University of Global Village (UGV)

Department of Electrical and Electronic Engineering

Power System-I

Course Title: Power System-I Lab

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Course Rationale

The Power Systems Lab provides students with the practical skills and theoretical knowledge required to analyze, simulate, and test various power system components and behaviors. It emphasizes the importance of accurate modeling, efficient load flow analysis, transformer testing, and the role of protection systems in maintaining the reliability of electrical power networks. Students will gain experience using MATLAB and experimental setups to bridge the gap between academic concepts and real-world applications.

Course Objectives

1. To introduce students to power factor correction techniques and their role in improving system efficiency.
2. To develop hands-on skills in forming and verifying Y-Bus and Z-Bus matrices for power systems using MATLAB.
3. To provide practical experience in solving load flow problems using Gauss-Seidel, Newton-Raphson, and Fast Decoupled methods.
4. To demonstrate the operation and testing of protective devices such as differential relays, CTs, and PTs.
5. To analyze power system behavior under fault conditions and propose effective solutions.
6. To simulate and verify the performance of transformers and other essential components using advanced software tools.

Course Learning Outcomes (CLOs)

CLO Number	Learning Outcome
CLO1	Understand the principles of power factor improvement and evaluate its impact on power systems.
CLO2	Formulate and verify Y-Bus and Z-Bus matrices using both manual methods and MATLAB simulations.
CLO3	Solve load flow problems using Gauss-Seidel, Newton-Raphson, and Fast Decoupled methods and analyze results.
CLO4	Demonstrate the operation and testing of protective devices, including CTs, PTs, and differential relays.
CLO5	Analyze power system performance under various fault conditions using theoretical and software-based methods.
CLO6	Test and verify transformer performance using experimental setups and MATLAB-based simulations.

Table 1: Lab activities overview for Power System Lab course-I

Experiment No.	Experiment Title	Topics Covered	Theory Time (hours)	Practical Time (hours)	Learning Outcomes	CLOs
1	Study of Power Factor Improvement	Power factor correction, active/reactive/apparent power, capacitive compensation	1.5	2	Understand power factor correction mechanisms and their effect on efficiency.	CLO1, CLO2
2	Y-Bus Formation Using MATLAB	Y-bus matrix formation using direct inspection and MATLAB	2	2.5	Develop and verify Y-bus matrix formation for power systems using MATLAB.	CLO3, CLO4
3	Z-Bus Formation Using MATLAB	Z-bus matrix formation using Z-bus building algorithm and MATLAB	2	2.5	Create and validate Z-bus matrices for impedance calculations in power systems using MATLAB.	CLO3, CLO4
4	Gauss-Seidel Load Flow Analysis Using MATLAB	Load flow analysis, iterative methods, and Gauss-Seidel algorithm	2.5	2.5	Perform load flow studies using the Gauss-Seidel method in MATLAB.	CLO4, CLO5
5	Newton-Raphson Load Flow Analysis Using MATLAB	Newton-Raphson algorithm for power flow studies	2.5	2.5	Solve power flow problems using Newton-Raphson method and analyze system performance.	CLO4, CLO5
6	Fast Decoupled Load Flow Analysis Using MATLAB	Fast decoupled load flow algorithm and its application in power flow studies	2.5	2.5	Apply fast decoupled load flow analysis to optimize computation for power system studies.	CLO4, CLO5
7	Differential Protection of 1-Phase Transformer	Transformer protection, differential relay operation, internal fault detection	2.5	3	Understand and implement differential protection for transformers to detect internal faults.	CLO5, CLO6
8	CT Testing by Using Mutual Inductance	Current transformer testing, mutual inductance principles	2	2.5	Test CT performance using mutual inductance and analyze transformer behavior.	CLO6
9	PT Testing by Using Mutual Inductance	Potential transformer testing, comparison method, and ratio calculations	2	2.5	Evaluate PT performance using mutual inductance and validate ratio and phase angle accuracy.	CLO6

Table 2: Week-wise details with assessment and resources for Power System Lab course-I

Week No.	Experiment Title	Topics Covered	Theory Time (hours)	Practical Time (hours)	Learning Outcomes	CLOs
1	Study of Power Factor Improvement	Power factor correction, active/reactive/apparent power, capacitive compensation	1.5	2	Understand power factor correction mechanisms and their effect on efficiency.	CLO1, CLO2
2-3	Y-Bus Formation Using MATLAB	Y-bus matrix formation using direct inspection and MATLAB	2	2.5	Develop and verify Y-bus matrix formation for power systems using MATLAB.	CLO3, CLO4
4-5	Z-Bus Formation Using MATLAB	Z-bus matrix formation using Z-bus building algorithm and MATLAB	2	2.5	Create and validate Z-bus matrices for impedance calculations in power systems using MATLAB.	CLO3, CLO4
6-7	Gauss-Seidel Load Flow Analysis Using MATLAB	Load flow analysis, iterative methods, and Gauss-Seidel algorithm	2.5	2.5	Perform load flow studies using the Gauss-Seidel method in MATLAB.	CLO4, CLO5
8-9	Newton-Raphson Load Flow Analysis Using MATLAB	Newton-Raphson algorithm for power flow studies	2.5	2.5	Solve power flow problems using Newton-Raphson method and analyze system performance.	CLO4, CLO5
10-11	Fast Decoupled Load Flow Analysis Using MATLAB	Fast decoupled load flow algorithm and its application in power flow studies	2.5	2.5	Apply fast decoupled load flow analysis to optimize computation for power system studies.	CLO4, CLO5
12-13	Differential Protection of 1-Phase Transformer	Transformer protection, differential relay operation, internal fault detection	2.5	3	Understand and implement differential protection for transformers to detect internal faults.	CLO5, CLO6
14-15	CT Testing by Using Mutual Inductance	Current transformer testing, mutual inductance principles	2	2.5	Test CT performance using mutual inductance and analyze transformer behavior.	CLO6
16-17	PT Testing by Using Mutual Inductance	Potential transformer testing, comparison method, and ratio calculations	2	2.5	Evaluate PT performance using mutual inductance and validate ratio and phase angle accuracy.	CLO6

Experiment No. 01

Experiment Name: Study of Power Factor Improvement

Objectives

To understand the power diagram, active, reactive, apparent power, distorted power and power factor correction.

Theory

In a simple alternating current (AC) circuit consisting of a source and a linear load, both the current and voltage are sinusoidal. If the load is purely resistive, the two quantities reverse their polarity at the same time. At every instant the product of voltage and current is positive, indicating that the direction of energy flow does not reverse. In this case, only real power is transferred.

If the load is purely reactive, the voltage and current are 90 degrees out of phase. For half of each cycle, the product of voltage and current is positive. Still, on the other half of the cycle, the product is negative, indicating that on average, exactly as much energy flows toward the load as flows back. There is no net energy flow over one cycle. In this case, only reactive energy flows—no net energy transfer to the load.

Conventionally, capacitors are considered to generate reactive power and inductors to consume it. This is the fundamental mechanism for controlling the power factor in electric power distribution and transmission; capacitors (or inductors) are inserted in a circuit to cancel reactive power 'consumed' by the load partially.

Reactive power flow on the alternating current transmission system is needed to support the transfer of real power over the network. In alternating current circuits energy is stored temporarily in inductive and capacitive elements, which can result in the periodic reversal of the direction of energy flow. The portion of power flow remaining after being averaged over a complete AC waveform is the real power, which is energy that can be used to do work (for example overcome friction in a motor, or heat an element). On the other hand the portion of power flow that is temporarily stored in the form of electric or magnetic fields, due to inductive and capacitive network elements, and returned to source is known as the reactive power.

AC connected devices that store energy in the form of a magnetic field include inductive devices called reactors, which consist of a large coil of wire. When a voltage is initially placed across the coil a magnetic field builds up, and it takes a period of time for the current to reach full value. This causes the current to lag the voltage in phase, and hence these devices are said to absorb reactive power.

A capacitor is an AC device that stores energy in the form of an electric field. When current is driven through the capacitor, it takes a period of time for charge to build up to produce the full voltage difference. On an AC network the voltage across a capacitor is always changing – the capacitor will oppose this change causing the voltage to lag behind the current. In other words the current leads the voltage in phase, and hence these devices are said to generate reactive power.

Energy stored in capacitive or inductive elements of the network give rise to reactive power flow. Reactive power flow strongly influences the voltage levels across the network. Voltage levels and reactive power flow must be carefully controlled to allow a power system to be operated within acceptable limits.

The ratio between real power and apparent power in a circuit is called the power factor. It's a practical measure of the efficiency of a power distribution system. For two systems transmitting the same amount of real power, the system with the lower power factor will have higher circulating currents due to energy that returns to the source from energy storage in the load. These higher currents produce higher losses and reduce overall transmission efficiency. A lower power factor circuit will have a higher apparent power and higher losses for the same amount of real power.

The power factor is *one* when the voltage and current are *in phase*. It is *zero* when the current leads or lags the voltage by *90 degrees*. Power factors are usually stated as *"leading"* or *"lagging"* to show the sign of the phase angle, where leading indicates a negative sign.

Purely capacitive circuits cause reactive power with the current waveform leading the voltage wave by 90 degrees, while purely inductive circuits cause reactive power with the current waveform lagging the voltage waveform by 90 degrees. The result of this is that capacitive and inductive circuit elements tend to cancel each other out.

