POWER SYSTEM PROTECTIVE RELAYING

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PROJECT-1
DESIGN OF INVERSE TIME OVER CURRENT RELAY (CO8)

BY-

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1. INTRODUCTION

1.1 OVERVIEW

Power system protection mainly deals with the protection of electrical power systems from faults by isolating the faulted parts from the rest of the electrical network. Fault occurrence in any part of the system may be due to short circuits, abnormal conditions, equipment failures such as a circuit breaker failure, insulation deterioration and so on. System protection is mainly required to protect the public, improve the system stability, minimize the damage to the equipment, protect against overloads, etc. Protective relays generally monitor the current and/or voltage of the power system to detect problems within the power system. Protection systems usually comprise of current and voltage transformers to step down the high voltages and currents to a convenient value, protective relays to sense a fault and initiate a trip, circuit breakers to open/close the systems and batteries to provide power.

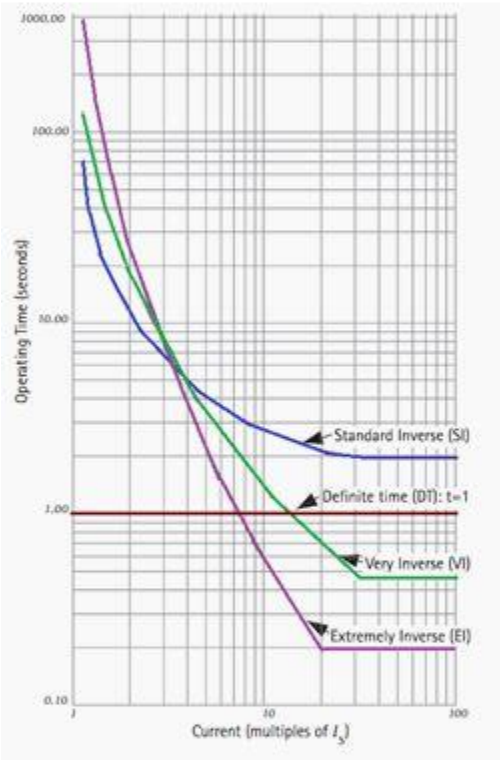
A relay is an automatic device which senses an abnormal condition of an electrical circuit and closes its contacts. These contacts in turn close and complete the circuit breaker trip coil circuit and hence, make the circuit breaker tripped for disconnecting the faulty portion of the electrical circuit from the rest of the healthy circuit. Relays are mainly chosen based on their characteristic, logic, actuating parameter and operation mechanism. Various types of relays are Electromagnetic Relay, Induction Cup Relay, Over current Relay, Differential Relay, Distance Relay, Instantaneous Relay, Inverse Time Relay, Thermal Relay, etc. Previously relays were mostly electromagnetic based, but microprocessor based relays have taken over the electromagnetic ones by providing protection and supervision impractical with the old relays.

1.2 INVERE TIME OVER CURRENT RELAYS

Over current relays are to protect an electrical system or equipment from over current faults like thermal current or short circuit current. For different characteristics of the circuits and equipments, over current relays are of different types. In the over current relays, there would be a current coil. When the current flows normally through the coil, the magnetic effect generated by the coil is not enough to move the moving element of the relay as in this condition; the restraining force is greater than the deflecting force. But when the current through the coil increases, the magnetic effects increases and beyond certain level of current, the deflating force generated by magnetic effect of coil, crosses the restraining force and as a result the moving element starts moving to change the contact position in the relay.

Inverse time is a natural character of any induction type rotating device. This means that if the input current is increased, the speed of rotation of the rotating art of the device is faster.

The time of operation varies inversely as the input current. This very particular characteristic is extremely suitable for over current protection. This is because the faults get cleared faster in this case. Although the time inverse characteristic is inherent to electromechanical induction disc relay, but the same characteristic can be achieved in microprocessor based relay by proper programming. The inverse time relay is further classified into inverse definite minimum time(IDMT), very inverse time, extremely inverse time over current relays.



