A New Technique Of Microcomputer
Based Overcurrent Relay

Mohammed Yahya Suliman

Technical College/Mosul

m_yahya1973@yahoo.com

Abstract

A new technique of three phase overcurrent relay is described in this paper. The performance of the new design shows the ability to obtain any shape of characteristic using exponential type model with high accuracy. Also the new design used more accuracy, fast measurement for peak detection with error less than 2%. The relay tested for normal and very inverse characteristics, also tested for line-to-line fault the results show the ability of discrimination the fault current and isolate the section of the system affected by a fault so that the remaining system can continue to operate normally.

Key-words: overcurrent relay, Peak detector, time coordination margin (TC), time multiplier setting (TMS), Programmable Peripheral Interface 8255 (PPI).

تقنية جديدة لمرحلة فرط التيار باستخدام الحاسب الدقيق

محمد يحيى سليمان

الكلية التقنية/الموصل

الخلاصة

تضمن البحث تقنية جديدة في مرحلة فرط التيار ثلاثية الطور. ان اداء التصميم الجديد اضهر القابلية العالية على تمثيل اي شكل لمنحني التيار-الزمن العكسي بأستعمال المعادلة الأسية و بدقة عالية. كما يتميز التصميم الجديد بأستعمال دائرة تحسس القيمة العظمى التي تتميز بسرعة قياس عالية و دقة تصل نسبة الخطأ فيها أقل من ٢%. تم أختبار المرحلة لنوعين من منحنيات التيار-الزمن العكسي ، كما تم أختبار المرحلة في حالة عطل (طور-طور) و أظهرت النتائج تمييز تيار العطل و عزل الجزء العاطل من الشبكة مع بقاء عمل باقي الشبكة بشكل طبيعي.

Introduction

Overcurrent protection is the simplest and least expensive form of fault protection that can be placed on transmission lines. The operating principles depend only on current magnitude. Phase overcurrent relays operate for all possible fault types, but require their pickup settings to be higher than the maximum expected normal or emergency load flow condition. Oververcurrent relays are widely used for the protection of radial transmission and distribution system [1].Such relays are relatively easy to set so that they will protect the system from short circuit faults in an adjacent component. Tripping may be instantaneous, delayed for a fixed time, or delayed for a time inversely proportional to the current magnitude.

Figure 1 shows some of the various shapes of time/current characteristics that may be used [2].
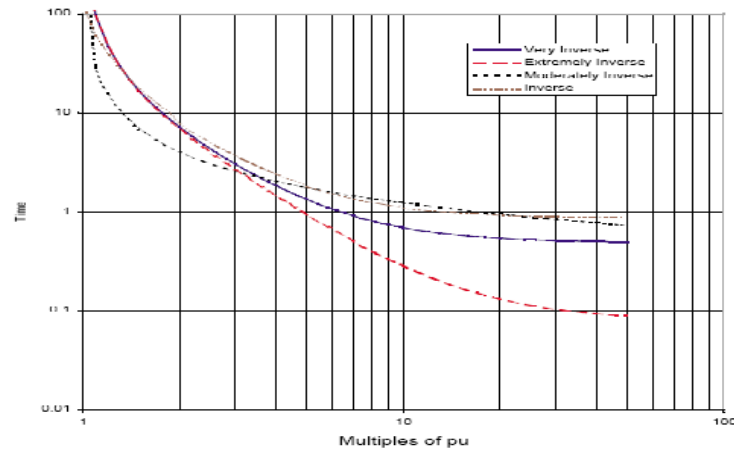

Fig 1 Time-current characteristics

Protection Modeling

In a system for which the fault current is practically determined by the fault location, without being substantially affected by changes in the power source impedance, it is advantageous to use inverse definite minimum time (IDMT) overcurrent protection. This protection provides reasonably fast tripping, even at a terminal close to the power source where the most severe faults can occur. When Z_S (the impedance between the relay and the power source) is small compared with that of the protected section Z_L, there is an appreciable difference between the current for a fault at the far end of the section ($E_S/(Z_S+Z_L)$, E_S: source voltage), and the current for a fault at the near end (E_S/Z_S). When operating time is inversely proportional to the current, the relay operates faster for a fault at the end of the section than the end nearer to the power

source, and the operating time ratio for a fault at the near end to the far end is $Z_S/(Z_S + Z_L)$ [3].

