TRV Problem With IEEE C37.013-1997

By

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Question Asked of IEEE about Standard C37.013-1997

How do I use the values in Tables 5, 6, 7, and 8 along with Figure 15 to draw a circuit breaker TRV capability curve so that the actual system TRV curve can be compared to the capability curve?

Presentation Outline

- Utility TRV Standard Applications
- Standard C37.013-1997 TRV Problem
- Similar Problem in Proposed Changes to C37.011 TRV Standard
- Solutions to Problems

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Utility Application of TRV Standards

- Generate Ideal Breaker Capability Curve
- Generate System TRV Response Curve
- Comparison of Ideal and System Curve

Ideal Breaker Capability Curve

- Ideal Breaker Capability Curve represents the Minimum Requirements for Circuit Breakers
- Actual Circuit Breakers Response May be Greater than the Standards Minimum
- Computer Programs Used For Curve Reproduction

EMTP Curve Generation

- Equations Defining Continuous Minimum Capability of Breaker Defined in Standard
- Curve Generated Based on Equations
- Curve Compared to System Response on Single Graph

C37.011-1994 Curve Equations

- Three Phase Bus Fault
- Short Line Fault

C37.011-1994 Three Phase Fault

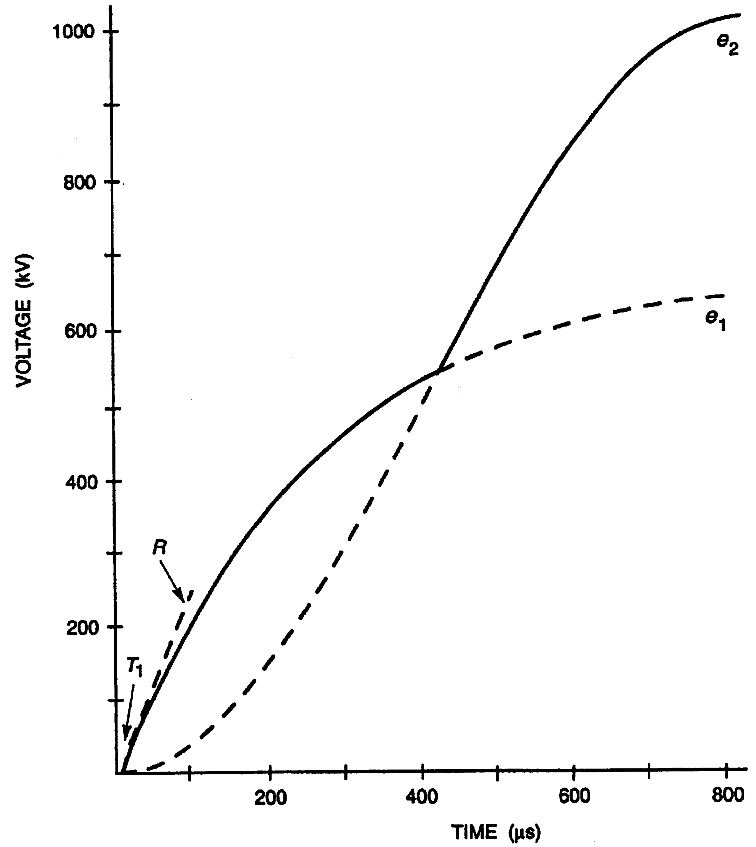

Figure 4—TRV related capability envelope for 550 kV circuit breaker at 75% of its rated fault current capability

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Figure 4—TRV related capability envelope for 550 kV circuit breaker at 75% of its rated fault current capability

The exponential-cosine envelope is defined by the larger of e_1 and e_2 in the following:

$$e_1 = E_1(1 - \varepsilon^{-t/T})\ \text{kV} \quad (1)$$

with a delay of T_1 μs

where

$T = E_1/R$

$$e_2 = \frac{E_2}{2}(1 - \cos(\pi t / T_2))\ \text{kV} \quad (2)$$

The constants in these equations (1) and (2) for this example are given in table 3 of ANSI C37.06-1987.

The multipliers to adjust for a fault current less than rated are given in table 6 of ANSI C37.06-1987. These multipliers are also given here in table 1.

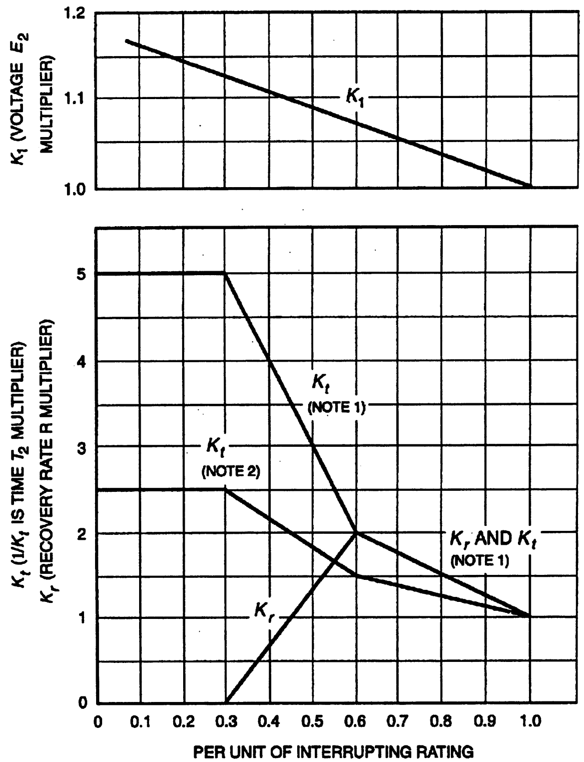
NOTE—Rating values from ANSI C37.06-1979 are used in this guide for examples. While revisions to ANSI C37.06-1979 may occur in the future, the same fundamental applications apply.

Table 1—Related required transient recovery voltage capabilities of circuit breakers at various interrupting levels for terminal faults

Percent of interrupting rating[a]	Multipliers for rated parameters				
	72.5 kV and below		121 kV and above		
	E_2	T_2	R	E_2	T_2
100	1.00	1	1	1.00	1
60	1.07	0.67	2	1.07	0.5
30	1.13	0.4	0	1.13	0.2
7	1.17	0.4	0	1.17	0.2

NOTE—Interpolation between the above given points is linear, as shown in figure 5.

