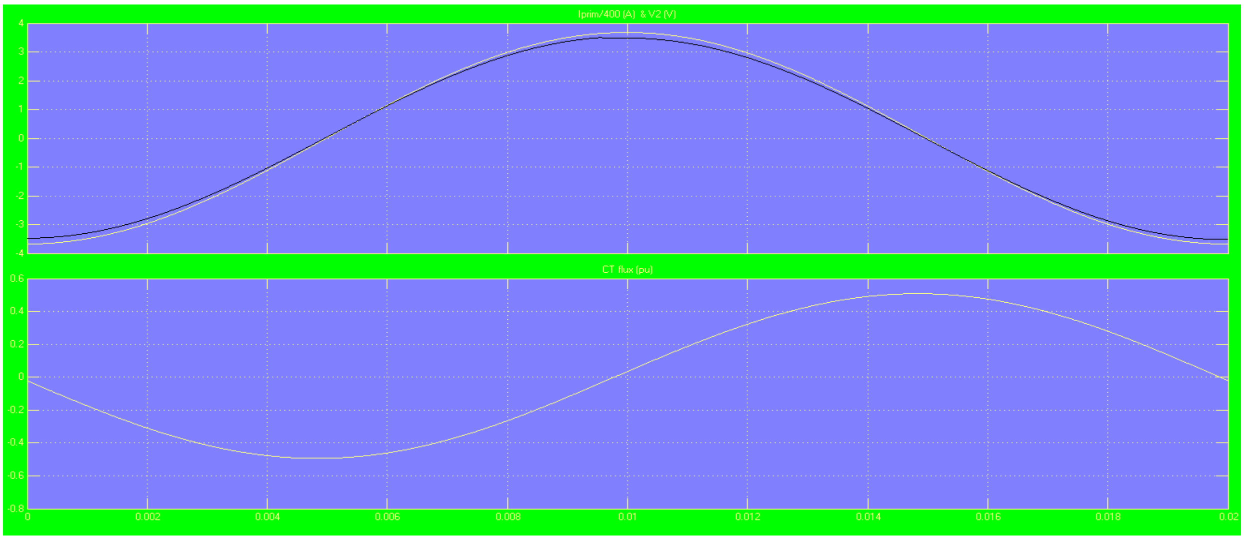
8.3 Waveforms:-

8.3.1 Error minimized:-



Fig(o)

8.3.2Voltage, current and CT flux :-



Fig(p)

8.4 Error compensation with active compensation

In our project we have used PID controller first we shall discuss the theory about PID controller.

8.4.1 Types of Controllers

Let us classify the controllers. There are mainly two **types of controllers** and they are written below: **Continuous Controllers:** The main feature of continuous controllers is that the controlled variable (also known as the manipulated variable) can have any value within the range of controller's output. Now in the continuous controller's theory, there are three basic modes on which the whole control action takes place and these modes are written below. We will use the combination of these modes in order to have a desired and accurate output.

8.4.1.1 Proportional controllers.

8.4.1.2 Integral controllers.

8.4.1.3 Derivative controllers.

Combinations of these three controllers are written below:

8.4.1.4 Proportional and integral controllers.

8.10.2.1 Proportional and derivative controllers.

Now we will discuss each of these modes in detail.

8.4.1.1 Proportional Controllers:-

We cannot use **types of controllers** at anywhere, with each type controller, there are certain conditions that must be fulfilled. With **proportional controllers** there are two conditions and these are written below:

Deviation should not be large, it means there should be less deviation between the input and output

Deviation should not be sudden.

Now we are in a condition to discuss proportional controllers, as the name suggests in a proportional controller the output (also called the actuating signal) is directly proportional to the error signal. Now let us analyze proportional controller mathematically. As we know in proportional controller output is directly proportional to error signal, writing this mathematically we have,

$$A(t) \propto e(t)$$

Removing the sign of proportionality we have,

$$A(t) = K_p \times e(t)$$

Where K_p is proportional constant also known as controller gain. It is recommended that K_p should be kept greater than unity. If the value of K_p is greater than unity, then it will amplify the error signal and thus the amplified error signal can be detected easily.