The resultant time-distance characteristics are shown in Figure 2, for radial networks with several feeder sections. With the same selective time coordination margin TC which is the sum of the breaker, over travel, and factor-of-safety times, the operating time can be further reduced by using a more inverse characteristic.
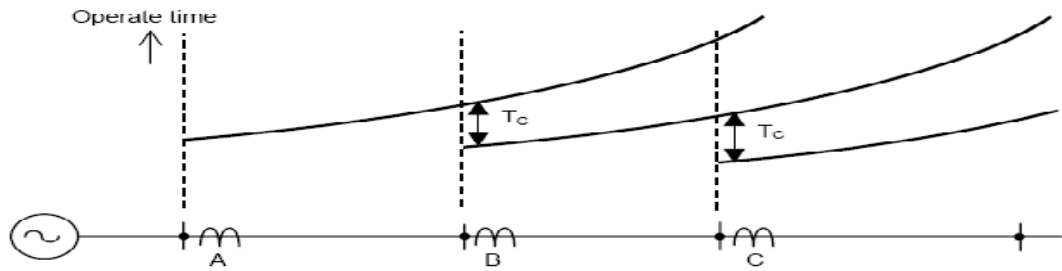

Fig 2 Time-distance Characteristics of Overcurrent Protection

The operating time of overcurrent protection elements have the IDMT (Inverse Definite Minimum Time) characteristics defined by equation (1) [4]:

$$t = TMSx \left\{ \left[\frac{K}{\left(\frac{I}{I_P} \right)^a - 1} \right] + c \right\}$$

..…………………………… (1)

Where:

t= Operating time for constant current I (seconds)

I= Energizing current (amps)

I_P= overcurrent setting (amps)

TMS=time multiplier setting

K, a, c= constants defining curve

Theory of measurement

The current signals are taken from the CTs connected as in appendix A [5, 6].

To detect the fault current, the maximum value of the sinusoidal waveform current should be measured [7,8].The instantaneous equation of the sinusoidal waveform current is:

$$i=I_mSin(\omega t)$$

………………………………………………………………..(2)

Where I_m is the maximum value.

To measure the maximum value a peak value detector circuit is used, the circuit consists of TLC372 fast comparator and two operational amplifiers LM385. Figure 3 shows the circuit of the detector with low-impedance output at $V_{OUT,}$ In addition, the TLC372 with high typical input impedance of 10^{12} eliminates any need for an input buffer stage, a feedback signal for the comparator acts as a reference level for comparison with the input signal's amplitude.
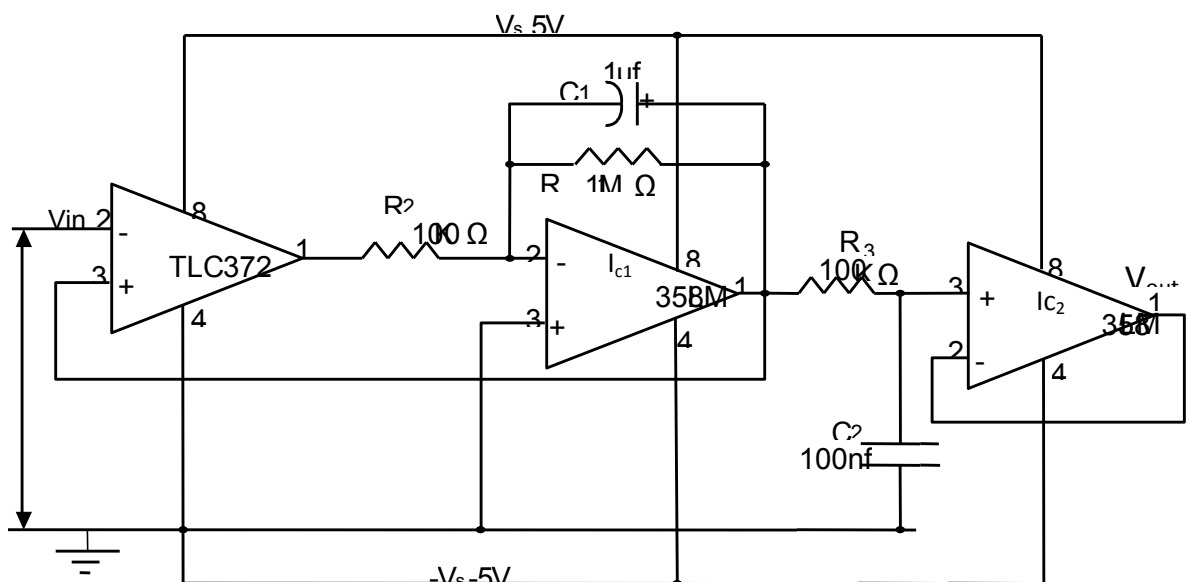
Fig 3 Peak value detector