[a] Ratio of the symmetrical current component of the current being considered to the related required symmetrical interrupting capability (defined in 5.10.2.1 of IEEE Std C37.04-1979) is stated in percent.



NOTES:
1—K_t = 121 kV and above.
2—K_t = 72.5 kV and below.
3—See table 1.

Figure 5—TRV rate and voltage multipliers for fractions of rated current

EMTP Program for Ideal Response

```
TACS HYBRID
C
C ENTER THE BREAKER VOLTAGE RATING IN VOLTS
11VRAT       123000.
C ENTER THE BREAKER CURRENT RATING IN AMPS
11IRAT        40000.
C ENTER THE BREAKER T2 TIME IN SECONDS
11T2         .000260
C ENTER THE BREAKER R VALUE IN VOLTS/SECOND
C       this comes from table 5 of ansi c37.06-1979
11R            1.8E9
C
C ENTER THE ACTUAL FAULT CURRENT IN AMPS
C
11CUR         30544.
C
C DETERMINE THE FRACTION OF RATED CURRENT
99TEV     = (VRAT.LE.72500)
99TEV1    = (VRAT.GT.72500)
99F1      = TEV*2.5 + TEV1*5.
99F2      = TEV*1.5 + TEV1*2.
99F3      = TEV*1.0 + TEV1*3.
99F4      = TEV*.5  + TEV1*1.
99TE      = CUR/IRAT
99TE1     = (TE.GE.0  .AND. TE.LE..3)
99TE2     = (TE.GT..3 .AND. TE.LE..6)
99TE3     = (TE.GT..6 .AND. TE.LE.1.0)
99KRT     = (TE1*0.) + (TE2*((TE-.3)/.3)*2)       +  (TE3*(2-(TE-.6)/.4))
99KR      = (TEV*0.) + (TEV1*KRT)
99KT      = (TE1*F1) + (TE2*(F2+F3*((.6-TE)/.3))) +  (TE3*(F2-F4*(TE-.6)/.4))
99KE      = 1+((1-TE)/.55)*.1
C
99E1      = 1.5*SQRT(2./3.)*VRAT
99E2      = (TEV*1.88*VRAT) + (TEV1*1.76*VRAT)
99T2B     = T2/KT
99E2B     = E2*KE
99RB      = R*KR
C
C
C CALCULATE THE TRV
C
C       this is equation 2) on page 5 of C37.011-1994
C       the form is (E2/2.0)*k1*(1-cos(pi*t*KT/T2)
C       ke is k1 and KT is 1/kt
C       the different equations for the value under, kt, are not presented
C       but are in figure 5 and Table 1
99BRKTRX  =E2B/2.*(1-COS(PI/T2B*TIMEX))
C       this is equation 1) on page 5 of C37.011-1994
C       the form is E1*(1-e**(1R*Kr*t/E1))
99BRKTRZ  =E1*(1.-EXP(-RB*TIMEX/E1))
IF (BRKTRX.GT.BRKTRZ) THEN
98FLAG    =1
ENDIF
IF (FLAG.EQ.1)THEN
98BRKTRV  =BRKTRX
ELSE
98BRKTRV  =BRKTRZ
ENDIF
C
33BRKTRVBRKTRXBRKTRZ
C
C <Name-<>InitialVal<-
77FLAG           0.0
C .....^..........^..
```

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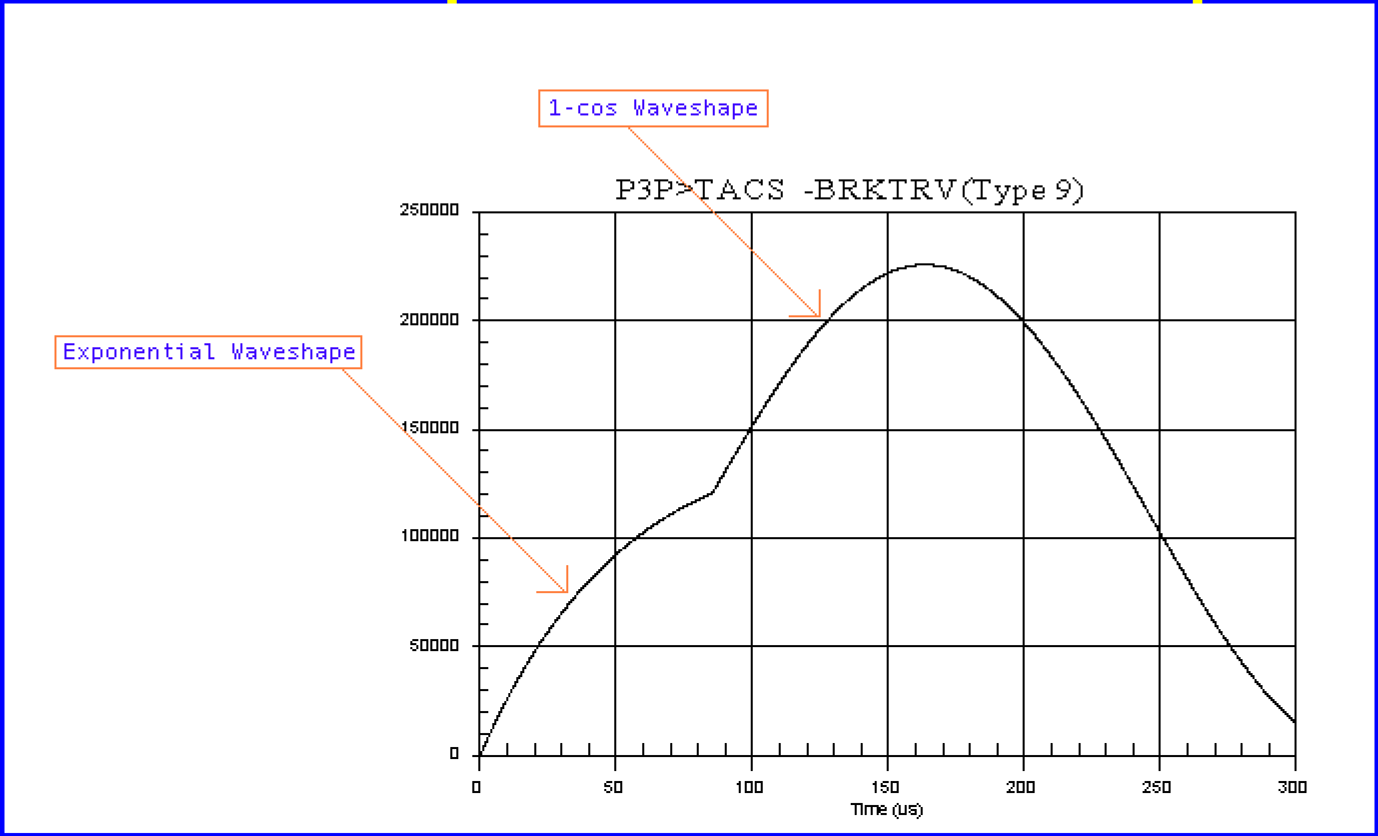
EMTP Output of Ideal Response