8.4.1.2 Integral Controllers:-

As the name suggests in **integral controllers** the output (also called the actuating signal) is directly proportional to the integral of the error signal. Now let us analyze integral controller mathematically. As we know in an integral controller output is directly proportional to the integration of the error signal, writing this mathematically we have,

$$A(t) \propto \int_0^t e(t)dt$$

Removing the sign of proportionality we have,

$$A(t) = K_i \times \int_0^t e(t)dt$$

Where K_i is integral constant also known as controller gain. Integral controller is also known as reset controller.

8.4.1.3 Derivative Controllers:-

We never use **derivative controllers** alone. It should be used in combinations with other modes of controllers because of its few disadvantages which are written below:

Now, as the name suggests in a derivative controller the output (also called the actuating signal) is directly proportional to the derivative of the error signal. Now let us analyze derivative controller mathematically. As we know in a derivative controller output is directly proportional to the derivative of the error signal, writing this mathematically we have,

$$A(t) \propto \frac{de(t)}{dt}$$

Removing the sign of proportionality we have,

$$A(t) = K_d \times \frac{de(t)}{dt}$$

Where K_d is proportional constant also known as controller gain. Derivative controller is also known as rate controller.

8.4.1.4 Proportional and Integral Controller:-

As the name suggests it is a combination of proportional and an integral controller the output (also called the actuating signal) is equal to the summation of proportional and integral of the error signal. Now let us analyze proportional and integral controller mathematically. As we know in a proportional and integral controller output is directly proportional to the summation of proportional of error and integration of the error signal, writing this mathematically we have

$$A(t) \propto \int_0^t e(t)dt + A(t) \propto e(t)$$

Removing the sign of proportionality we have,

$$A(t) = K_i \int_0^t e(t)dt + K_p e(t)$$

Where K_i and k_p proportional constant and integral constant respectively.

8.4.1.5 Proportional and Derivative Controller:-

As the name suggests it is a combination of proportional and a derivative controller the output (also called the actuating signal) is equals to the summation of proportional and derivative of the error signal. Now let us analyze proportional and derivative controller mathematically. As we know in a proportional and derivative controller output is directly proportional to summation of proportional of error and differentiation of the error signal, writing this mathematically we have,

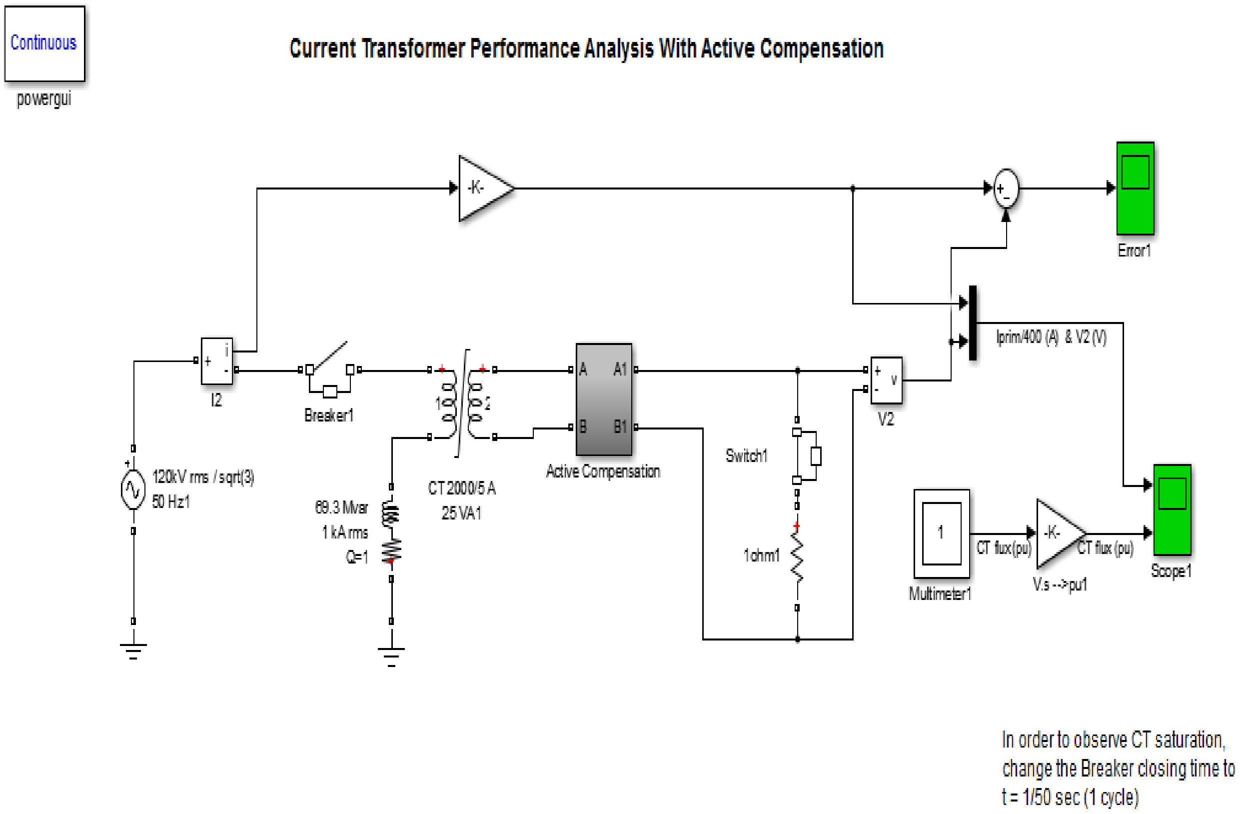
$$A(t) \propto \frac{de(t)}{dt} + A(t) \propto e(t)$$