When the input signal goes positive, the comparator's output turns on and sinks current through R1, charging current flows into C_1 from I_{C1} and the output V_{OUT} rises to the point at which it slightly exceeds the peak level of V_{IN}, producing a dc level at V_{OUT} that closely approximate the positive peak level of the input waveform. The values of R_1, R_2, and C_1 determine the ripple voltage on V_{OUT}, I_{C1} inverting input is held at virtual ground potential, so whenever I_{C1}'s output turns on, the voltage across R_1 approximately equals the negative-supply-rail voltage, -VS. Therefore, using a small value of R_1 injects a relatively large pulse of current into C1, thus allowing the circuit to respond quickly to a sudden increase in input-signal amplitude "fast-attack'' [9].

System Design

1-Hardware System Design

Figure 4 shows the block diagram arrangement of the protection system details in appendix C. From the figure, the programmable peripheral interface (PPI) is the main section of the interface system, which controls the input/output of the system that have 24 Input/Output ports grouped in

three 8-bits parallel ports A, B and C these ports specify input or output ports by control register of PPI. The computer specifies these ports by ordering write control word and send it to store in the control register of PPI, In this system the control word is 82H, according to the control word, B is the input port to input data, while A and C are the output ports port A for start of conversion of analog to digital converter and port C and the address of chip select of PPI is 400H and with address lines A_0 and A_1 according to the address lines port A is 401H, port B 402H and port C is 403H respectively. The analogue multiplexer used to integrate the three phase signals is shown in figure 4. The hardware system starts with initial input channels by the decoder to the control word of PPI to enable port B for input data from analog to digital converter and enable port C output port for select phase number through multiplexer to convert one value at each time to digital through analogue to digital converter, while port C8 to trip signal, port A give SC (Start of conversion), the result enter to the computer through data bus by port B of (PPI).The buffer circuit is located before PPI to protect it from the undesired value.

2-Software System Design

Figure 5 shows the flow chart arrangement for the software design of the overcurrent relay, the program is written in C language which is given in appendix B, start, with the initial input/output ports by sending the control word to control register of 8255 PPI, then initial input channels by the decoder to select the phase (I_{ph}), then 10 samples to be taken at (2KHz) from peak value detector circuit. The peak amplitude current (I_{max}) is compared with the setting point I_{pu} (pickup current value). Tripping signal send to tripping circuit (after delay time obtained from equation 1) when the measured value exceed the pickup value. The execution time of the overcurrent relay was 10 msec.

Discussion of the Results

Figure 6 and Table 2 show the test circuit's sine-wave-frequency response by plotting the error in V_{OUT} for three peak levels of V_{IN}. The figure show the error increase when frequency of the input signal increase so the circuit can be use in low frequency especially at 50Hz with high accuracy. Figure 7 shows the input versus output of the peak value

detector circuit where the output has a less than 2% error. The experimental results for the overcurrent relay consists of two types

time-current characteristics normal inverse and very inverse respectively as shown in Figure 8 and figure 9 at three types of time multiplier setting (TMS= 1, 0.6, 0.4), the coefficients of equation 1 (k, a and c) are listed in table 1. It can be noticed that good agreement is achieved between the practical design results and the published curves [2]. The advantages of the new design are fast measurement to the peak amplitude of the line current with high accuracy to make the relay sensitive to any abnormal condition also from the software design show the ability to obtain any shape of time-current characteristics by changing the value of the coefficients of equation 1 in the software program without need to change the hardware system.