C37.011-1994 Short Line Fault

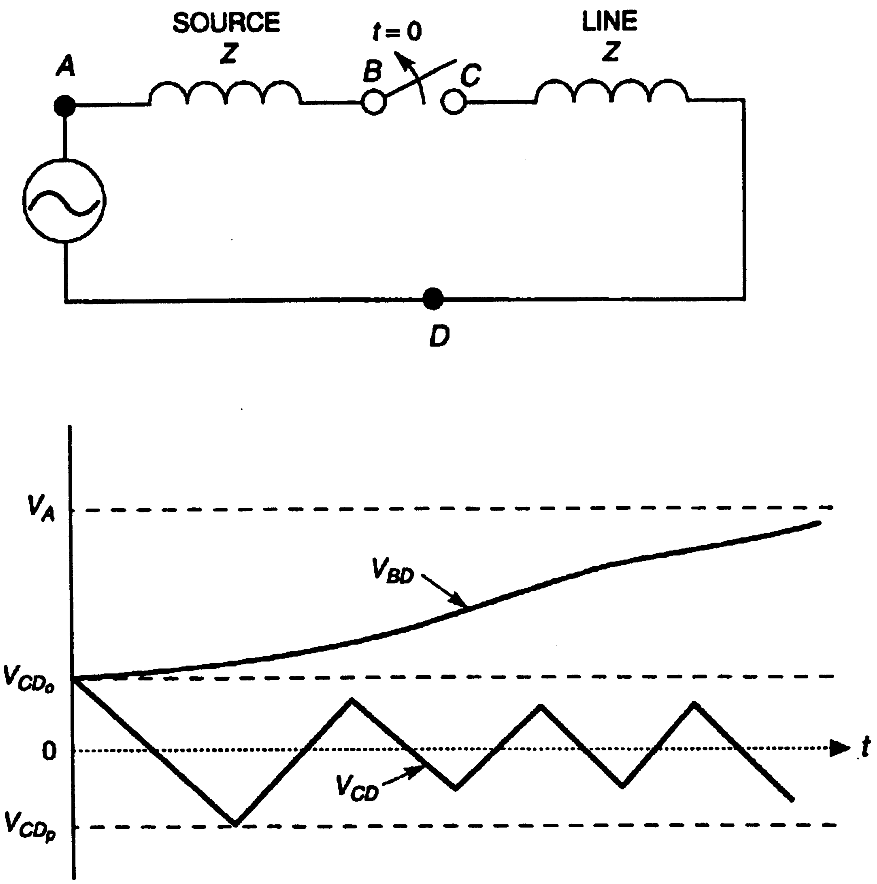


Figure 8—TRV waveshape for short-line fault

Short Line Fault Boundary Equations

$$e = d(1 - M)\sqrt{2}\left(\frac{1}{\sqrt{3}} E_{\text{max}}\right) \text{ kV} \qquad (4)$$

$$R_L = \sqrt{2}\ \omega\ \text{MIZ} \times 10^{-6} \text{ kV/}\mu\text{s} \qquad (5)$$