Where the waveforms are purely sinusoidal, the power factor is the cosine of the phase angle (φ) between the current and voltage sinusoid waveforms. Equipment data sheets and nameplates often will abbreviate power factor as "cosφ" for this reason.

Where the waveforms are not sinusoidal (for non – linear loads or electronic switching-based loads), the power factor is defined as the product of displacement factor ($\cos\varphi$) and distortion factor ($\frac{1}{\sqrt{1+(THDi)^2}\sqrt{1+(THDv)^2}}$) ≅ ($\frac{1}{\sqrt{1+(THDi)^2}}$). As most of the modern utility loads are non – linear. Therefore, conventional power factor (cosφ) measuring method will not produce actual results.

Equipment

- Watt & Power Factor Meter
- Resistive – Inductive Loads
- Resistive – Inductive – Capacitive Loads
- Uninterruptible Power Supply (UPS)
- Digital multimeter

Procedure

1. Connect the circuit as shown in Figure below.

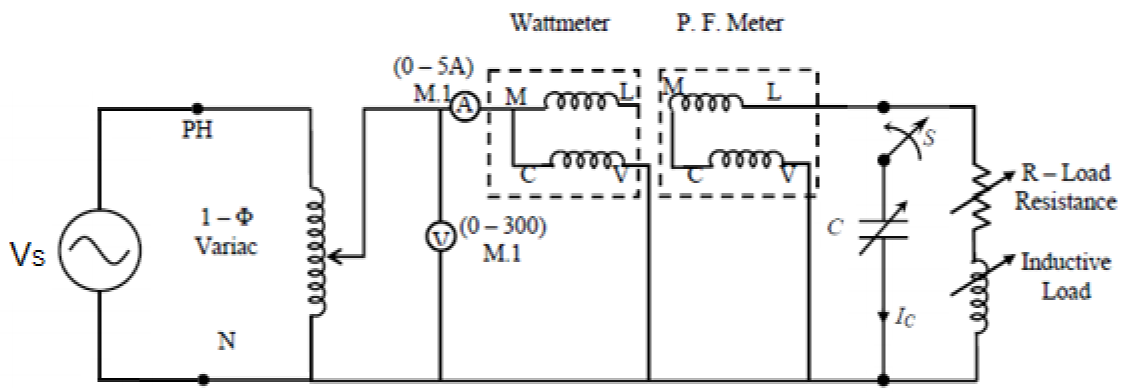


Figure : Circuit Diagram.

2. Connect the loads as per the specifications available in Table 1 and switch ON the power supply (Vs).
3. Measure the results without capacitor and put the reading in Table 1.
4. Note the power factor, total current and remaining parameters of the load without capacitor as per Table 1 Sr.#1 and put results in Table row#1.
5. Calculate the capacitance value for desired improved power factor as per example given below and install capacitor in parallel to load and put the reading in Table 1 Sr.#2.

Calculation: (Sample Calculation)

Sample calculations are performed for example as;

Example: A single-phase motor connected to 400V; 50 Hz supply takes 31.7 A at 0.7 lagging PF. Calculate the required capacitance to raise PF to 0.9 lagging.

Solution:

The active or wattful component of current remains the same before or after installing the capacitor.

As $I_M \cos\phi_M = I\cos\phi$

By putting values, we get

31.7x0.7 = Ix0.9

22.19 = Ix0.9

I = 24.65 A

The lagging reactive current reduces after PFI which is equal to difference between $I_M \sin\phi_M$ and I_C i.e.

$I\sin\phi = I_M \sin\phi_M - I_C$

24.65x0.436 = 31.7x0.714 $- I_C$

$I_C = 11.85\ A$

But $I_C = \frac{V}{X_C} = \frac{V}{1/2\pi f C} = V \times 2\pi f C$ Or $11.85\ A = 2\pi \times 50 \times C$

$\boldsymbol{C = 94.3 \times 10^{-6} F = 94.3 \mu F}$

Calculations:

$PF = \cos\phi = 0.9$

$\phi = \cos^{-1} PF = 25.842$

$\sin\phi = \sin 25.842 = 0.436$

Similarly

$PF = \cos\phi_M = 0.7$

$\phi_M = \cos^{-1} PF = 45.573$

$\sin\phi_M = \sin 45.573 = 0.714$

6. Connect the an electronic based non – linear load (UPS) as per Table 1 Sr.#3, measure the readings and put in respective row#3 of Table 1.
7. Assume desired PF value.
8. Calculate the capacitance value as per the PF calculations for harmonic based loads.
9. Install capacitor and put the measured results in Table 1 Sr.#4.
10. Verify and compare the calculated results with measured results of Table 1 Sr.#2 & 4. Are these results similar and if not, please justify.

Result:

Table 1: Measurement & Calculations Results.

Sr #	Load (W)	Vi	Total current (A)	Ic (A)	I_L(A)	cos θ	W	VAR	VA	X_C	C
1	R – L Load without Capacitor	220									

2	R – L Load with Capacitor										
3	R – L and UPS Load without Capacitor										
4	R – L and UPS Load with Capacitor										

Conclusi

EXP.NO: 02

Experiment Name: Y_{BUS} FORMATION USING MATLAB

Objective:

To obtain the Y_{bus} matrix for the given power system using Direct inspection and verify it using MATLAB.

Apparatus Required:

Personal Computer with MATLAB software.

Problem on formation of y_{bus}:

Find the Y_{bus} matrix for the given power system data using Direct inspection method

Sending end	Receiving end	Reactance values in ohms
1	2	j0.15
2	3	j0.10
1	3	j0.20
1	4	j0.10
4	3	j0.15

PROGRAM FOR YBUS FORMATION USING THE GIVEN DATA:

```
% ***** Matlab code for Ybus formation by direct inspection
method********** %

clc;
close all;
clear all;
zdata=[1 2 0 0.15;
1 3 0 0.2;
1 4 0 0.1;
 2 3 0 0.1;
3 4 0 0.15];
nl=zdata(:,1);                    % Sending end bus
nr=zdata(:,2);                    % Receiving end bus
R=zdata(:,3);                     % Resistance
X=zdata(:,4);                     % Reactance
nbr=length(zdata(:,1));
nbus = max(max(nl), max(nr));
Z = R + j*X;                      %branch impedance
y= ones(nbr,1)./Z;                %branch admittance
Ybus=zeros(nbus,nbus);            % initialize Ybus to zero
for k = 1:nbr;   % formation of the off diagonal elements

    if nl(k) > 0 & nr(k) > 0
    Ybus(nl(k),nr(k)) = Ybus(nl(k),nr(k)) - y(k);
    Ybus(nr(k),nl(k)) = Ybus(nl(k),nr(k));
    end
end
for n = 1:nbus       % formation of the diagonal elements
    for k = 1:nbr
    if nl(k) == n | nr(k) == n
    Ybus(n,n) = Ybus(n,n) + y(k);
    else
 end
    end
end
Ybus
```

COMMANDS USED IN THE PROGRAM:

- ybus is the command used to obtain the admittance matrix for the given system data using direct inspection method.
- zdata matrix consists of four columns in which
- 1^{st} column represent sending end
- 2^{nd} column represents receiving end
- 3^{rd} column represents resistance between the sending and receiving end
- 4^{th} column represents reactance between the sending and receiving end

<u>Expected Output:</u>

```
Ybus =

   0.0000 -21.6667i   0.0000 + 6.6667i   0.0000 + 5.0000i   0.0000 +10.0000i
   0.0000 + 6.6667i   0.0000 -16.6667i   0.0000 +10.0000i   0.0000 + 0.0000i
   0.0000 + 5.0000i   0.0000 +10.0000i   0.0000 -21.6667i   0.0000 + 6.6667i
   0.0000 +10.0000i   0.0000 + 0.0000i   0.0000 + 6.6667i   0.0000 -16.6667i
```

<u>Actual Output:</u>

EXP.NO: 03

Experiment Name: Z BUS FORMATION USING MATLAB

Objective:

To obtain the Z_{bus} matrix for the given power system using Z_{bus} building algorithm and to verify the same using MATLAB.

Apparatus Required:

Personal Computer with MATLAB software.

Problem On Formation Of Z_{bus}:

Find the bus impedance matrix using Z_{bus} building algorithm for the given power system whose reactance values are as follows.

Sending end	Receiving end	Reactance values in ohms
0	1	j0.05
1	2	j0.75
0	2	j0.075
2	3	j0.45
1	3	j0.3

COMMANDS USED IN THE PROGRAM:

- zbuild is the command used to obtain the impedance matrix for the given system data using Zbus building algorithm.