ESA-Bus of Microcomputer (Pentium 4 processor)

Data Bus

I/O Port 8255 (PPI)

PA Port A

PB Port B

8-bit   PB

PC8

PA

Analog to Digital Converter

V_{out}

Trip circuit

Peak value detector

V_{in}

PC1

Analog Multiplexer

Tripping signal

3-ph C.T.'s and scaling circuit

3-phase lines

Load

A   B   C   Circuit Breaker
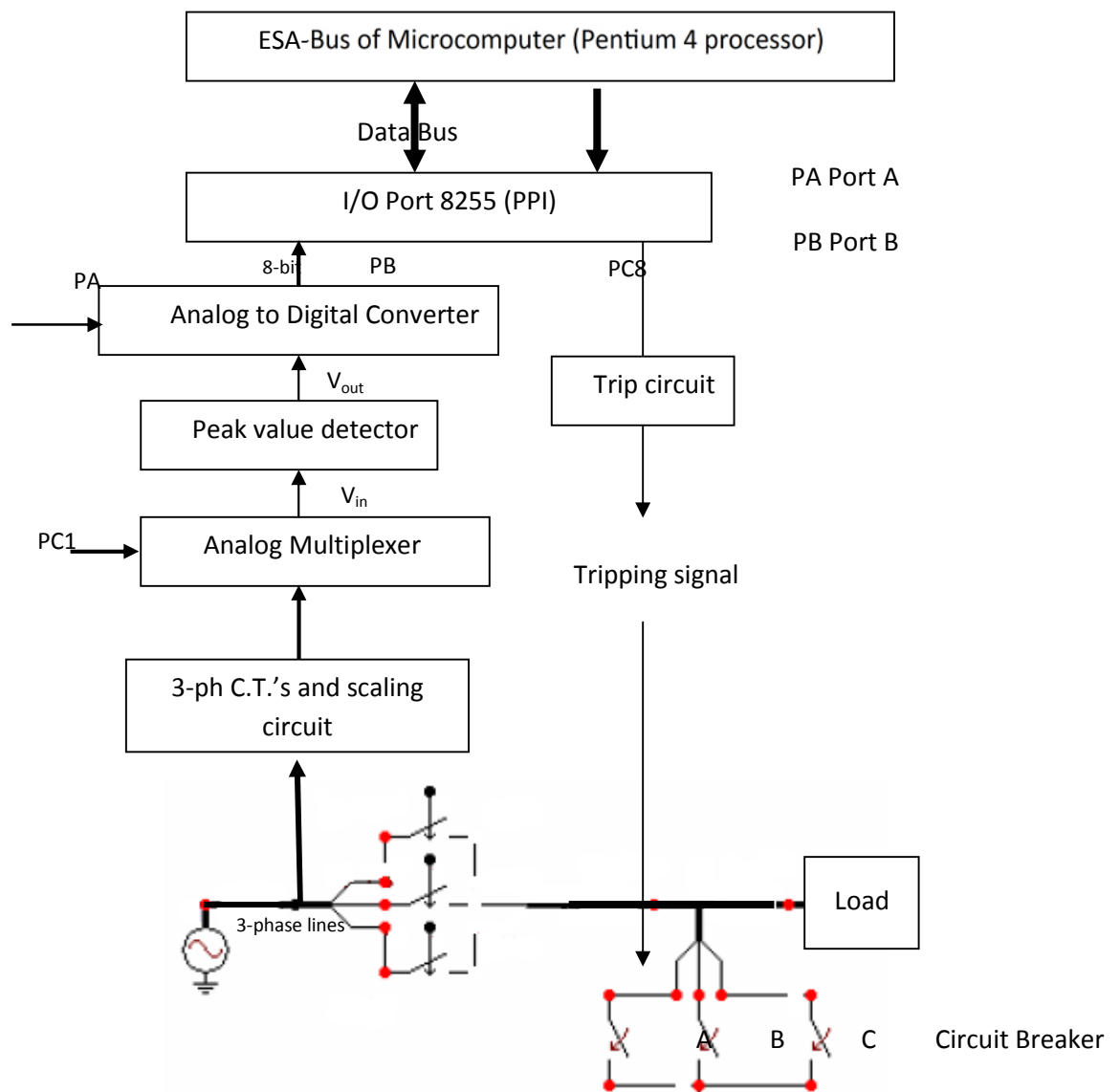
Fig 4 Block diagram of the protecon system

```
                         ┌─────────────┐
                         │    Start    │
                         └──────┬──────┘
                                │
                                ▼
              ┌────────────────────────────────────┐
              │   Initial  I/O ports by control word │
              └────────────────┬───────────────────┘
                                │
                                ▼
              ┌────────────────────────────────────┐
              │ Select phase one I_ph=1 by inial the │
              │              multiplexer             │
              └────────────────┬───────────────────┘
                                │
                                ▼
              ┌────────────────────────────────────┐
              │ samples taking at sampling frequency 2│
              │                 KHz                  │
              └────────────────┬───────────────────┘
                                │
                                ▼
              ┌────────────────────────────────────┐
              │  Average of 10 samples taken from peak│
              │        value detector circuit        │
              └────────────────┬───────────────────┘
                                │
                                ▼
              ┌────────────────────────────────────┐
              │     Obtain maximum value (I_max)     │
              └────────────────┬───────────────────┘
                                │
                                ▼
                          ◇ I_max:I_pu ◇ ──── Imax ‹ Ipu ────┐
                                │                             │
                           Imax› Ipu                          ▼
                                │                      ┌──────────────┐
Pu: pickup Current              ▼                      │ I_ph=I_ph+1  │
              ┌──────────────────────┐                 └──────┬───────┘
              │  Obtained operating   │                        │
              │    time using eq. 1   │                        ▼
              └──────────┬───────────┘                  ◇ I_ph:3 ◇ ── I_ph= 3
                         │                                    │
                         ▼                                  Iph  3
              ┌──────────────────────┐
              │  Tripping signal send │
              └──────────┬───────────┘
                         │
                         ▼
                   ┌───────────┐
                   │    End    │
                   └───────────┘
```