Removing the sign of proportionality we have,

$$A(t) = K_d \frac{de(t)}{dt} + K_p e(t)$$

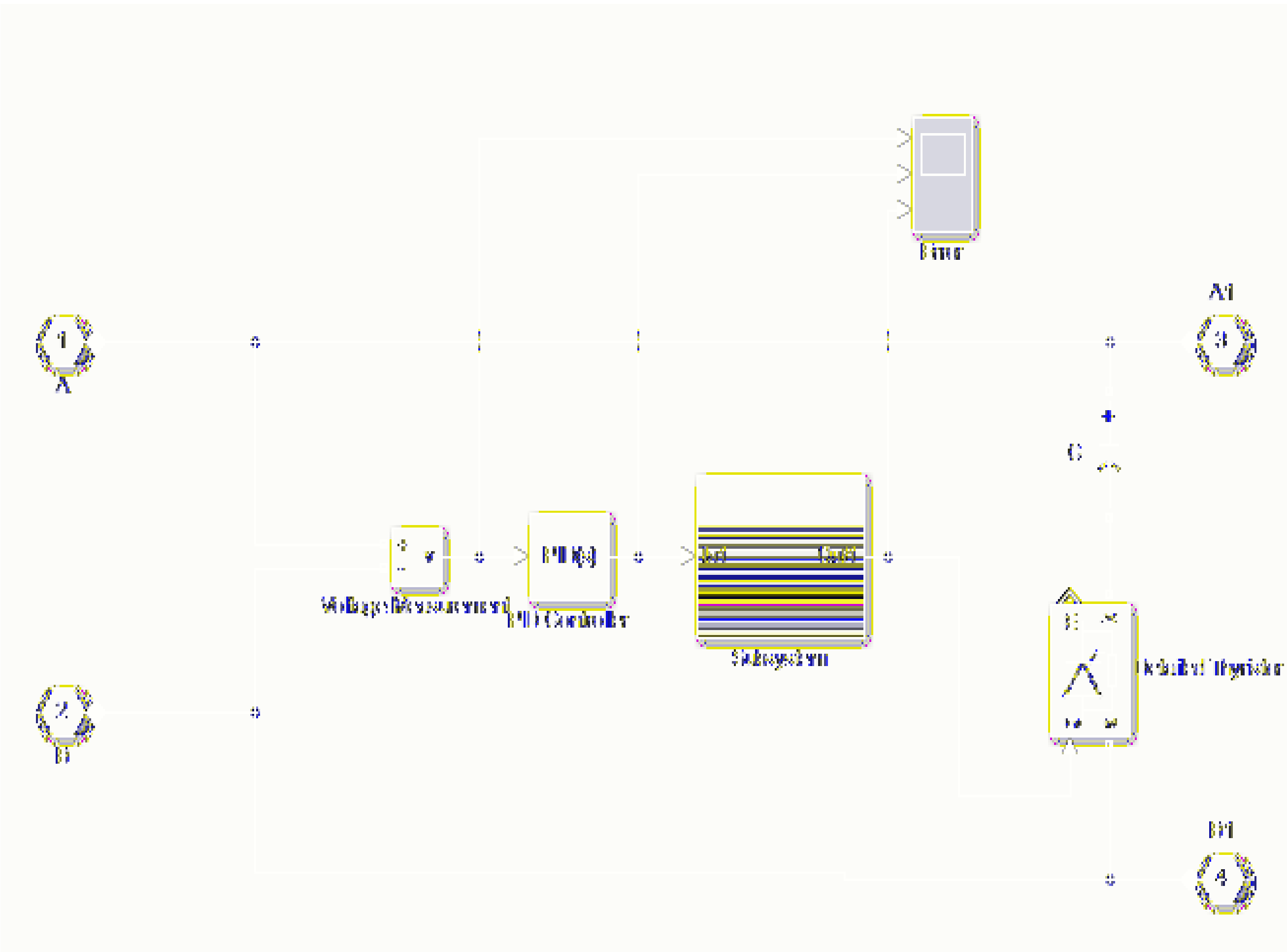
Where K_d and k_p proportional constant and derivative constant respectively.