- linedata matrix consists of four columns in which
- 1st column represent sending end
- 2nd column represents receiving end
- 3rd column represents resistance between the sending and receiving end in ohms
- 4th column represents reactance between the sending and receiving end in ohms

PROGRAM FOR FORMATION OF Z_{BUS} USING THE GIVEN DATA:

```
clc
clear all
close all
linedata=[0 1 0 0.05
0 2 0 0.075
1 2 0 0.75
1 3 0 0.30
2 3 0 0.45];
nl = linedata(:,1); nr = linedata(:,2); R = linedata(:,3);
X = linedata(:,4);
nbr=length(linedata(:,1)); nbus = max(max(nl), max(nr));
ZB = R + j*X;
Zbus = zeros(nbus, nbus);
tree=0;  %%%%new
% Adding a branch from a new bus to reference bus 0
  for I = 1:nbr
  ntree(I) = 1;
      if nl(I) == 0 | nr(I) == 0
          if nl(I) == 0
              n = nr(I);
          elseif nr(I) == 0
              n = nl(I);
          end
              if abs(Zbus(n, n)) == 0
                  Zbus(n,n) = ZB(I);
                  tree=tree+1;%%new
                              end
              ntree(I) = 2;

      end
  end

% Adding a branch from new bus to an existing bus
while tree < nbus  %%% new

  for n = 1:nbus
     nadd = 1;
     if abs(Zbus(n,n)) == 0
        for I = 1:nbr
            if nadd == 1;
                if nl(I) == n | nr(I) == n
                   if nl(I) == n
                       k = nr(I);
                   elseif nr(I) == n
                       k = nl(I);
                   end
                     if abs(Zbus(k,k)) ~= 0
                          for m = 1:nbus
                              if m ~= n
                              Zbus(m,n) = Zbus(m,k);
                              Zbus(n,m) = Zbus(m,k);
```

```
                        else, end
                    end
                    Zbus(n,n) = Zbus(k,k) + ZB(I);
                    tree=tree+1; %%new
                    nadd = 2;
                    ntree(I) = 2;
               else
               end
          else
          end
      else
      end
   end
  else
  end
end


end  %%%%%%new

% Adding a link between two old buses
  for n = 1:nbus
      for I = 1:nbr
          if ntree(I) == 1
             if nl(I) == n | nr(I) == n
                 if nl(I) == n
k = nr(I);
                 elseif nr(I) == n
k = nl(I);
                 end
             DM = Zbus(n,n) + Zbus(k,k) + ZB(I) - 2*Zbus(n,k);
                  for jj = 1:nbus
                  AP = Zbus(jj,n) - Zbus(jj,k);
                       for kk = 1:nbus
                       AT = Zbus(n,kk) - Zbus(k, kk);
                       DELZ(jj,kk) = AP*AT/DM;
                       end
                  end
                  Zbus = Zbus - DELZ;
                  ntree(I) = 2;
             else,
end
          else,
end
      end

  end
Zbus
```

Expected Output:

```
Zbus =

   0.0000 + 0.0450i   0.0000 + 0.0075i   0.0000 + 0.0300i
   0.0000 + 0.0075i   0.0000 + 0.0638i   0.0000 + 0.0300i
   0.0000 + 0.0300i   0.0000 + 0.0300i   0.0000 + 0.2100i
```

ACTUAL OUTPUT:

Experiment No: 04
Experiment Name: GAUSS-SEIDEL LOAD FLOW ANALYSIS USING MATLAB

Objective:

To solve power flow problems by the method of Gauss-Seidel using MATLAB.

Apparatus Required:-

S.No	Apparatus	Quantity
01	MATLAB Software	1

Procedure:-

1. Turn on your personal computer.
2. Click on the MATLAB icon of your personal computer.
3. Click the file button and select the new Blank M-file.
4. Type the program on the new M-file for corresponding bus system.
5. After completion of the program, save and run.
6. Note down the line flow and losses.
7. Close the MATLAB tool and turnoff your pc.

PROGRAM:-

```
% Program for Gauss - Seidel Load Flow Analysis

clc;
close all;
clear all;
%          From    TO    Resistance Reactance
linedata = [ 1      2      0.10    0.20;
         1      4      0.05    0.20;
         1      5      0.08    0.30;
         2      3      0.05    0.25;
         2      4      0.05    0.10;
         2      5      0.10    0.30;
         2      6      0.07    0.20;
         3      5      0.12    0.26;
         3      6      0.02    0.10;
         4      5      0.20    0.40;
         5      6      0.10    0.30];
nl=linedata(:,1);               % Sending end bus
nr=linedata(:,2);               % Receiving end bus
R=linedata(:,3);                % Resistance
X=linedata(:,4);                % Reactance
nbr=length(linedata(:,1));
nbuses = max(max(nl), max(nr));
Z = R + j*X;                         %branch impedance
y= ones(nbr,1)./Z;                   %branch admittance
Ybus=zeros(nbuses,nbuses);           % initialize Ybus to zero
for k = 1:nbr;  % formation of the off diagonal elements
   if nl(k) > 0 & nr(k) > 0
   Ybus(nl(k),nr(k)) = Ybus(nl(k),nr(k)) - y(k);
   Ybus(nr(k),nl(k)) = Ybus(nl(k),nr(k));
   end
end
for n = 1:nbuses        % formation of the diagonal elements
   for k = 1:nbr
   if nl(k) == n | nr(k) == n
   Ybus(n,n) = Ybus(n,n) + y(k);
   else
 end
   end
end
% |Bus|Type| Vsp |theta |PGi |QGi | PLi | QLi | Qmin | Qmax |
busdata = [ 1     1    1.05     0     0.0    0    0      0      0      0;
            2    2    1.05     0     0.5    0    0      0    -0.5   1.0;
            3    2    1.07     0     0.6    0    0      0    -0.5   1.5;
            4    3    1.0      0     0.0    0   0.7    0.7     0      0;
            5    3    1.0      0     0.0    0   0.7    0.7     0      0;
            6    3    1.0      0     0.0    0   0.7    0.7     0      0 ];
bus = busdata(:,1); % Bus number
type = busdata(:,2); % Type of Bus 1-Slack, 2-PV, 3-PQ.
```

```
V = busdata(:,3); % Initial Bus Voltages.
th = busdata(:,4); % Initial Bus Voltage Angles.
GenMW = busdata(:,5); % PGi, Real Power injected into the buses.
GenMVAR = busdata(:,6); % QGi, Reactive Power injected into the buses.
LoadMW = busdata(:,7); % PLi, Real Power Drawn from the buses.
LoadMVAR = busdata(:,8); % QLi, Reactive Power Drawn from the buses.
Qmin = busdata(:,9); % Minimum Reactive Power Limit
Qmax = busdata(:,10); % Maximum Reactive Power Limit
nbus = max(bus); % To get no. of buses
P = GenMW - LoadMW; % Pi = PGi - PLi, Real Power at the buses.
Q = GenMVAR - LoadMVAR; % Qi = QGi - QLi, Reactive Power at the buse
Vprev = V;
toler = 1; % Tolerence.
iteration = 1; % iteration starting
while (toler > 0.00001) % Start of while loop
 for i = 2:nbus
 sumyv = 0;
 for k = 1:nbus
 if i ~= k
 sumyv = sumyv + Ybus(i,k)* V(k); % Vk * Yik
 end
 end
 if type(i) == 2 % Computing Qi for PV bus
 Q(i) = -imag(conj(V(i))*(sumyv + Ybus(i,i)*V(i)));
 if (Q(i) > Qmax(i)) || (Q(i) < Qmin(i)) % Checking for Qi Violation.
 if Q(i) < Qmin(i) % Whether violated the lower limit.
 Q(i) = Qmin(i);
 else % No, violated the upper limit.
 Q(i) = Qmax(i);
 end
 type(i) = 3; % If Violated, change PV bus to PQ bus.
 end
 end
 V(i) = (1/Ybus(i,i))*((P(i)-j*Q(i))/conj(V(i)) - sumyv); % Compute Bus Voltages.
 if type(i) == 2 % For PV Buses, Voltage Magnitude remains same, but Angle changes.
     r=abs(Vprev(i));
     o=angle(V(i));
 V(i) = r*cos(o) + j*r*sin(o);  % rect = real + j*imag

 end
 end
 iteration = iteration + 1; % Increment iteration count.
 toler = max(abs(abs(V) - abs(Vprev))); % Calculate tolerance.
 Vprev = V; % Vprev is required for next iteration, V(i) = pol2rect(abs(Vprev(i)), angle(V(i)));
end % End of while loop / Iteration
iteration; % Total iterations.
V; % Bus Voltages in Complex form.
Vmag = abs(V); % Final Bus Voltages.
Ang = 180/pi*angle(V); % Final Bus Voltage Angles in Degree
disp('******************************************** ')
disp('          Gauss Seidel Load-Flow Study    ')
```

```
disp('****************************************** ')
disp('      Bus      Voltage     Angle ')
disp('      no       Volts       Degree ')
ywz=[  bus(:,1)      Vmag              Ang ];
disp(ywz)
disp('****************************************** ')
```

Experiment No. 05
Experiment Name: Newton Raphson Method Load Flow Analysis Using Matlab

Objective:
To solve power flow problems by the method of NR using MATLAB.

Apparatus Required:-

S.No	Apparatus	Quantity
1	MATLAB Software	1

Procedure:-

1. Turn on your personal computer.
2. Click on the MATLAB icon of your personal computer.
3. Click the file button and select the new Blank M-file.
4. Type the program on the new M-file for corresponding bus system.
5. After completion of the program, save and run.
6. Note down the line flow and losses.
7. Close the MATLAB tool and turnoff your pc.