Imax ‹ Ipu

Imax› Ipu

$I_{ph}=I_{ph}+1$

Pu: pickup Current

I_{ph}:3

$I_{ph}= 3$

Iph 3

Obtained operating time using eq. 1

Tripping signal send

End

Fig 5 Flow chart of overcurrent relay

Table 1

Relay Type	k	a	c

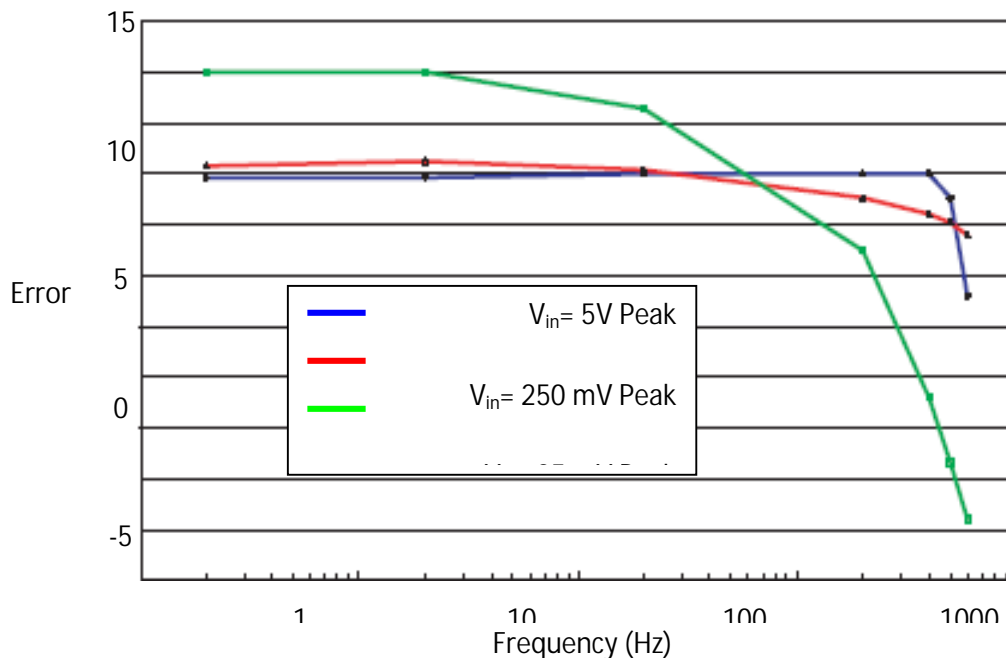| Normal Inverse	0.14	0.02	0
Very Inverse	13	1	0

Fig 6 plon g the di erence between peak signal levels and output voltage for three peak levels illustrates the detector's frequency response.