$$T_L = \frac{e}{R_L}\ \mu\text{s} \qquad (6)$$

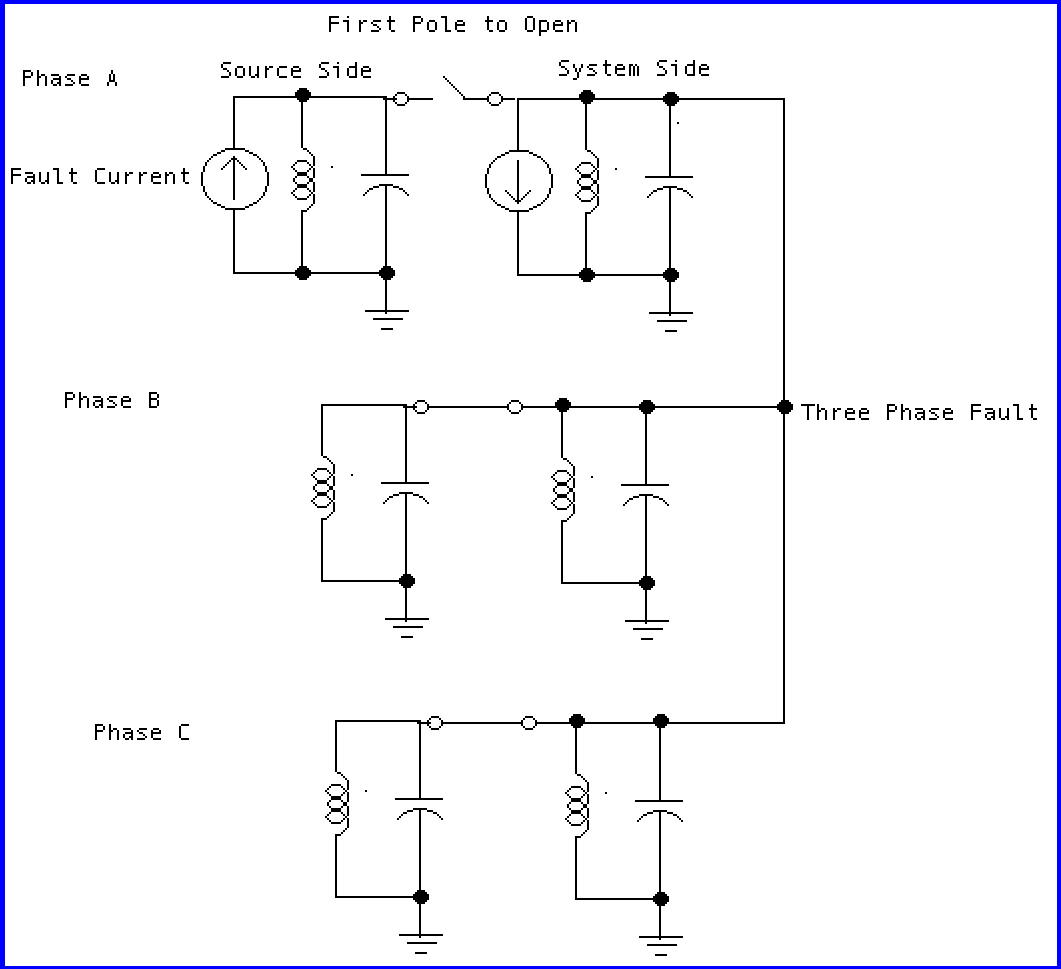
System TRV Response

- System Fault Modeled in Simulation Program
- Response across First Pole To Open Graphed
- Graph Compared to Minimum Breaker Capability Curve
- Capacitance added if Minimum Breaker Capability Curve Exceeded

Simple System Fault Model

- Pre-Opening Current Injected
- Model Capacitances and Inductances
- Fault Three Phases
- Monitor Voltage Across First Open Contact

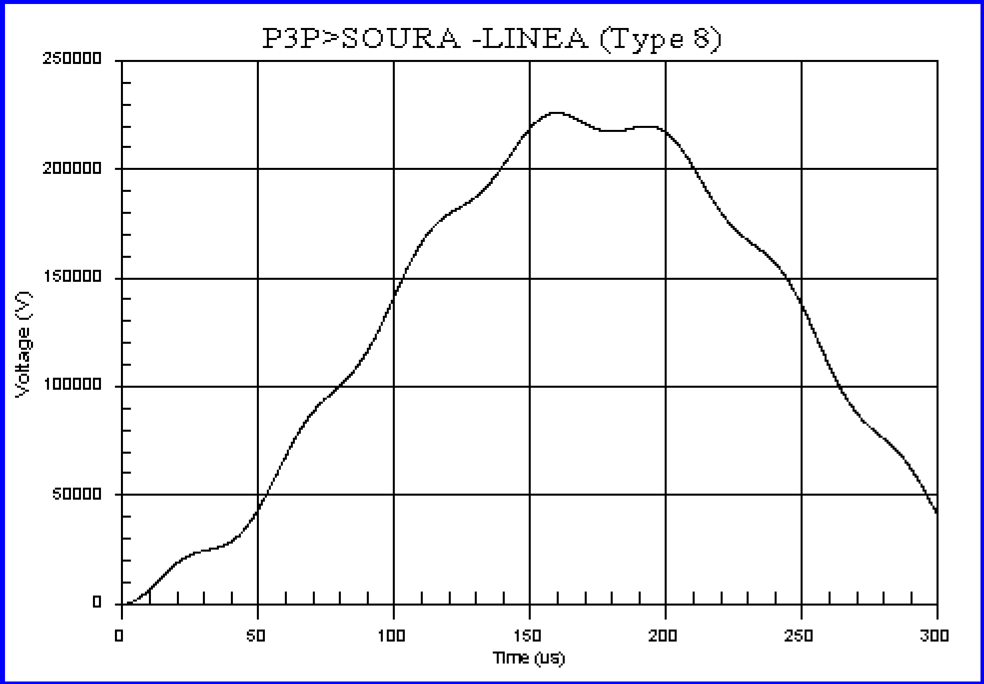
Drawing of Simple Fault Circuit



Program for Circuit Simulation

```
C <Bus M<Bus K<Bus 3<Bus 4<----R<----L<----C<---R2<---L2<---C2<---R3<---L3<---C3
  SOURA                         0.100
  SOURB                         0.100
  SOURC                         0.100
C .....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^
C <Bus M<Bus K<Bus 3<Bus 4<----R<----L<----C<---R2<---L2<---C2<---R3<---L3<---C3
  SOURA                               .50000
  SOURB                               .50000
  SOURC                               .50000
C .....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^
C <Bus M<Bus K<Bus 3<Bus 4<----R<----L<----C<---R2<---L2<---C2<---R3<---L3<---C3
  LINEA                         5.500
  LINEB                         5.500
  LINEC                         5.500
C .....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^
C <Bus M<Bus K<Bus 3<Bus 4<----R<----L<----C<---R2<---L2<---C2<---R3<---L3<---C3
  LINEA                               .55000
  LINEB                               .55000
  LINEC                               .55000
C .....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^
C
BLANK CARD ENDING BRANCH DATA
C SWITCHES
C
C <Bus K<Bus M<---Tclose<----Topen<-------Ie<---Vflash<-Special-<-Bus5<-Bus6<--O
  SOURA LINEA        1.        1.                                              2
C .....^.....^.........^.........^.........^.........^.........^.....^.....^...^
C <Bus K<Bus M<---Tclose<----Topen<-------Ie<---Vflash<-Special-<-Bus5<-Bus6<--O
  LINEA LINEB        0.        1.
  LINEB LINEC        0.        1.
C .....^.....^.........^.........^.........^.........^.........^.....^.....^...^
BLANK CARD  ENDING SWITCHES
C
C SOURCE
C
C <--Bus<V<Amplitude<-----Freq<----Phase<-------A1<-------T1<---Tstart<----Tstop
14SOURA -1  -157871.       60.       90.
14LINEA -1   157871.       60.       90.
C .....^.^.........^.........^.........^.........^.........^.........^.........^
BLANK CARD ENDING SOURCE CARDS
C OUTPUT SPECIFICATION CARDS
C <Bus 1<Bus 2<Bus 3<Bus 4<Bus 5<Bus 6<Bus 7<Bus 8<Bus 9<Bus10<Bus11<Bus12<Bus13
  LINEA SOURA
C .....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^
BLANK CARD
C PLOTS CARDS
BLANK CARD
BLANK CARD
BEGIN NEW DATA CASE
BLANK CARD
```