1.3 PROJECT OBJECTIVE

Design a typical inverse-time-over current relay (CO-8) with the following settings:

- Time dial setting: “User selectable”
- Tap setting: “User selectable”

Given Conditions:

- System frequency: 60 Hz
- Sampling rate: 16 Samples/Cycle

Testing Procedure

- Test One: Pure sinusoidal wave with two current levels (Normal and abnormal)
- Test Two: Pure sinusoidal wave with four current levels.
- Test Three: Four current levels. Short circuit current contains DC offset and Harmonics.

2. ADOPTED METHODOLOGY

2.1 TIME DIAL SETTING AND TAP SETTING

When the current reaches its pre determined value, the length of the time taken by the unit to close its contacts is determined by the setting of the time dial. The contacts close when the dial is set to 0. When the dial is set on 10, the disk must travel maximum amount to close the contacts. This gives the maximum time setting. The primary adjustment for the time of operation of the unit is made by means of the time dial. The time dial is the control that determines the value of the integral at which the trip output is actuated, and hence controls the time scale of the time-current characteristic produced by the relay.

Relay sensitivity is determined by the tap setting. Every relay has many taps, each of which represent the minimum current at which the unit will start to operate. This is the minimum pick up value.

According to IEEE Std C37.112,
A current operated relay that produces an inverse time-current characteristic by integrating a function of current t(I) with respect to time. The function t(I) is positive above and negative below a predetermined input current called the pickup current. Pickup current is therefore the current at which integration starts positively and the relay produces an output when the integral reaches a predetermined positive set value.

2.2 TIME CHARACTERISTIC CURVE

A time characteristic curve defines the operating time of a protective device for various magnitudes of operating current. These characteristics give contact closing time for various time dial settings when the indicted multiples of tap value current are applied to the relay. Starting at time 0.01 seconds and a given value of fault current and proceeding upwards along the plot at the value of fault current, the first device whose curve is intersected should be the first device to operate. Here, a CO8 relay is used. It is a single phase, non directional time over current relay. The relay is used for over current protection where coordination with other devices is involved and also for backup protection for other relays.

The equations governing the time characteristic curves of CO 8 relay are:

t(I)=TD*((A/(M^p -1))+B)

t(I)= Trip time in seconds,

TD= Time Dial setting

A,B,p= Constants

M=Irms/Ip

Irms=RMS value of the current(CT secondary)