Second advantage all three phase current are common in comparison with the multiple of pick up value and one characteristic curve is representing

all three phase lines. Figure 10 show the operation of the over current relay under fault condition, here fault occurs when t=100ms. Responding to phase-phase fault type (Phase B and Phase C). Its shows that this overcurrent relay can operate properly within about one cycle after fault occurs. Also the relay distinguishes between the steady state fault and the transient conditions.

Conclusion:

The new technique of overcurrent relay show fast measuring to the peak amplitude of phase current with high accuracy also gives the ability to obtain any type of inverse time-current characteristic by changing the coefficients of equation 1 in the software program with high range of time multiplier setting (TMS). This is important in radial protection system also it has the ability to isolate any type of fault in about one cycle after fault occurs as shown in figure 10.

Table 2

Frequency (Hz)	Error V_{in}=5V Peak (%)	Error V_{in}=250mV Peak (%)	Error V_{in}=25mV Peak (%)
1	-0.4	0.8	10
10	-0.4	1.2	10
50	0	0.4	6.4
100	0	-2.4	-7.6
200	-2.4	-4	-22
10000	-12	-4.8	-28.4
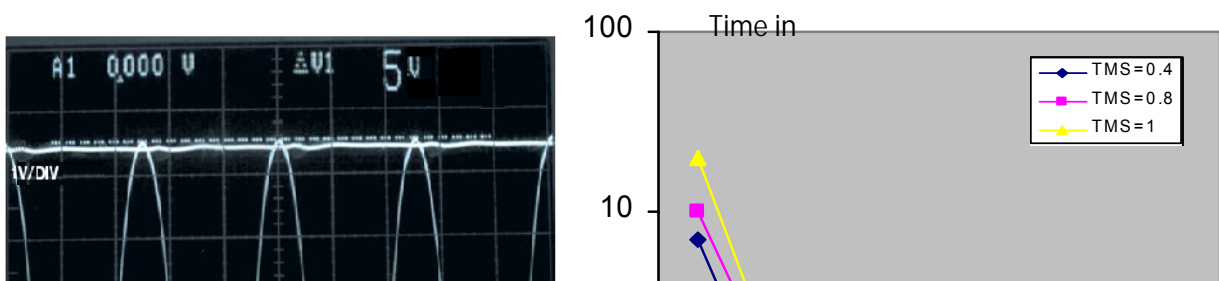
Fig 7 An oscilloscope photo displays

input versus output voltages for a 5V, 50Hz

Fig 8 Time current characterisc   for Normal Inverse

10 ── Time in

| TMS = 0 .4 |
| TMS = 0 .8 |
| TMS = 1 |

0.1

500

300
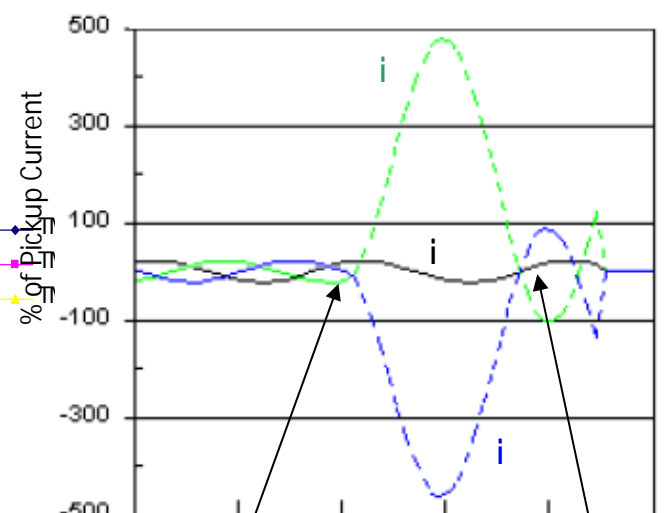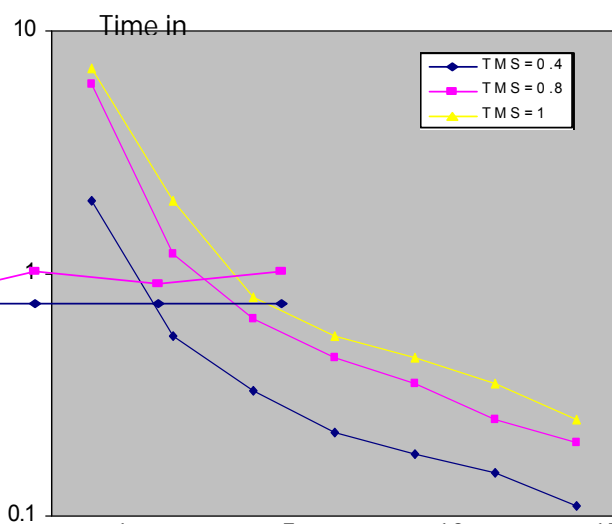
100