Output of System Response



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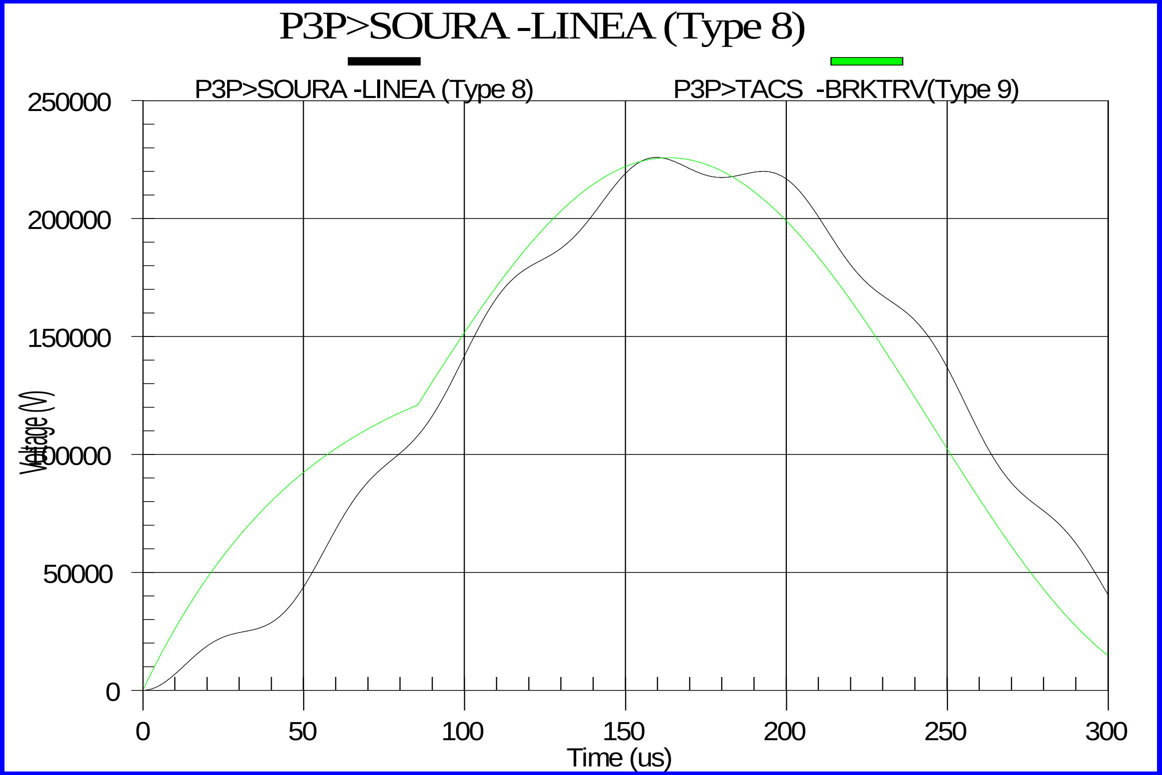
Comparison of Breaker Capability Curve and System Response



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C37.013-1997 TRV Problem

- Minimum Range Specified For Circuit Breakers Capability Curve
- No Boundary Defined for System Response
- No Equations for Minimum Circuit Breaker Capability Curve
- Unable to Determine System Capacitance Needed

Minimum Range Specified

- Rate of Rise
- Time Delay
- Peak Voltage
- Tangent in Undefined Region
- Top of Curve Function Described
- No Defining Equations

Minimum Breaker Requirements

TRV parameters listed in Tables 5 and 6 apply to the first-pole-to-clear for a three-phase fault, with a first-pole-to-clear factor equal to 1.5. The TRV oscillates as shown in Figure 15.

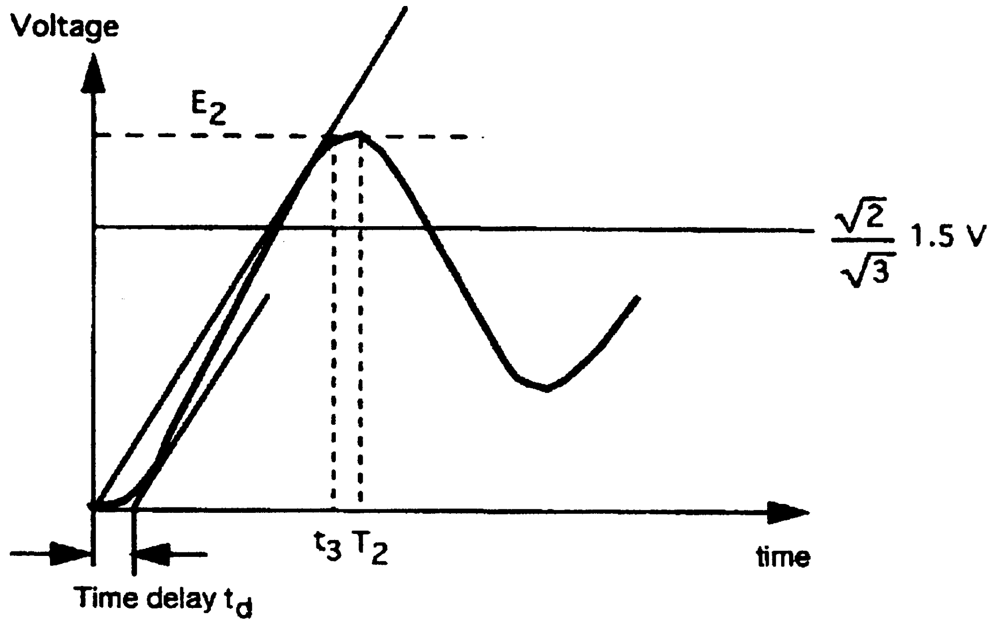


Figure 15—Inherent TRV curve for first-pole-to-clear for required symmetrical interrupting capability for three-phase faults

Minimum Breaker Requirements

The curve rises to the crest value, E_2 equal to 1.84 V where V is the rms value of the rated maximum voltage in kV and the value 1.84 is equal to

$$\sqrt{\left(\frac{2}{3}\right)} \times 1.5 \text{ (= first-pole-to-clear factor)} \times 1.5 \text{ (= amplitude factor)}$$

The rising part of the TRV curve is bounded by two lines. One line goes through the origin and tangent to the TRV curve with a slope equal to the TRV rate. The other line has the same slope and goes through the point t_d, time delay.