8.5 Circuit Diagram:-



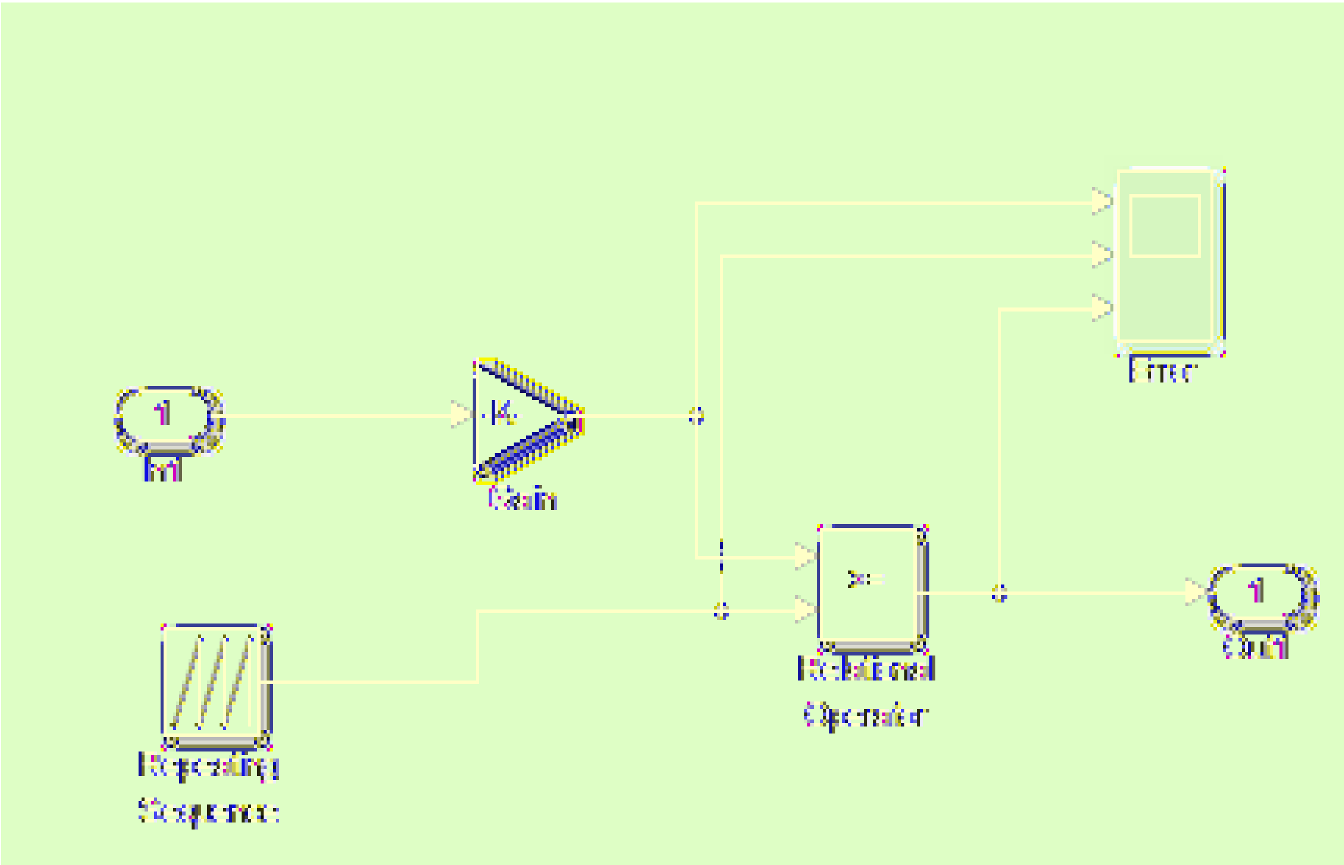
Fig(q)