PROGRAM:

```
% Program for Newton Raphson Load Flow Analysis

clc;
close all;
clear all;
%             From    To       R          X
%             Bus     Bus      (pu)       (pu)
linedata=[    1       2        0.0192     0.0575
              1       3        0.0452     0.1652
              2       4        0.0570     0.1737
              3       4        0.0132     0.0379
              2       5        0.0472     0.1983
              2       6        0.0581     0.1763
              4       6        0.0119     0.0414
              5       7        0.0460     0.1160
              6       7        0.0267     0.0820
              6       8        0.0120     0.0420
              6       9        0.0        0.2080
              6      10        0.0        0.5560
              9      11        0.0        0.2080
              9      10        0.0        0.1100
              4      12        0.0        0.2560
             12      13        0.0        0.1400
             12      14        0.1231     0.2559
             12      15        0.0662     0.1304
             12      16        0.0945     0.1987
             14      15        0.2210     0.1997
             16      17        0.0824     0.1923
             15      18        0.1073     0.2185
             18      19        0.0639     0.1292
             19      20        0.0340     0.0680
             10      20        0.0936     0.2090
             10      17        0.0324     0.0845
             10      21        0.0348     0.0749
             10      22        0.0727     0.1499
             21      23        0.0116     0.0236
             15      23        0.1000     0.2020
             22      24        0.1150     0.1790
             23      24        0.1320     0.2700
             24      25        0.1885     0.3292
             25      26        0.2544     0.3800
             25      27        0.1093     0.2087
             28      27        0.0        0.3960
             27      29        0.2198     0.4153
             27      30        0.3202     0.6027
             29      30        0.2399     0.4533
              8      28        0.0636     0.2000
              6      28        0.0169     0.0599     ];
nl=linedata(:,1);                  % Sending end bus
nr=linedata(:,2);                  % Receiving end bus
R=linedata(:,3);                   % Resistance
X=linedata(:,4);                   % Reactance
nbr=length(linedata(:,1));
No_of_Bus = max(max(nl), max(nr));
Z = R + j*X;                               %branch impedance
y= ones(nbr,1)./Z;                        %branch admittance
Ybus=zeros(No_of_Bus,No_of_Bus);              % initialize Ybus to zero
for k = 1:nbr;    % formation of the off diagonal elements
    if nl(k) > 0 & nr(k) > 0
```

```
    Ybus(nl(k),nr(k)) = Ybus(nl(k),nr(k)) - y(k);
    Ybus(nr(k),nl(k)) = Ybus(nl(k),nr(k));
    end
end

for n = 1:No_of_Bus        % formation of the diagonal elements
    for k = 1:nbr
    if nl(k) == n | nr(k) == n
    Ybus(n,n) = Ybus(n,n) + y(k);
    else
 end
    end
end
% Bus     Bus    Vol    Vol       Generating     Load       Reactive Power limit
          % no    type   Mag     angle       Pg     QG      Pl      Ql      Qmax     Qmin
busdata=  [ 1      1     1.06     0          0       0       0       0       0        0;
            2      2     1.043    0         40    50.0    21.7    12.7     -40       50;
            3      3     1.0      0          0       0     2.4     1.2       0        0;
            4      3     1.06     0          0       0     7.6     1.6       0        0;
            5      2     1.01     0          0    37.0    94.2    19.0     -40       40;
            6      3     1.0      0          0       0     0.0     0.0       0        0;
            7      3     1.0      0          0       0    22.8    10.9       0        0;
            8      2     1.01     0          0    37.3    30.0    30.0     -10       40;
            9      3     1.0      0          0       0     0.0     0.0       0        0;
            10     3     1.0      0          0    19.0     5.8     2.0       0        0;
            11     2     1.082    0          0    16.2     0.0     0.0      -6       24;
            12     3     1.0      0          0       0    11.2     7.5       0        0;
            13     2     1.071    0          0    10.6     0.0     0.0      -6       24;
            14     3     1.0      0          0       0     6.2     1.6       0        0;
            15     3     1.0      0          0       0     8.2     2.5       0        0;
            16     3     1.0      0          0       0     3.5     1.8       0        0;
            17     3     1.0      0          0       0     9.0     5.8       0        0;
            18     3     1.0      0          0       0     3.2     0.9       0        0;
            19     3     1.0      0          0       0     9.5     3.4       0        0;
            20     3     1.0      0          0       0     2.2     0.7       0        0;
            21     3     1.0      0          0       0    17.5    11.2       0        0;
            22     3     1.0      0          0       0     0.0     0.0       0        0;
            23     3     1.0      0          0       0     3.2     1.6       0        0;
            24     3     1.0      0          0     4.3     8.7     6.7       0        0;
            25     3     1.0      0          0       0     0.0     0.0       0        0;
            26     3     1.0      0          0       0     3.5     2.3       0        0;
            27     3     1.0      0          0       0     0.0     0.0       0        0;
            28     3     1.0      0          0       0     0.0     0.0       0        0;
            29     3     1.0      0          0       0     2.4     0.9       0        0;
            30     3     1.0      0          0       0    10.6     1.9       0        0
];
        G=real(Ybus);    % Separation of YBus
        B=imag(Ybus);
        BMva=100;
busNo=busdata(:,1);
type=busdata(:,2);
V=busdata(:,3);
del=busdata(:,4);
Pg=busdata(:,5)/BMva;
Qg=busdata(:,6)/BMva;
Pl=busdata(:,7)/BMva;
Ql=busdata(:,8)/BMva;
Qmin=busdata(:,9)/BMva;
Qmax=busdata(:,10)/BMva;
PV_Bus=find(type==2|type==1);
```

```
PQ_Bus=find(type==3);    % type1(Slack),type2(PV_Bus Bus),type3(PQ_Bus Bus )
```

```
No_of_PQ_Bus=length(PQ_Bus);
No_of_PV_Bus=length(PV_Bus);
Active_Power_specified=Pg-Pl;
Reactive_Power_specified=Qg-Ql; % Net Power flow through different node
Iter=1;Tol=1; % Iterantion And tolerance
while Tol>1e-5
    P=zeros(No_of_Bus,1);
    Q=zeros(No_of_Bus,1);
    for i=1:No_of_Bus
        for j=1:No_of_Bus
 P(i)=P(i)+V(i)*V(j)*(G(i,j)*cos(del(i)-del(j))+B(i,j)*sin(del(i)-del(j)));
 Q(i)=Q(i)+V(i)*V(j)*(G(i,j)*sin(del(i)-del(j))-B(i,j)*cos(del(i)-del(j)));
        end
    end
    % Verification of limit violation for reactive power
    if Iter>2 && Iter<=7
        for n=2:No_of_Bus
            if type(n)==2;
                QG=Q(n)+Ql(n);
                if QG > Qmax(n)
                    V(n)=V(n)-0.01;
                elseif QG < Qmin(n)
                    V(n)=V(n)+0.01;
                end
            end
        end
    end

    dPa=Active_Power_specified-P;
    dQa=Reactive_Power_specified-Q;
    dP=dPa(2:No_of_Bus);
    k=1;
    dQ=zeros(No_of_PQ_Bus,1);
    for i=1:No_of_Bus
        if type(i)==3
            dQ(k,1)=dQa(i);
            k=k+1;
        end
    end
    M=[dP;dQ];% delta Matrix
    %% Formation Fo Jacobian Matrix[J1 J2;J3 J4]
    %% Formation Of J1
    J1=zeros(No_of_Bus-1,No_of_Bus-1);
    for i=1:No_of_Bus-1
        m=i+1;
        for j=1:No_of_Bus-1;
            n=j+1;
            if m==n
                for n=1:No_of_Bus
                J1(i,j)=J1(i,j)+V(m)*V(n)*(-G(m,n)*sin(del(m)-
del(n))+B(m,n)*cos(del(m)-del(n)));
                end
                J1(i,j)=J1(i,j)-V(m)^2*B(m,m);
            else
                 J1(i,j)=V(m)*V(n)*(G(m,n)*sin(del(m)-del(n))-
B(m,n)*cos(del(m)-del(n)));
            end
        end
    end
    %% Formation Of J2
    J2=zeros(No_of_Bus-1,No_of_PQ_Bus);
    for i=1:No_of_Bus-1
```

```
m=i+1;
```

```
        for j=1:No_of_PQ_Bus
            n=PQ_Bus(j);
            if m==n
                for n=1:No_of_Bus
                    J2(i,j)=J2(i,j)+V(n)*(G(m,n)*cos(del(m)-
del(n))+B(m,n)*sin(del(m)-del(n)));
                end
                J2(i,j)=J2(i,j)+V(m)*G(m,m);
            else
                J2(i,j)=V(m)*(G(m,n)*cos(del(m)-del(n))+B(m,n)*sin(del(m)-
del(n)));
            end
        end
    end



    %% Formation Of J3
    J3=zeros(No_of_PQ_Bus,No_of_Bus-1);
    for i=1:No_of_PQ_Bus
        m=PQ_Bus(i);
        for j=1:No_of_Bus-1
            n=j+1;
            if m==n
                for n=1:No_of_Bus
                    J3(i,j)=J3(i,j)+V(m)*V(n)*(G(m,n)*cos(del(m)-
del(n))+B(m,n)*sin(del(m)-del(n)));
                end
                J3(i,j)=J3(i,j)-V(m)^2*G(m,m);
            else
                J3(i,j)=V(m)*V(n)*(-G(m,n)*cos(del(m)-del(n))-
B(m,n)*sin(del(m)-del(n)));
            end
        end
    end
    %% Formation Of J4
    J4=zeros(No_of_PQ_Bus,No_of_PQ_Bus);
    for i=1:No_of_PQ_Bus
        m=PQ_Bus(i);
        for j=1:No_of_PQ_Bus
            n=PQ_Bus(j);
            if m==n
                for n=1:No_of_Bus
                J4(i,j)=J4(i,j)+V(n)*(G(m,n)*sin(del(m)-del(n))-
B(m,n)*cos(del(m)-del(n)));
                end
                J4(i,j)=J4(i,j)-V(m)*B(m,m);
            else
                J4(i,j)=V(m)*(G(m,n)*sin(del(m)-del(n))-B(m,n)*cos(del(m)-
del(n)));
            end
        end
    end



   J=[J1 J2;J3 J4]; % Jacobian Matrix
   X=inv(J)*M;
    dTh=X(1:No_of_Bus-1); % Change in angle
    dV=X(No_of_Bus:end);     % change in volatge mag
    del(2:No_of_Bus)=del(2:No_of_Bus)+dTh; % Voltage angle update
    % voltage mag update
```

```
k=1;
for n=2:No_of_Bus
    if type(n)==3
        V(n)=V(n)+dV(k);
        k=k+1;
    end
```

```
    end
    Iter=Iter+1;
    Tol=max(abs(M));
end

Q=zeros(No_of_Bus,1);
 for i=1:No_of_Bus
        for j=1:No_of_Bus
            P(i)=P(i)+V(i)*V(j)*(G(i,j)*cos(del(i)-
del(j))+B(i,j)*sin(del(i)-del(j)));
            Q(i)=Q(i)+V(i)*V(j)*(G(i,j)*sin(del(i)-del(j))-
B(i,j)*cos(del(i)-del(j)));
        end
 end
 for i=1:No_of_Bus
     del(i)=180*del(i)/pi; % Converion radian to degree
 end

disp('***************************************** ')
disp('       Newton Raphson Load-Flow Study    ')
disp('***************************************** ')
disp('      Bus      Voltage     Angle ')
disp('      no       Volts       Degree ')
ywz=[ busNo(:,1)      V          del ];
disp(ywz)
disp('*****************************************  ')
```