Near the crest, the TRV curve has approximately a 1 – cosine wave-shape with a time-to-crest equal to

$$T_2 = \frac{t_3}{0.85} = \frac{E_2}{0.85 \times \text{TRV rate}}$$

System Source Fault

- Long Delay
- Short T2
- Large Window for System Response
- 1-cos Waveshape Fits Into Window

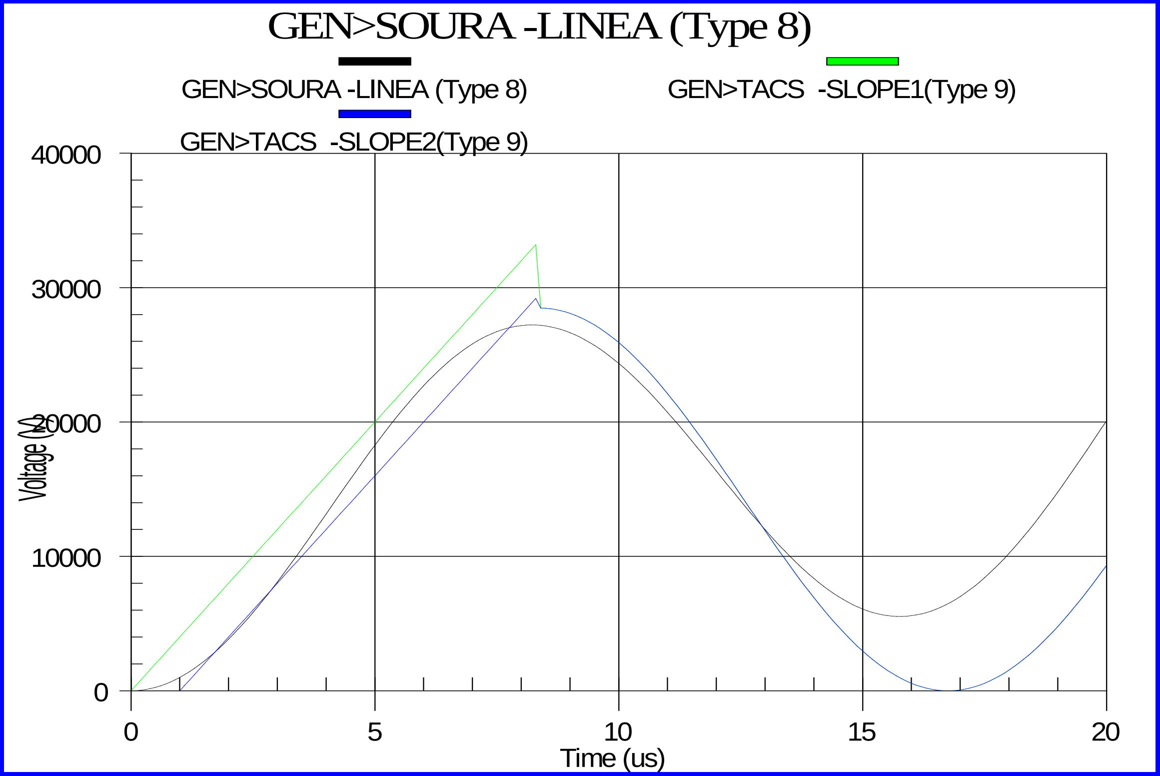
System Source Fault

Table 5—TRV parameters for system-source faults

Transformer rating MVA	T_2 in µs	Inherent TRV	
		E_2-crest voltage	TRV rate kV/µs
100 or less	0.62 *V*	1.84 *V*	3.5
101–200	0.54 *V*	1.84 *V*	4.0
201–400	0.48 *V*	1.84 *V*	4.5
401–600	0.43 *V*	1.84 *V*	5.0
601–1000	0.39 *V*	1.84 *V*	5.5
1001 or more	0.36 *V*	1.84 *V*	6.0

NOTES
1—Time delay shall be equal to or less than 1 µs.
2—*V* is the rated maximum voltage in kV.