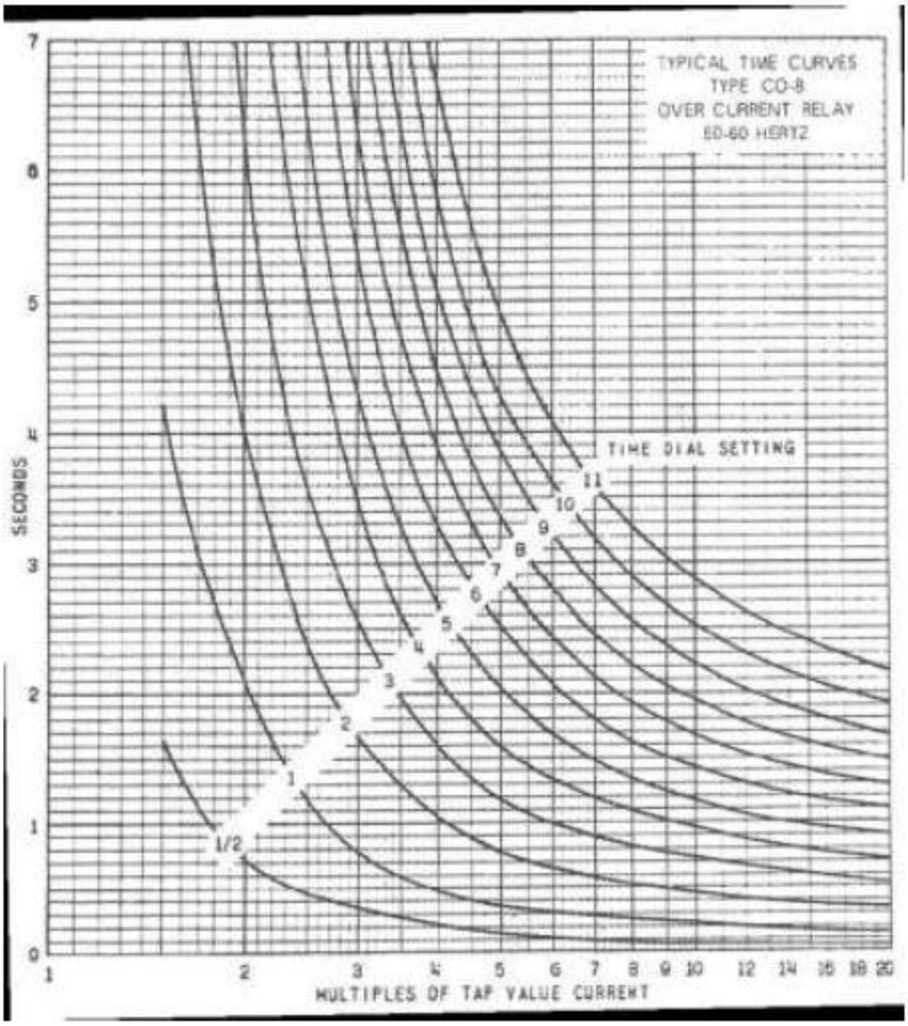
Ip=Tap setting

The constants values in the std. are given where,

A=8.9341

B=0.17966

P=2.0938



For this M level current the disc in electromechanical relay will rotate for t(I) seconds. The relay will trip when the integral of this time becomes greater than or equals to 1.

I.e. $\int 1/t(I)\, dt=1$

This integral gives you the operating time.

2.3 THEORY OF FILTERING SIGNAL

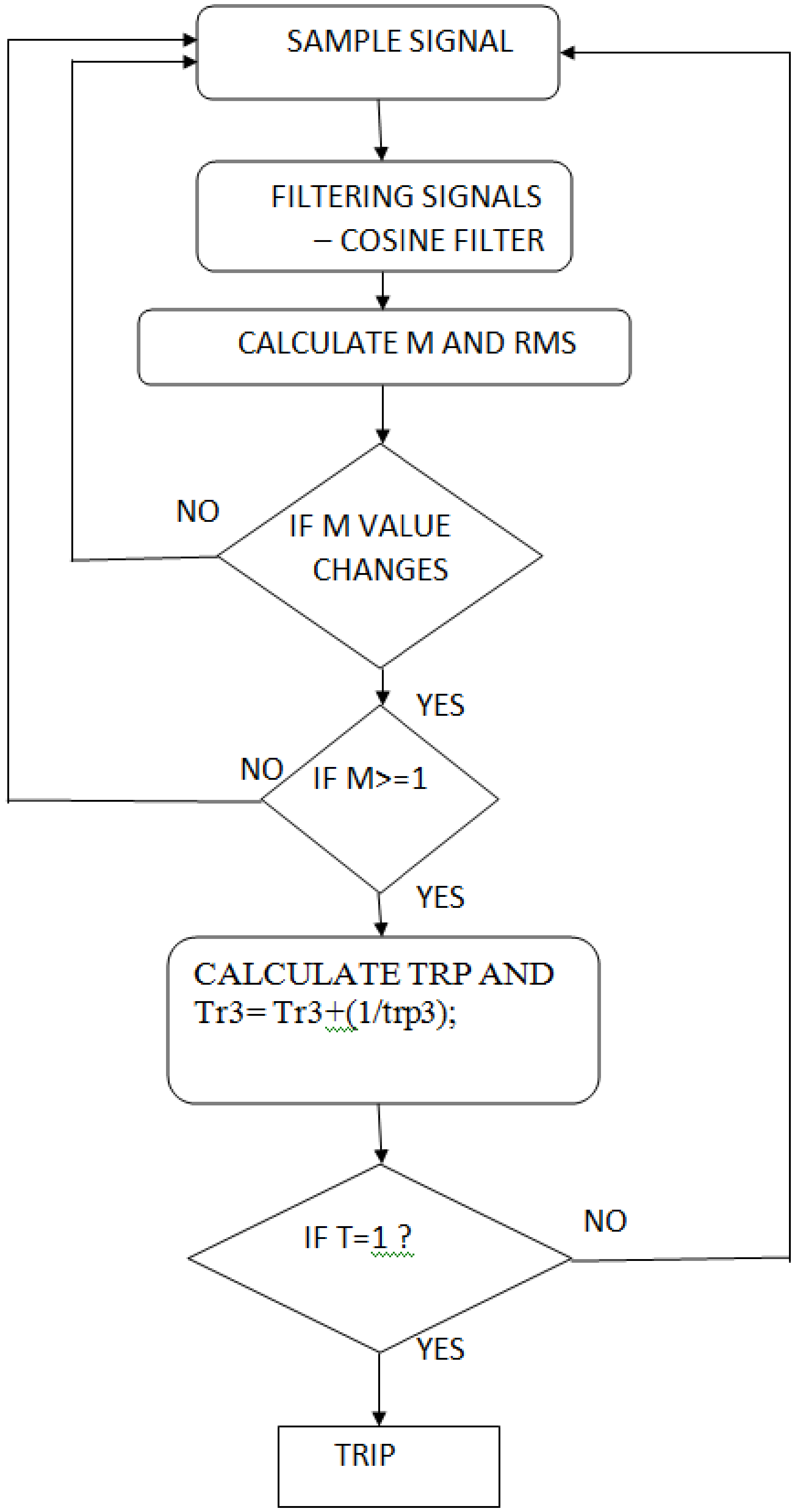
The relaying signals, that is the fault current and voltage contain harmonics and dc offset components which require filtering before feeding them to the relay. Digital filtering is the process of multiplying the successive samples by filter coefficients and combining them to obtain corresponding components of input. In this project, a cosine filter is used to remove the DC and harmonics as it has a good transient response over a Fourier filter. We sample at a rate of 16 samples/cycle.