8.5.1 PID Controller as an error compensating element:-



Fig(r)

8.5.2 Subsystem circuit diagram:-

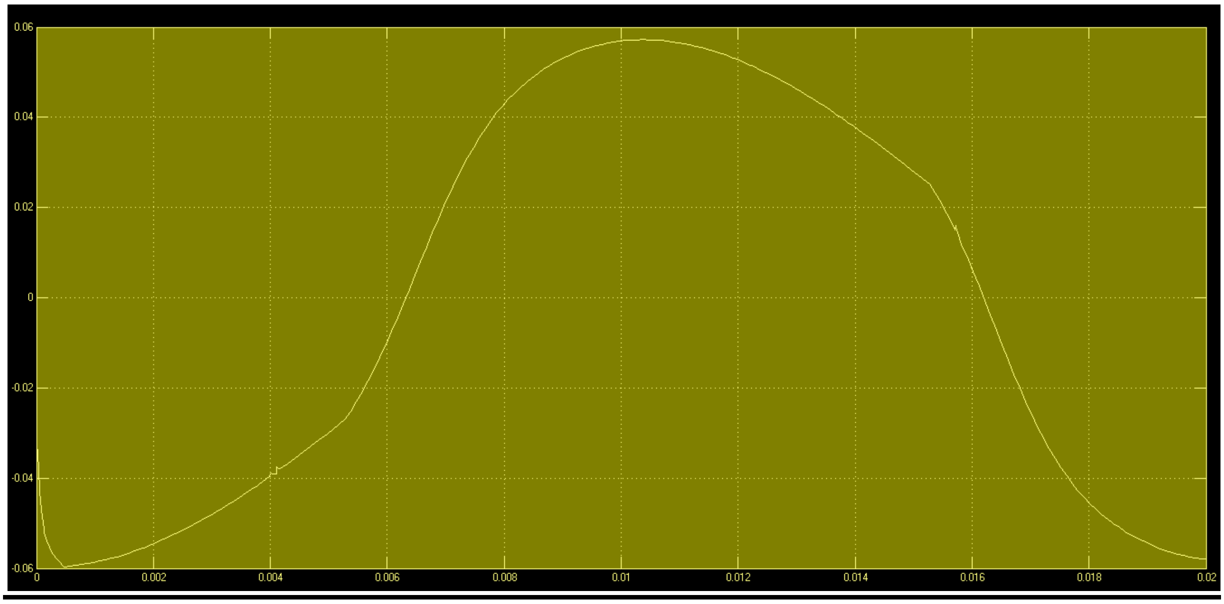


Fig(s)