% of Pickup Current

-100

-300

-500

i

i

i

i

Fig 9 Time current characterisc for
Fig 10 Phase currents when B-C phase fault occurs

References

1-IEEE Guide for Protective Relay Applications to Transmission Lines, sept. 2000

2- Arun Phadke, "Power System Protection", CRC Press 2001.

3- Abdul Saha and Abbas, "Microprocessor based fast system for measuring power, and peak amplitude of voltage and current ", IE (I) Journal-ET vol. 69,feb. 1989, pp56-58.

4- ArturoConde, Emesto Vazquez, "A Time Overcurrent Adaptive Relay", International Journal of Electrical Power and Energy Systems, Vol.-25, Issue-10, Dec 2003 pp. 841-847.

5- Abd-AL-Satar "Microprocessor Controlled overcurrent relay for three phase system", M.Sc. thesis, University of Mosul, Mosul, 1994.

6- GE Power Mangement "Tow vs. Three overcurrent Elements for Phase Fault Protection in Feeder Relays" Technical Notes, 2000.

7-Dinesh Birla and Rudra Prakash "Time-Overcurrent relay Coordination", International Journal of Emerging Electric Power Systems, vol. 2, Issue2, 2005.

8- Mark Brown, Ben Ramesh "Practical Power Systems Protection", Elsevier Press 2004.

9- Anthony H Smith, Scitech "Inexpensive peak detector requires few components", EDN Journal, Jul 2000.

Appendix A

CT's are in wye connected with phase and ground relays. The currents Ia, Ib, and Ic are the vector currents, and the CT ratio is assumed to be 1/1 to simplify the mathematics. Vectorially, the primary and secondary currents are inphase, neglecting phase-angle errors in the CT's.

 The symmetrical-component method of analysis is a powerful tool, not only for use in calculating the power-system currents and voltages for unbalanced faults but also for analyzing the response of protective relays. In terms of phase-sequence components of the power-system currents, the output of wye-connected CT's is as follows:

$Ia = Ia_1 + Ia_2 + Ia_0$

………………………………………………………….(a-1)

$Ib = Ib_1 + Ib_2 + Ib_0 = a^2 Ia_1 + a Ia_2 + Ia_0$ …………………… …………….(a-2)

$$Ic = Ic_1 + Ic_2 + Ic_0 = aIa_1 + a^2Ia_2 + Ia_0$$
…………………………….…………(a-3)

$$Ia + Ib + Ic = Ia_0 + Ib_0 + Ic_0 = 3Ia_0 = 3Ib_0 = 3Ic_0$$
…………..……….……..(a-4)

Where 1, 2, and 0 designate the positive-, negative-, and zero-phase-sequence components, respectively, and where 'a' and 'a^{2}' are operators that rotate a quantity counterclockwise 120^0 and 240^0, respectively. The connection of the C.Ts of designed three phase overcurrent relay shown below, the resistance (burden) that connect across the secondary of C.T.:

Burden (in VA) $= I_s^2 R$

Where:

R: resistance

I_s: secondary current

The resistance connected across the secondary to convert the line current to voltage in the range of analog to digital converter (±5V).
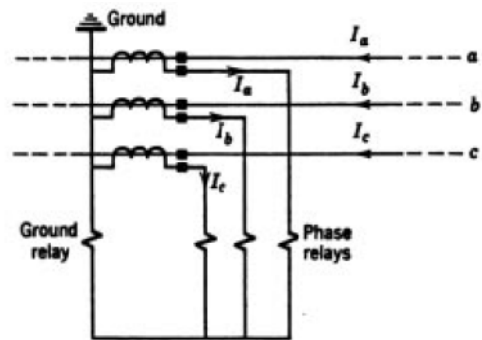
Appendix B