The equation used for filtering is given as:

The filter coefficients $$CFC_n = \cos\left[\frac{2\pi}{16}\cdot n\right] \tag{1}$$

The Cosine filter $$IX_{smpl+spc} = \frac{2}{N+1}\sum_{n=0}^{N} I_{smpl+spc-n}\, CFC_n \tag{2}$$

2.4 LOGICAL FLOW CHART



3. ANALYSIS

3.1 CODE

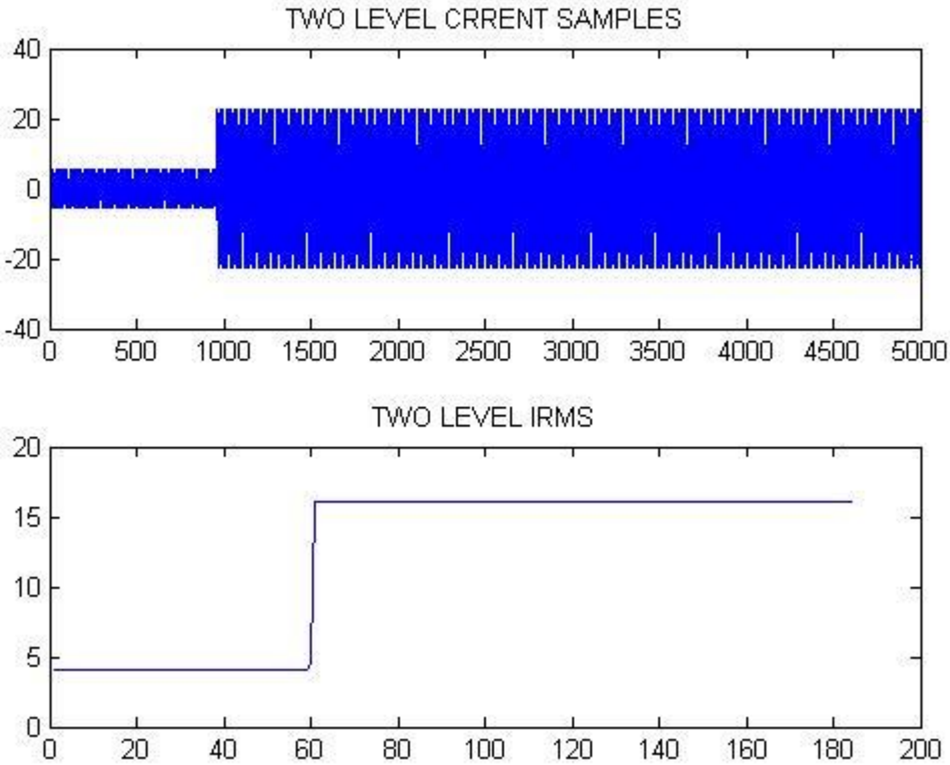
```
clc;
clear all;
X=xlsread('C:\Users\Dell\Desktop\RELAY\Test Signal.xlsx','A:A');
Z=xlsread('C:\Users\Dell\Desktop\RELAY\Test Signal.xlsx','B:B');
Y=xlsread('C:\Users\Dell\Desktop\RELAY\Test Signal.xlsx','C:C');

%Initializing A,B,P values
B=0.17966;
A=8.9341;
P=2.0983;
fz = 60;
tap_set = 5;
time_ds = 2;

%ANALYSIS OF FOUR LEVEL FAULT CURRENT WITH HARMONICS AND DC
a=0;
M=0;
sum=0;
rms=0;
irms=0;
c=0;
trp3=0;
tr3=0;
I=0;
m=0;
h=0;
p=0;
cf=0;
opt_time=0;

%Cosine Filter is used to filter DC Harmonics
for m=1:16
    cf(m)=cos((pi*(m-1))/8);
end

%Calculating the co efficients of the filter
for n=1:4985
    p=1;
    for o=16:-1:1
        h=(Z(n+o-1)*cf(p))+h;
        p=p+1;
    end
    I(n)=h/8;
    h=0;
end

for r=1:311
    %For the loop of one cycle = 16 samples
    for s=1:16
        sum=sum+((I(16*(r-1)+s))^2);
    end
    %Sum of squares of 16 samples
    rms=sqrt(sum/16);
    sum=0;
    %Calculation of rms value
    irms(r)=rms;
    %Finding the multiples of tap setting
    M=rms/tap_set;
```

```
    if(M>=1)
        c=c+1;
        trp3=time_ds*((A/((M^P)-1))+B)*fz;
        %Calculation of the trip time
        tr3=tr3+(1/trp3);
        if(tr3>=1)
            %Calculation of the operating time
            opt_time=c/fz;
     break;
        end
    end

end

%TWO LEVEL FAULT CURRENT ANALYSIS
sum_1=0;
rms_1=0;
irms_1=0;
M1=0;
c_1=0;
tr_1=0;
trp_1=0;
opt_time1=0;
for a=1:311
    %For the loop of one cycle = 16 samples
    for b=1:16
        sum_1=sum_1+((X(16*(a-1)+b))^2);
    end
    %Sum of squares of 16 samples
    rms_1=sqrt(sum_1/16);
    sum_1=0;
    %Calculation of rms value
    irms_1(a)=rms_1;
    %Finding the multiples of tap setting
    M1=rms_1/tap_set;
   if(M1>=1)
        c_1=c_1+1;
        %Calculation of the trip time
        trp_1=time_ds*((A/((M1^P)-1))+B)*fz;
        tr_1=tr_1+(1/trp_1);
        if(tr_1>=1)
            %Calculation of the operating time
            opt_time1=c_1/fz;
     break;
        end
   end

end
% FOUR LEVEL FAULT CURRENT ANALYSIS
sum_2=0;
rms_2=0;
irms_2=0;
M2=0;
c_2=0;
trp_2=0;
tr_2=0;
opt_time2=0;
for i=1:311
    %For the loop of one cycle = 16 samples
    for j=1:16
        sum_2=sum_2+((Y(16*(i-1)+j))^2);
```