8.6 Components used:-

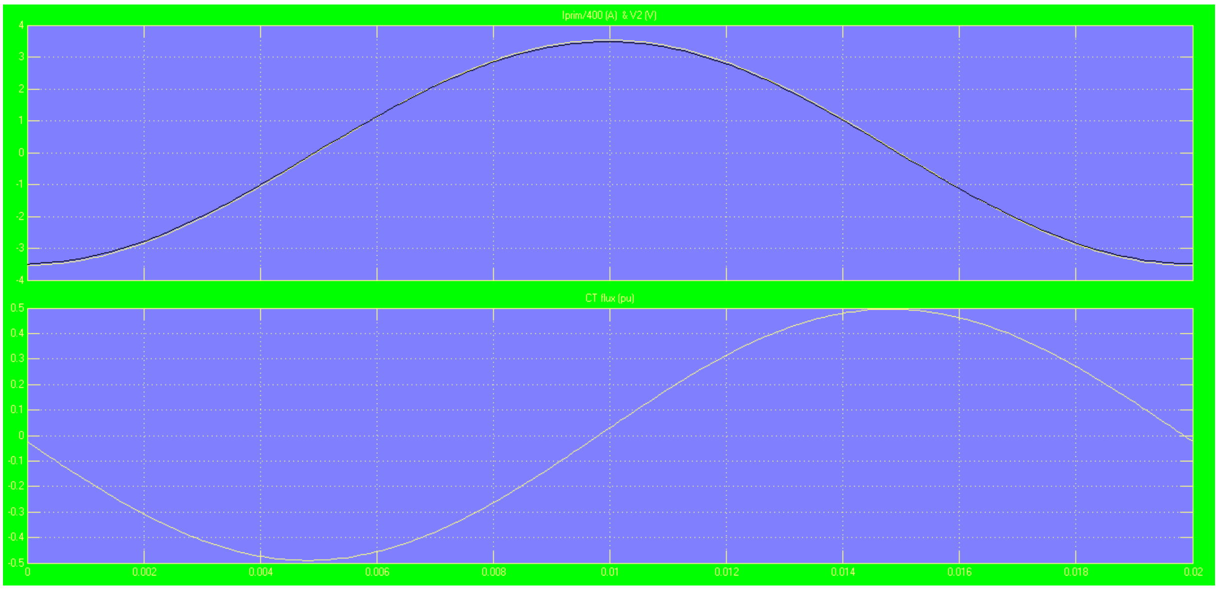
- AC vtg source(120KV)
- Continuous power gui
- Circuit breaker
- Current transformer(2000/5A,25VA)
- PID Controller as an error compensating element
- Ammeter
- Voltmeter
- Gain
- Summer
- Multiplexer
- Scope(for viewing error and measurement of current and voltage)
- Multimeter

8.7 Error minimized:-



Fig(t)

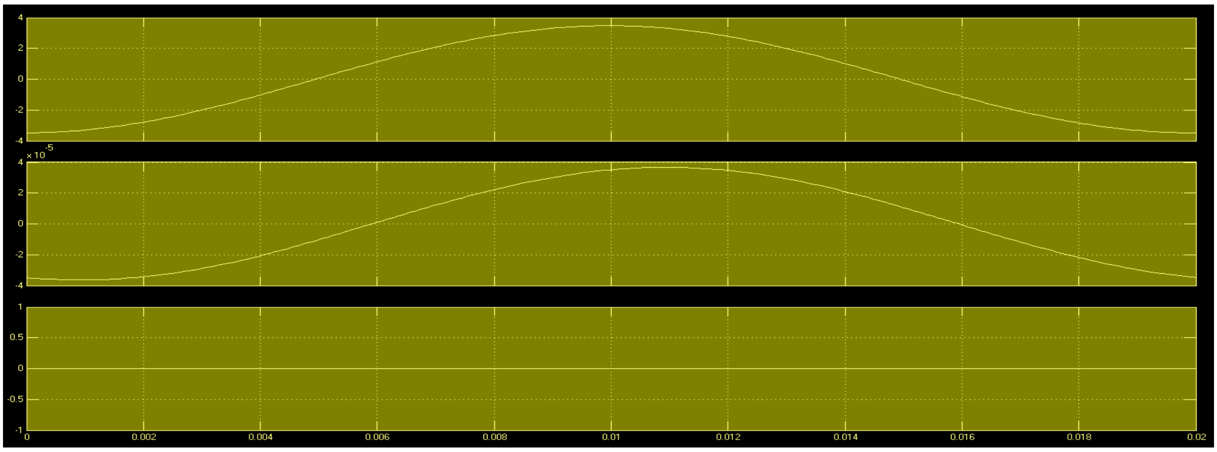
8.7.1 Voltage, current and CT flux :-



Fig(u)