Experiment No. 06
Experiment Name: Fast Decoupled Load Flow Analysis Using Matlab

Objective:
To solve power flow problems by the method of fast decoupled using MATLAB.

Apparatus Required:-

S.No	Apparatus	Quantity
4	MATLAB Software	1

Procedure:-
1. Turn on your personal computer.
2. Click on the MATLAB icon of your personal computer.
3. Click the file button and select the new Blank M-file.
4. Type the program on the new M-file for corresponding bus system.
5. After completion of the program, save and run.
6. Note down the line flow and losses.
7. Close the MATLAB tool and turnoff your pc.

PROGRAM:

```
% Program for Fast decoupled  Load Flow Analysis

clc;
close all;
clear all;

%        from to  Resistance Reactance%
line = [1 4     0.0     0.0576;
        4 5     0.017   0.092;
        5 6     0.039   0.17;
        3 6     0.0     0.0586;
        6 7     0.0119  0.1008;
        7 8     0.0085  0.072;
        8 2     0.0     0.0625;
        8 9     0.032   0.161;
        9 4     0.01    0.085];
nl=line(:,1);                 % Sending end bus
```

```
nr=line(:,2);                   % Receiving end bus
R=line(:,3);                    % Resistance
X=line(:,4);                    % Reactance
nbr=length(line(:,1));
nbuses = max(max(nl), max(nr));
Z = R + j*X;                                %branch impedance
y= ones(nbr,1)./Z;                         %branch admittance
Ybus=zeros(nbuses,nbuses);              % initialize Ybus to zero
for k = 1:nbr;    % formation of the off diagonal elements
    if nl(k) > 0 & nr(k) > 0
    Ybus(nl(k),nr(k)) = Ybus(nl(k),nr(k)) - y(k);
    Ybus(nr(k),nl(k)) = Ybus(nl(k),nr(k));
    end
end
for n = 1:nbuses        % formation of the diagonal elements
    for k = 1:nbr
    if nl(k) == n | nr(k) == n
    Ybus(n,n) = Ybus(n,n) + y(k);
    else
 end
    end
end
b = -imag(Ybus);
%   |Bus| Vsp |theta |PGi |QGi | PLi | QLi | Qmin | Qmax |type
bus = [ 1       1.04     0.00    0.00       0.00  0.00   0.00  0.00
0.00 1;
        2       1.02533  0.00    1.63      0.00   0.00   0.00   0.00
0.00 2;
        3       1.02536  0.00    0.85      0.00   0.00   0.00   0.00
0.00 2;
        4       1.00     0.00    0.00      0.00   0.00   0.00   0.00
0.00 3;
        5       1.00     0.00    0.00      0.00   0.90   0.30   0.00
0.00 3;
        6       1.00     0.00    0.00      0.00   0.00   0.00   0.00
0.00 3;
        7       1.00     0.00    0.00      0.00   1.00   0.35   0.00
0.00 3;
        8       1.00     0.00    0.00      0.00   0.00   0.00   0.00
0.00 3;
        9       1.00     0.00    0.00      0.00   1.25   0.50   0.00
0.00 3];

%formation of b' matrtix
b1=zeros(nbuses-1,nbuses-1);
for i = 1:nbuses-1
    for j = 1:nbuses-1
        b1(i,j) =b(i+1,j+1);
    end
end
b1;
```

```
%formation of b" matrtix
%assuming all the load buses are at last
b2=zeros(nbuses-3,nbuses-3);
for i = 1:nbuses-3
    for j = 1:nbuses-3
        b2(i,j) =b(i+3,j+3);
    end
end
b2;
v = bus(:,2);
del = bus(:,3);
Pg = bus(:,4);
Qg = bus(:,5);
Pd = bus(:,6);
Qd = bus(:,7);
Pspec = Pg-Pd;
Qspec = Qg-Qd;
iter = 1;
slack = 1;
tolerance = .01;
flag=1;
while flag==1;

    m = real(Ybus);
    n = imag(Ybus);
    P = zeros(nbuses,1);
    Q = zeros(nbuses,1);
    iter= iter+1;


for i=1:nbuses     %finding  bus real and reactive power
    for j=1:nbuses
        P(i)  = P(i)+  (v(i)*v(j)*(m(i,j)*cos(del(i)-
del(j))+n(i,j)*sin(del(i)-del(j))));
        Q(i)  = Q(i)+  (v(i)*v(j)*(m(i,j)*sin(del(i)-del(j))-
n(i,j)*cos(del(i)-del(j))));
    end
end

P
Q
%finding del P by v
for i=1:(nbuses-1)
    if(i<slack)
        delP(i,1)= Pspec(i)-P(i);
    else
        delP(i,1)=(Pspec(i+1)-P(i+1));

    end
    delPbyv(i,1)=delP(i,1)/v(i,1);
end
```

```
 %finding del Q by v
c=0;
for i=1:nbuses
    if bus(i,10)==3
        c=c+1;
        delQ(c,1)= (Qspec(i)-Q(i));
        delQbyv(c,1)= delQ(c,1)/v(i,1);
    end
end

if max(abs(delP))>tolerance | max(abs(delQ))>tolerance
    flag=1;    % tolerance check
else
    flag=0;
end


%calc correction vector
deldel = inv(b1)*delPbyv;
delv = inv(b2)*delQbyv;

%updating values
for i=1:(nbuses-1)
    del(i+1,1)= del(i+1,1)+deldel(i,1);
end

c=0;
for i=1:nbuses
    if bus(i,10)==3
        c=c+1;
        v(i,1)=v(i,1)+delv(c,1);
    end
end

iter
v
del
end
disp('*******************************************  ')
disp('    Fast   decoupled   Load-Flow   Study    ')
disp('*******************************************  ')
disp('      Bus       Voltage      Angle ')
disp('      no        Volts        Degree ')
ywz=[  bus(:,1)       v             del ];
disp(ywz)
disp('*******************************************  ')
```

Exp. No.: 07
Experiment Name: Differential Protection Of 1 – Phase Transformer

Objectives:

To protect the transformer from any internal faults in between primary and secondary by detecting the primary and secondary currents, using the differential protection relays.

Apparatus Required:

1) An Isolation transformer 500VA, 230V/230V
2) Differential protection unit
3) 1 - ϕ Variac 10A, 230V/270V
4) Rheostat 100 ohms /5A

Theory:

In distribution transformers, if any fault occurs in oil, can be detected by Buchholz relay and the transformer will be protected by Buchholz relay trip mechanism. But this relay will not protect if any fault occurs within the transformer windings. Hence to protect the transformer from fault currents in primary & secondary windings, the differential protection relay to be used.

The current coil in the relay will sense the fault currents and will activate the trip circuit of the relay and disconnect the load from transformer when fault currents are detected

The CTs` used in primary & secondary as per the circuit shown below, are connected to the respected relays of primary & secondary in series when fault currents occur than the relay gets activated and trip the load.

Description:

Generally "Differential protection" is provided in the electrical power transformer rated more than 5 MVA. The differential relays normally respond to those faults which occur inside the differential protection zone of the transformer.

The differential relay actually detects the primary and secondary faults, if any, and in turn trip the load connected to the transformer. The primary current Ip and secondary current Is is set in the relay through set mechanism and if any faults occurs in the transformer, these currents will increase the set value, then the trip mechanism will activate and trips the relay.