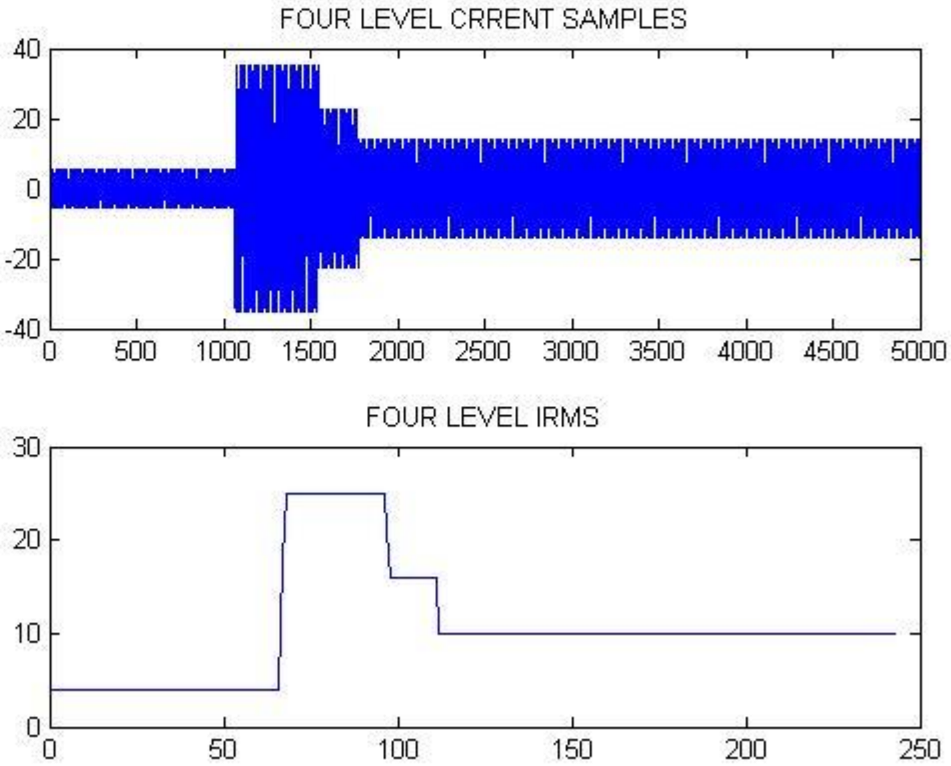
```
     end
     %Sum of squares of 16 samples
     rms_2=sqrt(sum_2/16);
     sum_2=0;
     %Calculation of rms value
     irms_2(i)=rms_2;
     %Finding the multiples of tap setting
     M2=rms_2/tap_set;
    if(M2>=1)
        c_2=c_2+1;
        %Calculation of the trip time
        trp_2=time_ds*((A/((M2^P)-1))+B)*fz;
        tr_2=tr_2+(1/trp_2);
        if(tr_2>=1)
            %Calculation of the operating time
            opt_time2=c_2/fz;
     break;
        end
    end

end
figure;
subplot(2,1,1)
plot(X);
title('TWO LEVEL CRRENT SAMPLES');
subplot(2,1,2)
plot(irms_1);
title('TWO LEVEL IRMS');

figure;
subplot(2,1,1)
plot(Y);
title('FOUR LEVEL CRRENT SAMPLES');
subplot(2,1,2)
plot(irms_2);
title('FOUR LEVEL IRMS');

figure;
subplot(3,1,1)
plot(Z);
title('FOUR LEVEL CRRENT SAMPLES WITH HARMONICS');
subplot(3,1,2)
plot(I);
title('FILTERED CURRENT');
subplot(3,1,3)
plot(irms);
title('FOUR LEVEL CRRENT IRMS WITH HARMONICS');
```