8.8 PID controller waveforms:-

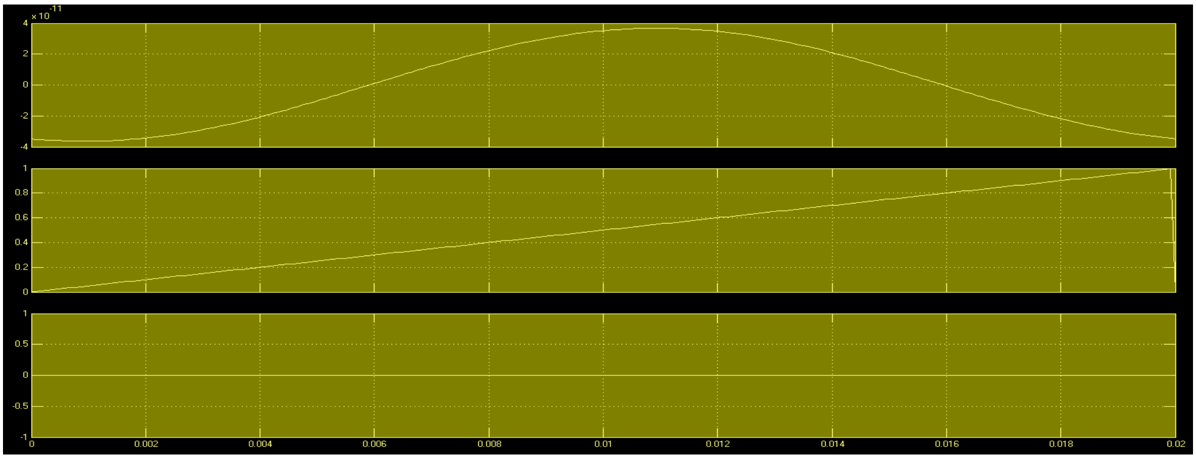
8.8.1 Error minimized



Fig(v)

8.9 Subsystem waveforms:-

8.9.1 Error waveform:-



Fig(w)

8.10 Advantages of Active compensation

8.10.1 Advantages of Proportional Controller

- Proportional controller helps in reducing the steady state error, thus makes the system morestable
- Slow response of the over damped system can be made faster with the help of these controllers.

8.10.2 Disadvantages of Proportional Controller

- Now there are some serious disadvantages of these controllers and these are written as follows:
- Due to presence of these controllers we some offsets in the system.
- Proportional controllers also increase the maximum overshoot of the system.

8.10.3 Advantages of Integral Controller

- Due to their unique ability they can return the controlled variable back to the exact set point following a disturbance that's why these are known as reset controllers.

8.10.4 Disadvantages of Integral Controller

- It tends to make the system unstable because it responds slowly towards the produced error.

8.10.5 Advantages of Derivative Controller

- The major advantage of derivative controller is that it improves the transient response of the system.

8.10.6 Disadvantages of Derivative Controller

- It never improves the steady state error.
- It produces saturation effects and also amplifies the noise signals produced in the system

CHAPTER 9

FUTURE SCOPE

We can implement our project practically in hardware form with any ckt having current transformer which will help in reducing the error which will help in increasing the magnitude of current.

We shall try to implement this project in hardware form in future .

9.1 CONCLUSION & RESULTS

Our project describes how the errors occurs in case of current transformers in detail and what are the possible steps to minimise these errors.

If this errors are minimised probably the faults occuring due to the ever increasing consumer demand may be cleared within fraction of time.

So, the efficiency of the power system along with the reliability may increase and the continuity of supply would be maintained

So, we hope that if our project is found to be successful it could be adopted in the existing power system power system network.

Error without compensation=0.1928

Error with passive compensation=0.1275

Error with active compensation=0.0572

BIBLIOGRAPHY

The information for the above report have been accessed from the following online URL:-

- Electrical4u.com
- Wikipedia.com
- Goodnews11.hubpages.com

Papers referred:

- PASSIVE AND ACTIVE COMPENSATIONS FOR CURRENT TRANSFORMERS