The software program of three phase over current relay

```
#include<stdio.h>
#include<dos.h>
```

```c
#include<math.h>
#define pi 4*atan
#define cosec(x) 1/sin(x)
main(){
unsigned int a[10],c[10];
int z,I,h,l,he,g,j,l,sum,v,t,q;
outportb(0x403,0x82)
  for(he=0x80;he<=0x82;he++){          /*  phase selection */
outportb(0x402,he);
 label  sum=0;
for(z=1;z<=10;z++){
a[z]=inportb(0x401);  /* Input samples */
 c[z]=a[z]*0,039-5;   /* convert to analog  */
if(g>=-0.039)|(g<=0.039) goto label;
sum=sum+1;
v=sum/5.5   /* setting pickup  */
while(v>=1) {
 t=pow(v,1); q=2500/t ;              /* time setting */
delay(q);
outportb(0x400,1) ; /* trip signal to circuit breaker */
end:
```
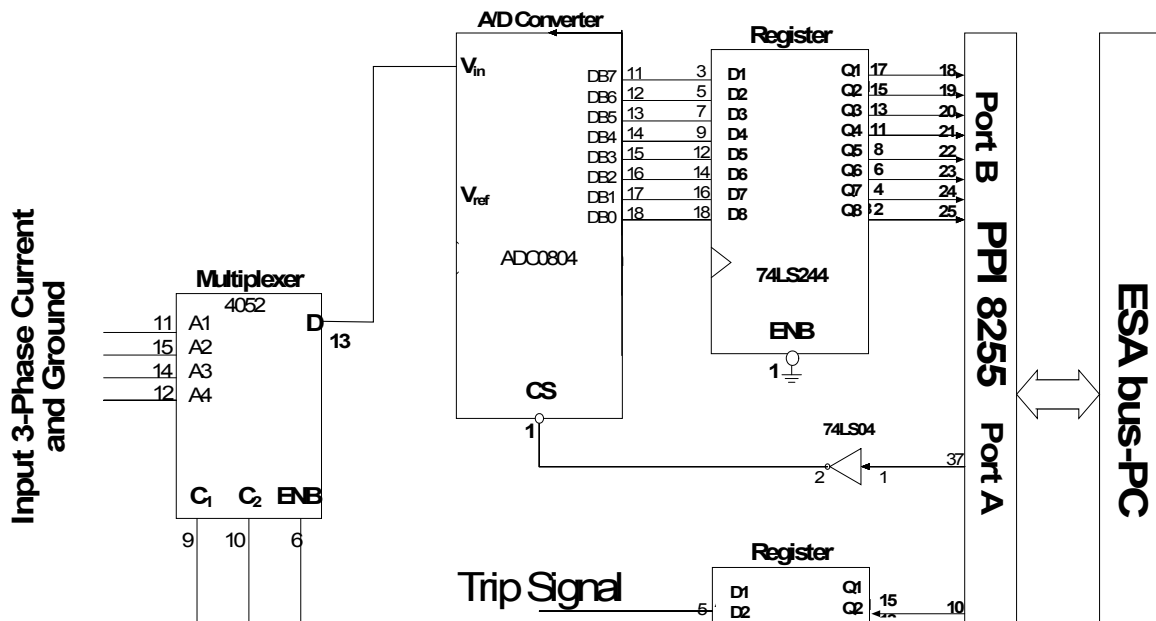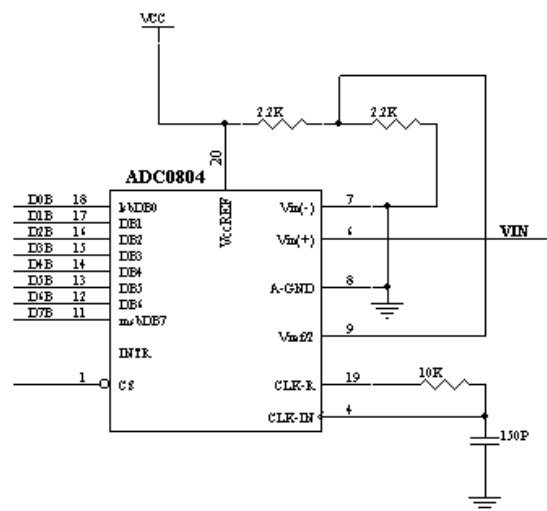
Appendix C

The interface and analog to digital conversion connection of the designed relay

The work was carried out at the college of Engg. University of Mosul