3.2 RESULTS

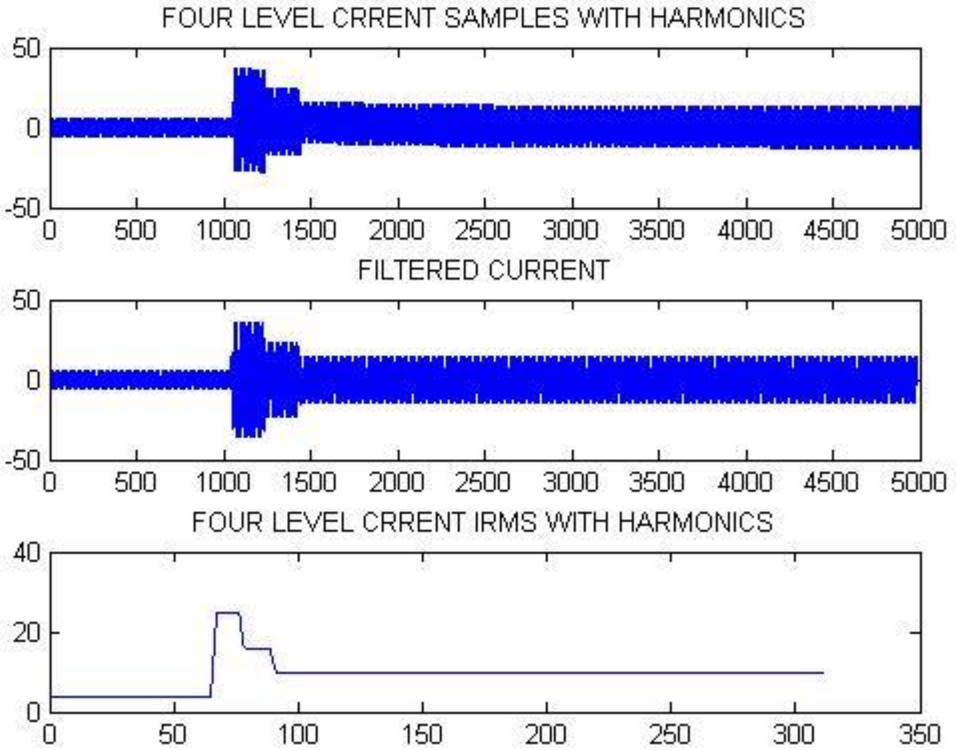
1. TWO LEVEL FAULT CURRENT



2. FOUR LEVEL FAULT CURRENT



3. FOUR LEVEL FAULT CURRENT WITH HARMONICS



A	8.9341	8.9341	8.9341
B	0.1797	0.1797	0.1797
I	<1x4985 double>	-35.36...	35.3510
M	2.0000	2.0000	2.0000
M1	3.2000	3.2000	3.2000
M2	2.0000	2.0000	2.0000
P	2.0983	2.0983	2.0983
X	<5000x1 double>	-22.62...	22.6274
Y	<5000x1 double>	-35.35...	35.3553
Z	<5000x1 double>	-27.58...	36.7438
a	184	184	184
b	16	16	16
c	246	246	246
c_1	124	124	124
c_2	177	177	177
cf	<1x16 double>	-1	1
fz	60	60	60
h	0	0	0
i	243	243	243
irms	<1x311 double>	4.0000	25.0000
irms_1	<1x184 double>	4.0000	16.0000
irms_2	<1x243 double>	4.0000	25.0000
j	16	16	16
m	16	16	16
n	4985	4985	4985
o	1	1	1
opt_time	0	0	0
opt_time1	2.0667	2.0667	2.0667
opt_time2	2.9500	2.9500	2.9500
p	17	17	17
r	311	311	311

rms	10.0000	10.0000	10.0000
rms_1	16.0000	16.0000	16.0000
rms_2	10.0000	10.0000	10.0000
s	16	16	16
sum	0	0	0
sum_1	0	0	0
sum_2	0	0	0
tap_set	5	5	5
time_ds	2	2	2
tr3	0.9308	0.9308	0.9308
tr_1	1.0012	1.0012	1.0012
tr_2	1.0027	1.0027	1.0027
trp3	348.2129	348.21...	348.21...
trp_1	123.8544	123.85...	123.85...
trp_2	348.2128	348.21...	348.21...

4. CONCLUSION

The CO8 relay is a type of induction based over current relay which is used to disconnect circuits when the current in them exceeds a particular value. It is used as a backup relay for other relays and is used to protect the relays. The over current relay unit settings can be defined by either tap setting and time dial position setting or a specific time of operation at a current multiple of the tap setting. A cosine filter was used in the project for the relay design. Tap setting is chosen as 5A and the time dial is chosen as 2.

INPUT	OPERATING TIME(SECONDS)	TRIPPING TIME(SECONDS)
TWO LEVEL FAULT CURRENT	2.0667	1.0012
FOUR LEVEL FAULT CURRENT	2.9500	1.0027
FOUR LEVEL FAULT CURRENT WITH HARMONICS	0	0.9308

5. REFERENCES

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3. Lewis Blackburn, "protective relaying principles and applications," third edition. Feng-Jih Wu, Chih-Ju Chou, Ying Lu, and Jarm-Long Chung, "Modeling Electromechanical Overcurrent Relays Using Singular Value Decomposition," Journal of Applied Mathematics, vol. 2012, Article ID 104952, 18 pages, 2012. doi:10.1155/2012/104952

4. IEEE Standard C37.112-1996, IEEE Standard Inverse-Time Characteristic Equations for over current Relays.