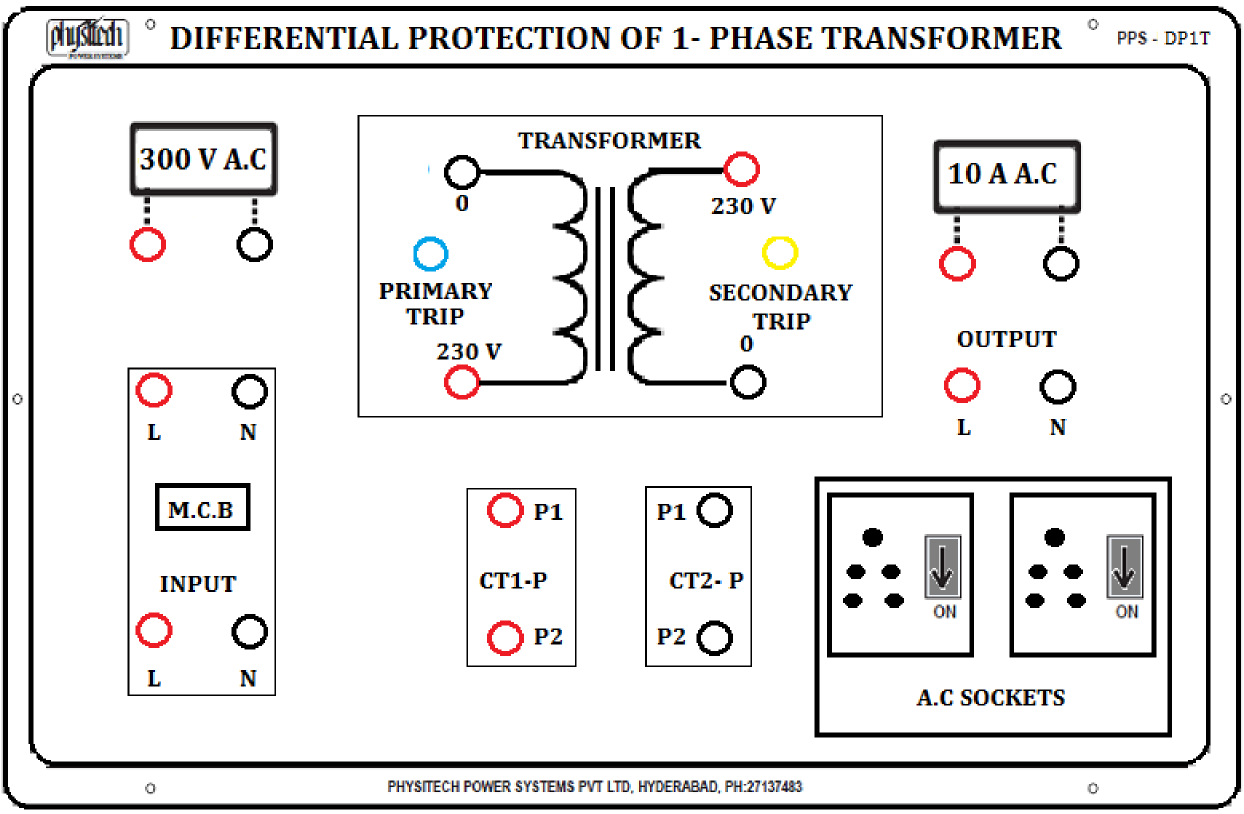
Principal of Operation:

Principle of differential protection scheme is one simple technique. The differential relay actually compares primary & secondary currents of the power transformer, if any unbalance is found in between primary and secondary currents the relay will actuate and in turn trip the primary and Secondary breakers (here we have used potential free contacts of relays).Hence the transformer will be protected from any fault currents .

Front Panel Details:

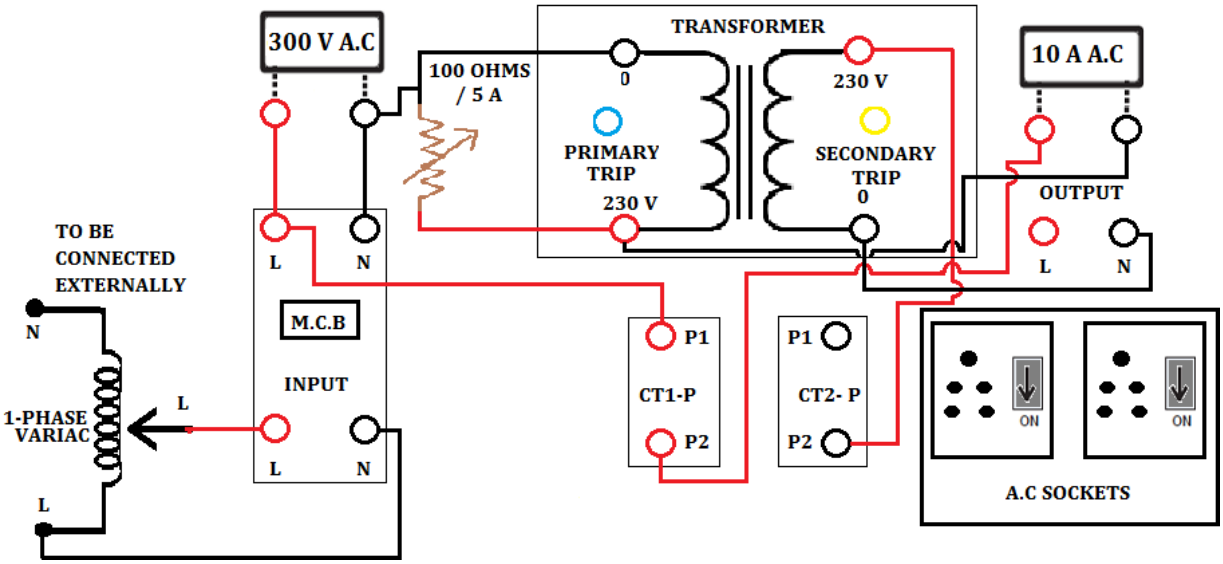
1. Voltmeter : Digital Voltmeter AC 300V to read output Voltage
2. Ammeter : Digital AC Ammeter 10A to read output Secondary current
3. MCB : Input ON/OFF
4. Input Terminals : To connect AC Voltage from variac to unit
5. Transformer Terminals : 500VA Transformer to be connected from outside to these terminals (primary &secondary respectively)
6. CT-P & CT-S Terminals : To connect CT-P, to input of the transformer in series to the input line,
   To connect CT-S to output of the transformer in series to the O/P line
7. Output : Load shall be connected across the output terminals

Front Panel Lay Out:

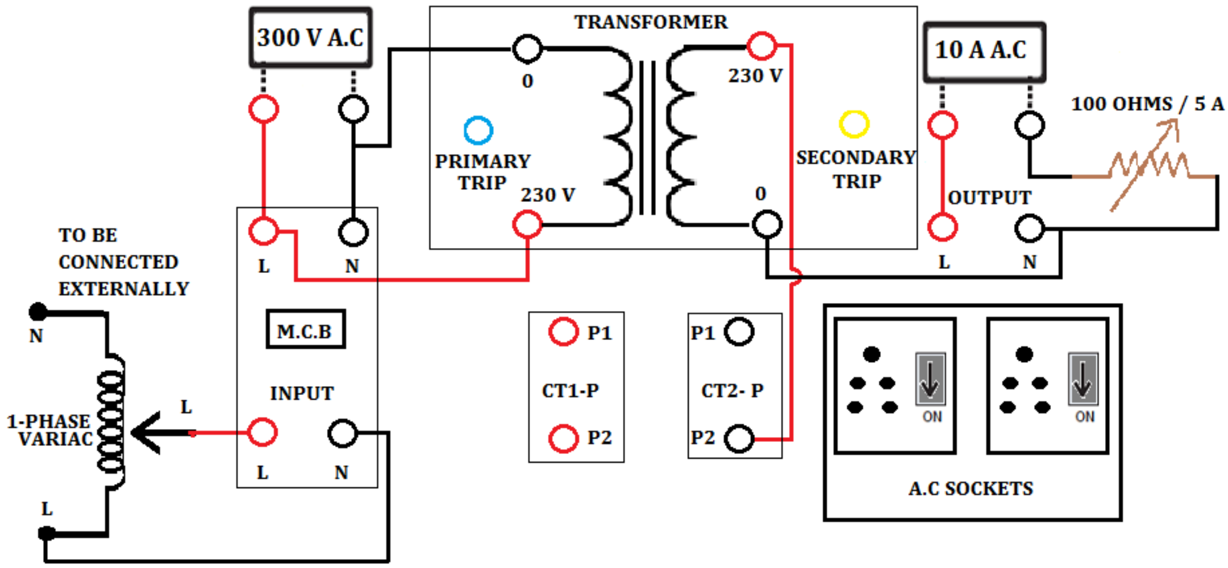


Wiring diagram:

PRIMARY TRIP WIRING DIAGRAM



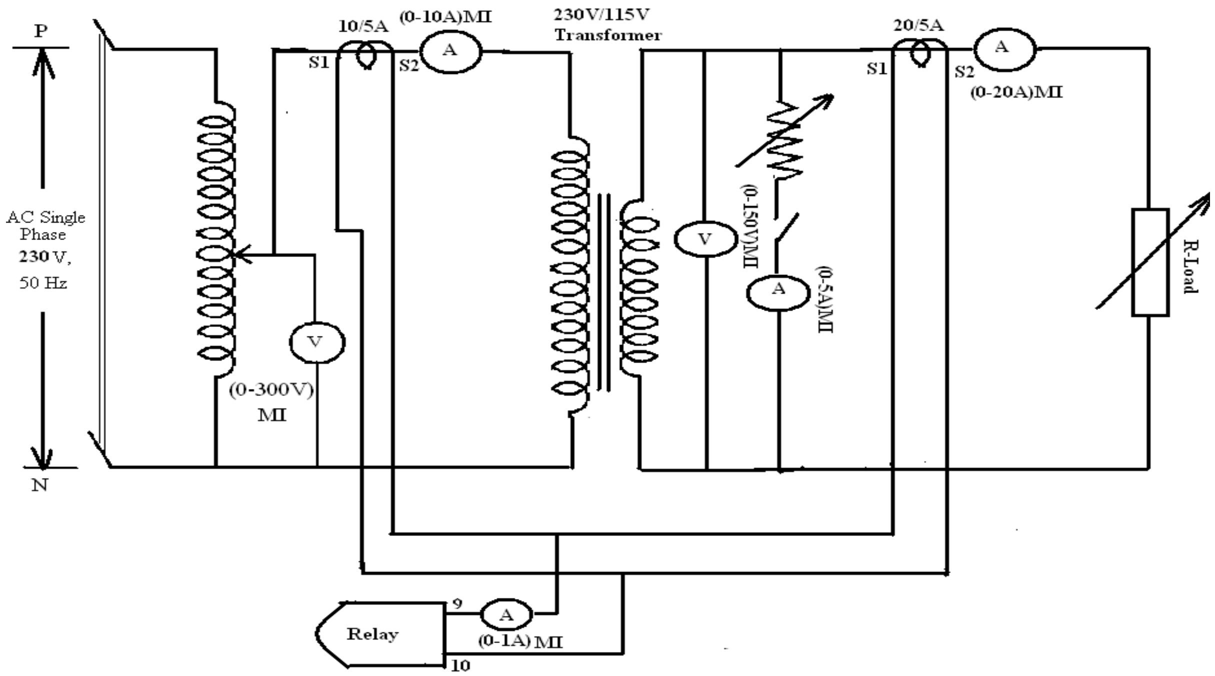
SECONDARY TRIP WIRING DIAGRAM



Wiring Procedure:

1. Connect 1-Phase ,230/270VVariac to input of the control unit at L&N terminals
2. Connect MCB output terminals to transformer terminals through CT-P in series.
3. (L to CT-P 1 end and CT-P 2 to transformer line terminal and neutral to transformer neutral.
4. Connect voltmeter across primary of transformer
5. Connect transformer secondary line to CTS1 terminal & neutral to neutral
6. Connect load across the output
7. Switch on the variac & MCB of control unit
8. Increase supply voltage up to 230V
9. Increase the load up to, since it is more than set value and gets disconnected. Secondary trip lamp indicators
10. Connect load across primary current is more than rated current, primary gets disconnected and primary trip lamp indicates.

CIRCUIT DIAGRAM:



PROCEDURE:

1. Make the connections as shown in fig.
2. Select the transformation ratio 2:1 and the C.T. ratios of 2:1 and 4:1Set PSM of the relay equalto 0.5.
3. Apply rated voltage 230V to primary by varying the variac.
4. Without applying fault, note down different meter readings.
5. By applying load observe whether the relay is operating or not.
6. Now close the switch so as to create an internal fault.
7. Note the various ammeter readings when relay operates.
8. Create primary fault at different loads and note the various meter readings.

9. Now create a secondary fault and observe whether the relay operates or not, note the various meter readings.

READINGS AND TABULAR FORM:

For Primary Fault

S.No	$I_{Primary}$	$I_{Secondary}$	I_{relay}	I_{fault}	Relay operates /doesn't operate

For Secondary Fault

S.No	$I_{Primary}$	$I_{secondary}$	I_{relay}	I_{fault}	Relay operates /doesn't operate

RESULT:

The Differential protection of single phase transformer was demonstrated When the balanced currents are flowing through transformer, load is in active condition. If any faults occurs across primary & secondary winding the particular windings gets disconnected and verified.

Exp. No.: 08
Experiment Name: CT TESTING BY USING MUTUAL INDUCTANCE

Objectives:

To test a given Current Transformer (CT) by using Resistance and Mutual Inductance.

APPARATUS:

a) Rheostat 50 ohms/ 2 amps…. 01 no
b) Galvanometer AC………. 01 no
c) Ammeters digital, 2 A…. 02 no`s
d) Built-in CT'S, current sources & mutual Inductance.

THEORY:

The current transformer is used with its primary winding connected in series with lines carrying the current to be measured and hence, the primary current I dependent upon the load connected to the system and is not determined by the load connected to the secondary winding of the current transformer. Te primary winding consists of a few turns only so, there is no appreciable voltage drop across it. The secondary winding of the current transformer has more number of turns, the exact number being determined b the turn's ratio. The ammeter is connected directly across the secondary winding terminals. Thus, a current transformer operates its secondary winding nearly under short circuit conditions.

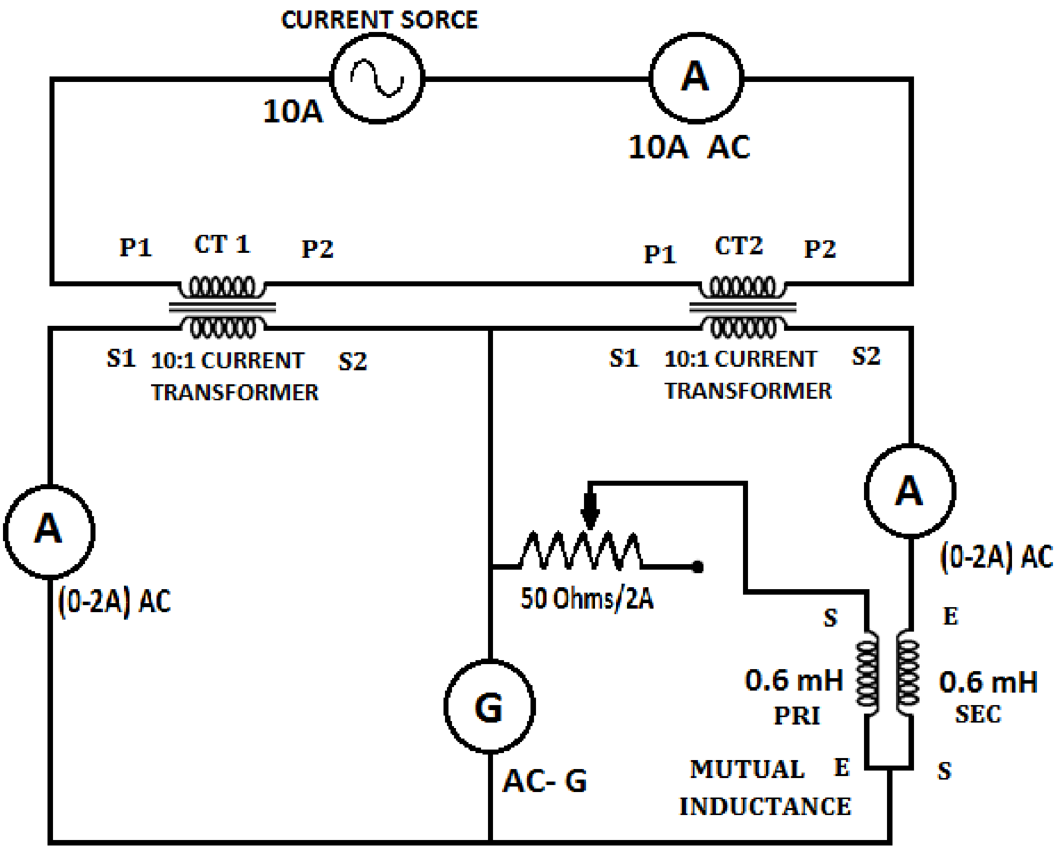
S and X are standard and are unknown transformers respectively, the primary winding is connected in series and supplied with current from a suitable source. The secondary windings are also connected in series, with such polarity that both tend to send current in the same direction, and any desired impedance loads such as Zs and Zx complete the circuit. A suitable detector D is then connected so as to bridge across between the transformers.

It is evident that the current $\Delta\tau$ through the detectors is necessarily equal to the vector differences in the secondary current IS AND Ik of the transformers. Consequently, if the magnitude and phase are measured, the difference in performance of the two transformers can be computed.