System Source Fault Simulation



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Generator Source Fault

- Short Delay
- Long T2
- Small Window
- 1-cos Waveshape Does Not Fit in Window

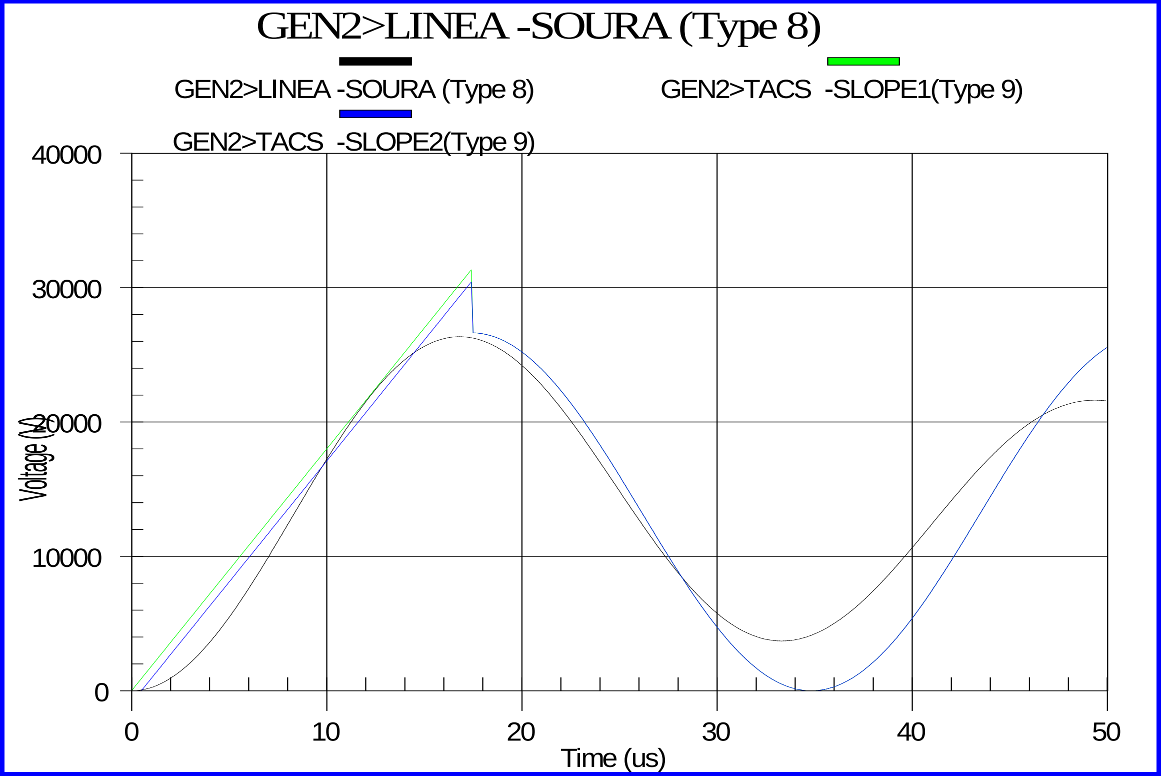
Generator Source Fault

Table 6—TRV parameters for generator-source faults

Generator rating MVA	T_2 in µs	Inherent TRV	
		E_2-crest voltage	TRV rate kV/µs
100 or less	1.35 *V*	1.84 *V*	1.6
101–400	1.20 *V*	1.84 *V*	1.8
401–800	1.08 *V*	1.84 *V*	2.0
801 or more	0.98 *V*	1.84 *V*	2.2

NOTES
1—Time delay shall be equal to or less than 0.5 µs.
2—*V* is the rated maximum voltage in kV.

Generator Source Fault Simulation



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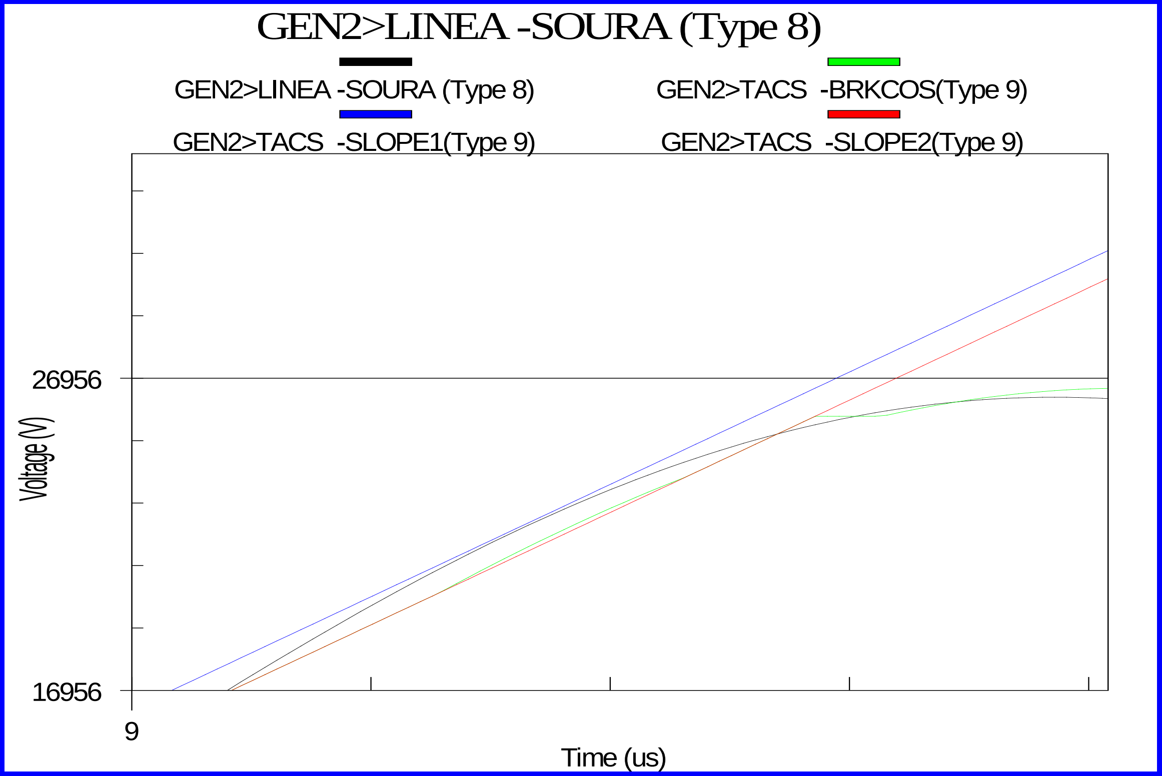
Problem Area In Last Graph