PROCEDURE:

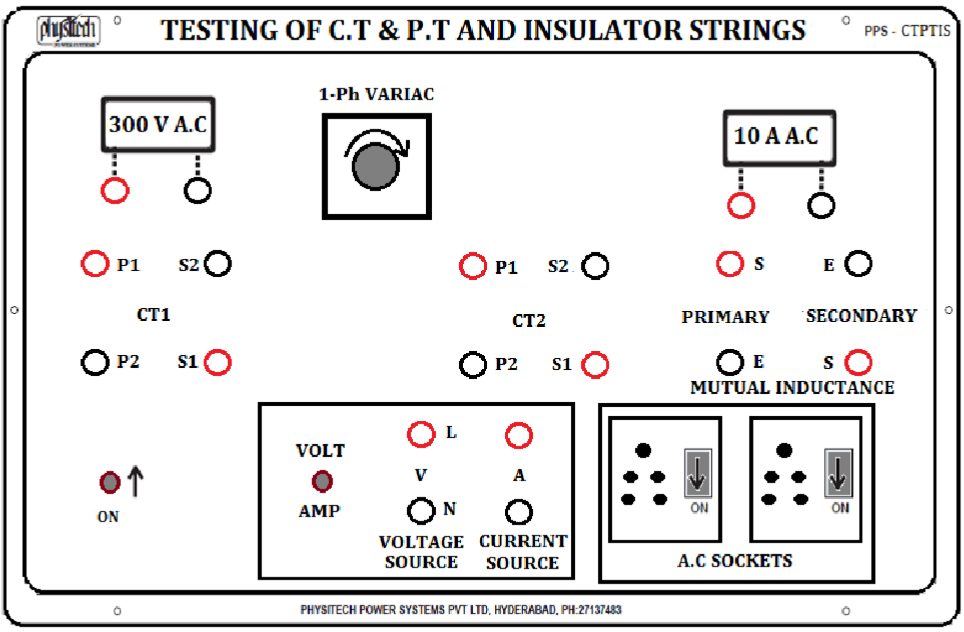
1) Connect the circuit as per the diagram given below.
2) Switch on the supply and increase the voltage to primary winding of PT by varying the auto transformer, and note down the readings.
3) Adjust the rheostat (r) such that the galvanometer reads zero (null deflector), then again note down the readings.
4) Bring back the auto transformer to its initial position and switch of the supply.

CIRCUIT DIAGRAM:



Front panel:

For both C.T & P.T



PRECAUTIONS:

- All connections should be tight and right as per the given circuit diagram.
- Proper range of meters should be selected.
- Un-insulated parts shouldn't be touched.
- Ammeter should always be connected in series, and volt meter in parallel with the circuit.
- Before switching ON the circuit, check whether the position of pointer in the meters is at zero or not, if not then bring them to zero.
- Checks for parallax error, if it exists then remove it.

TABULAR COLUMN:

S.No	C.T Range	CT Primary Current (A)	CT Secondary Current (A)
1			
2			

RESULT: Current Transformer (CT) is tested by using the given resistance and Mutual Inductance.

Exp. No.: 09
Experiment Name: PT TESTING BY USING MUTUAL INDUCTANCE

Objective:

To test a given Potential Transformer by using Mutual Inductance.

APPARATUS:

1) Potential Transformer, 230 V /230 V - 01 No
2) Galvanometer, AC - 01 No
3) Built-in Mutual Inductance - 01 No
4) Built-in 1-phaseVariac, 230/270 V, AC, 2 amps - 01 No
5) Rheostat, 50 ohms/2 amps - 01 No
6) Digital Voltmeter, AC, 300 V - 01 No
7) Digital Ammeters, AC, 2 amps - 02 No`s
8) Rheostat, 150 ohms/2amps - 01 No

THEORY:

The transformer used for voltage measurement in a given circuit are called potential transformers or P.T's. Potential transformers are used to operate voltmeters, the potential coils of watt meters and relays from high voltage lines. The P.T's are as similar to power transformers except loading and is quite small.

Effect of power factor:

The transformation ratio of the PT is increased if secondary burden is inductive in nature. The power factor reduces if secondary burden increases and power factor increases if burden is reduced and it can be observed by connecting an adjustable inductive load across the P.T.

Comparison method:

This method is similar to Silsbee's deflection comparison method for current transformers. The ratio and phase angle errors of a test transformer are determined in the terms of a standard transformer having a same ratio. The two transformers primaries are joined together in parallel. The load is to be connected in the secondary of the test transformer

The two wattmeter's voltage coils are to be connected across the standard transformer and current coils are connected in series and supply to be taken from phase shifting transformer. The voltmeters are to be connected across both the transformers and ammeter to be connected across the secondary of the test transformer.

Test method:

1) Supply to be given to the transformers from Variac.
2) Apply 230V AC to the P.T
3) Supply to be given to the phase shifting transformer
4) Adjust the rheostat such that wattmeter w reads zero.

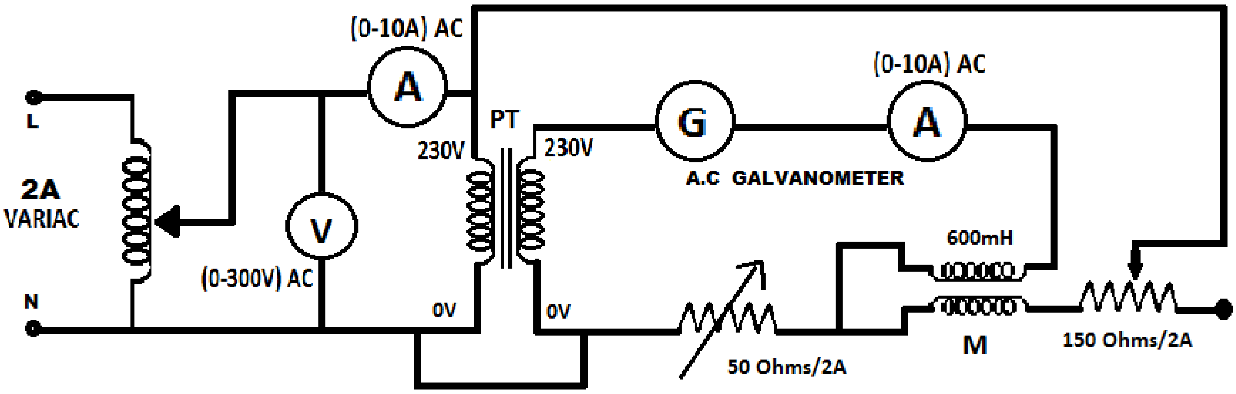
Calculations of ratio:

w11 is the reading of the wattmeter W1
w22 is the reading of the wattmeter W2
Ratio of transformers Rt / Rs = Vt / Vs = Vt*I / Vs*I = w11 / (w11-w12)
Ratio of the transformer under test Rt= Rs(1+ w12 / w11)

PROCEDURE:

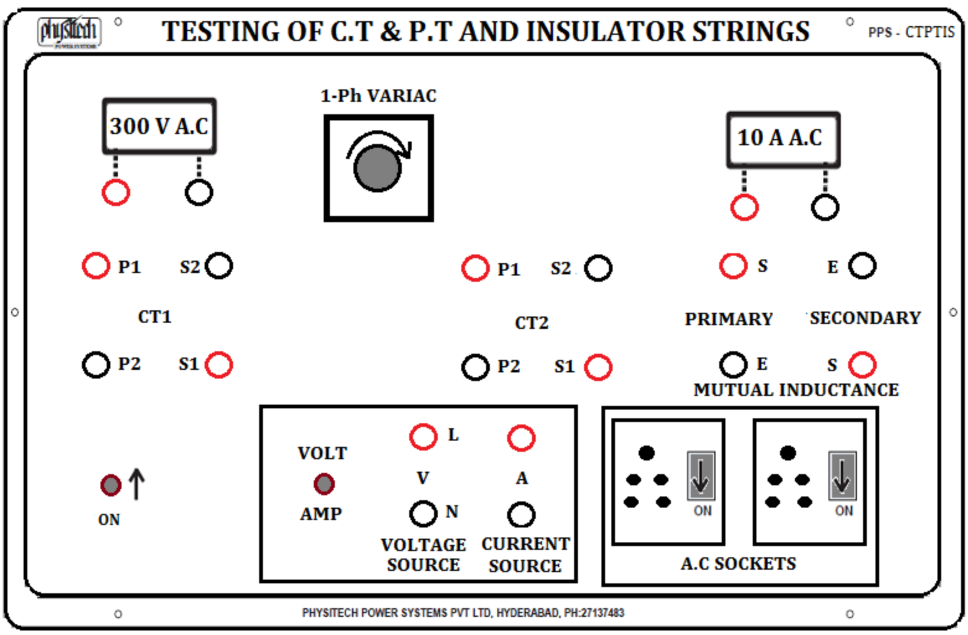
1. Connect the circuit as per the diagram.
2. Switch on the supply and increase the current in the primary winding by varying the current source.
3. Note down the ammeter readings in un-balanced condition.
4. Now adjust the rheostat (Zs) such that Galvanometer reads zero.
5. Then note down the readings, and bring back the current source to minimum position and switch off.

CIRCUIT DIAGRAM:



Front panel:

For both C.T & P.T



PRECAUTIONS:

- All connections should be tight and right as per the given circuit diagram.
- Proper range of meters should be selected.
- Un-insulated parts shouldn't be touched.
- Ammeter should always be connected in series, and volt meter in parallel with the circuit.
- Before switching ON the circuit, check whether the position of pointer in the meters is at zero or not, if not then bring them to zero.
- Checks for parallax error, if it exists then remove it.

TABULAR COLUMN:

S.No	P.T Range	PT Primary Voltage (V)	PT Secondary Voltage (V)
1			
2			

RESULT: The given Potential Transformer (PT) is tested by using Mutual Inductance.