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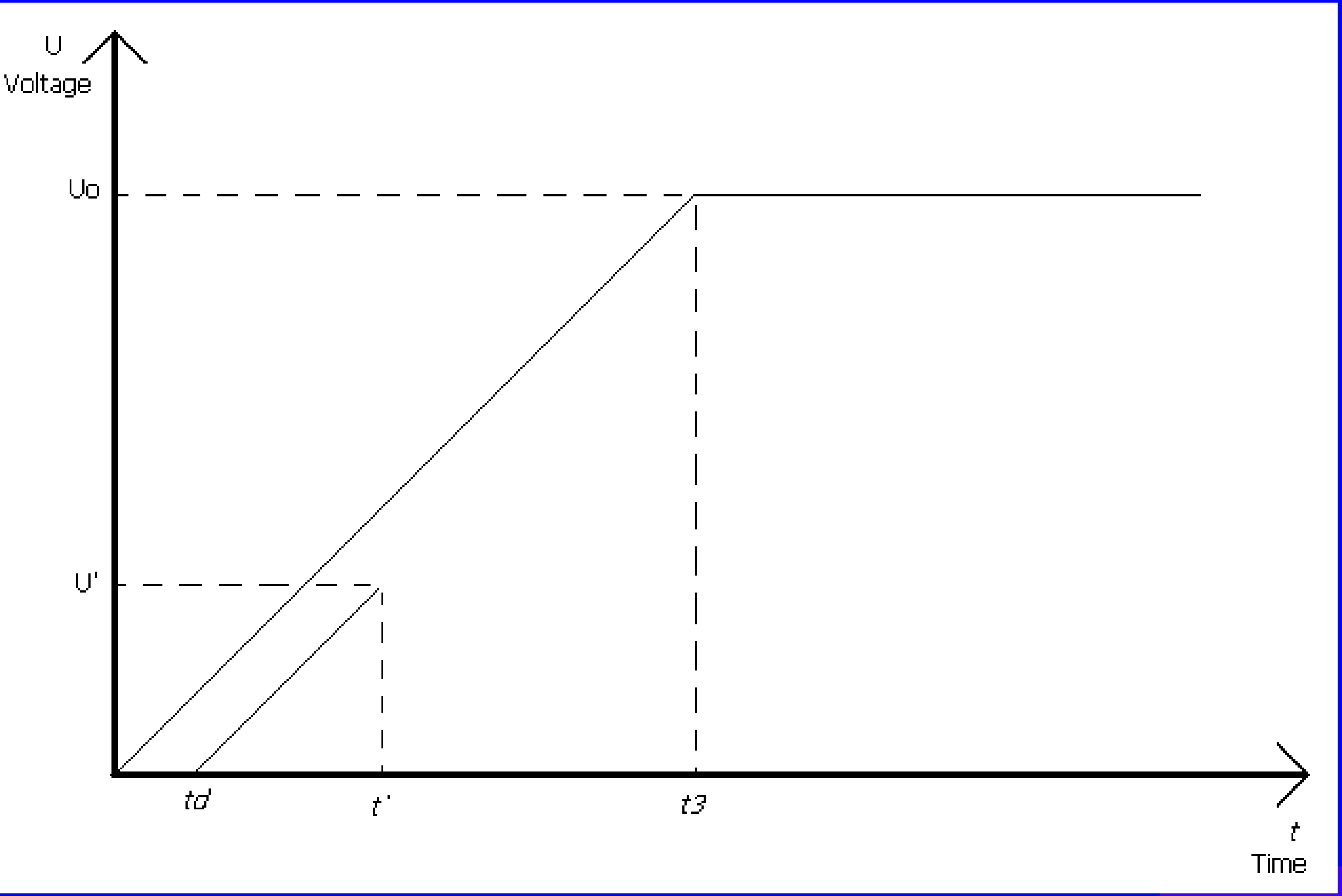
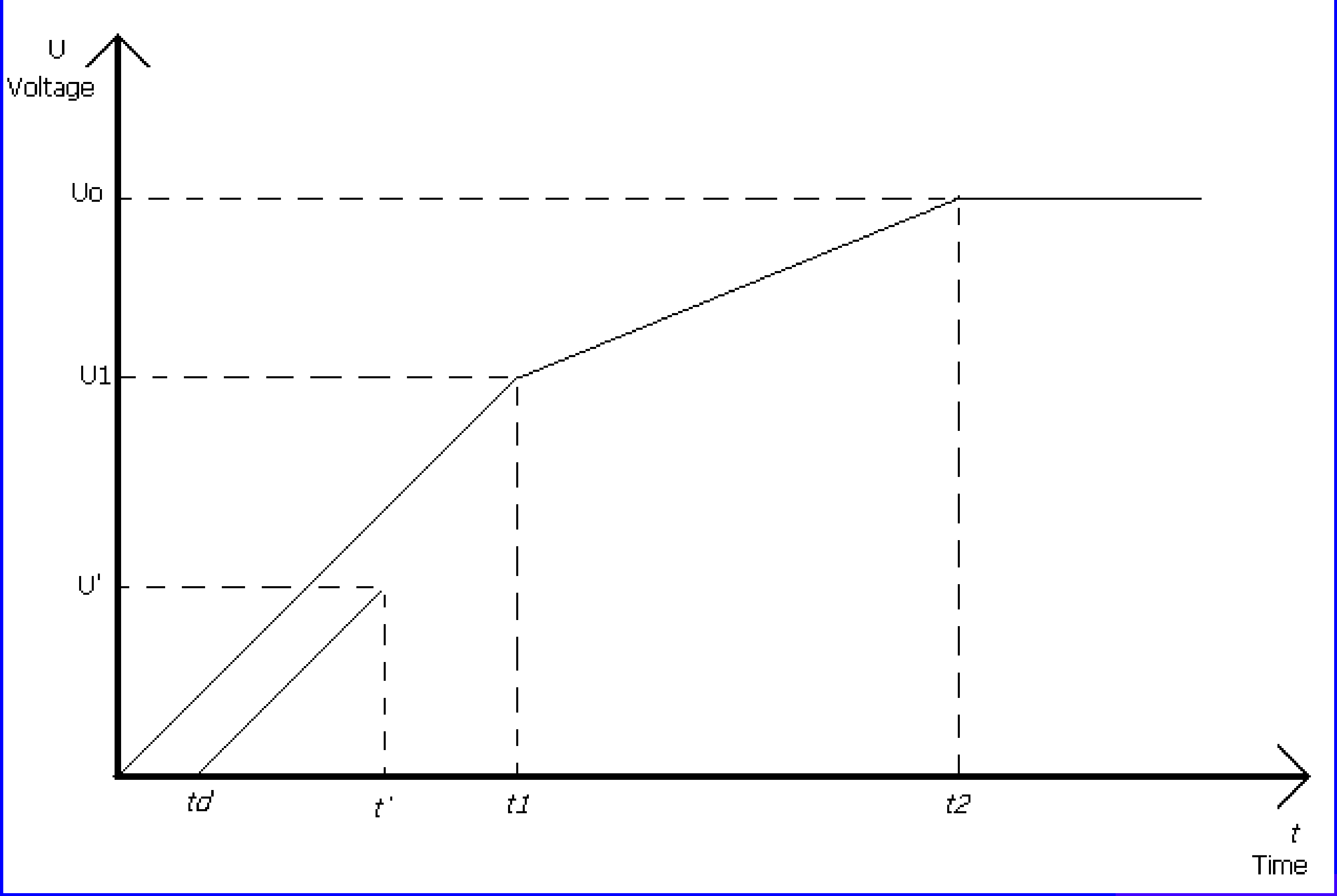
Similar Problem With C37.011 Proposed Changes

- IEC Harmonization with IEEE
- IEC Standard 56 Waveshapes to Replace Defined Functions
- 2 Parameter Function
- 4 Parameter Function
- Circuit Breaker Range
- No System Response Boundary Defined

2 Parameter Function of IEC 56 (Similar to IEEE C37.013-1997)



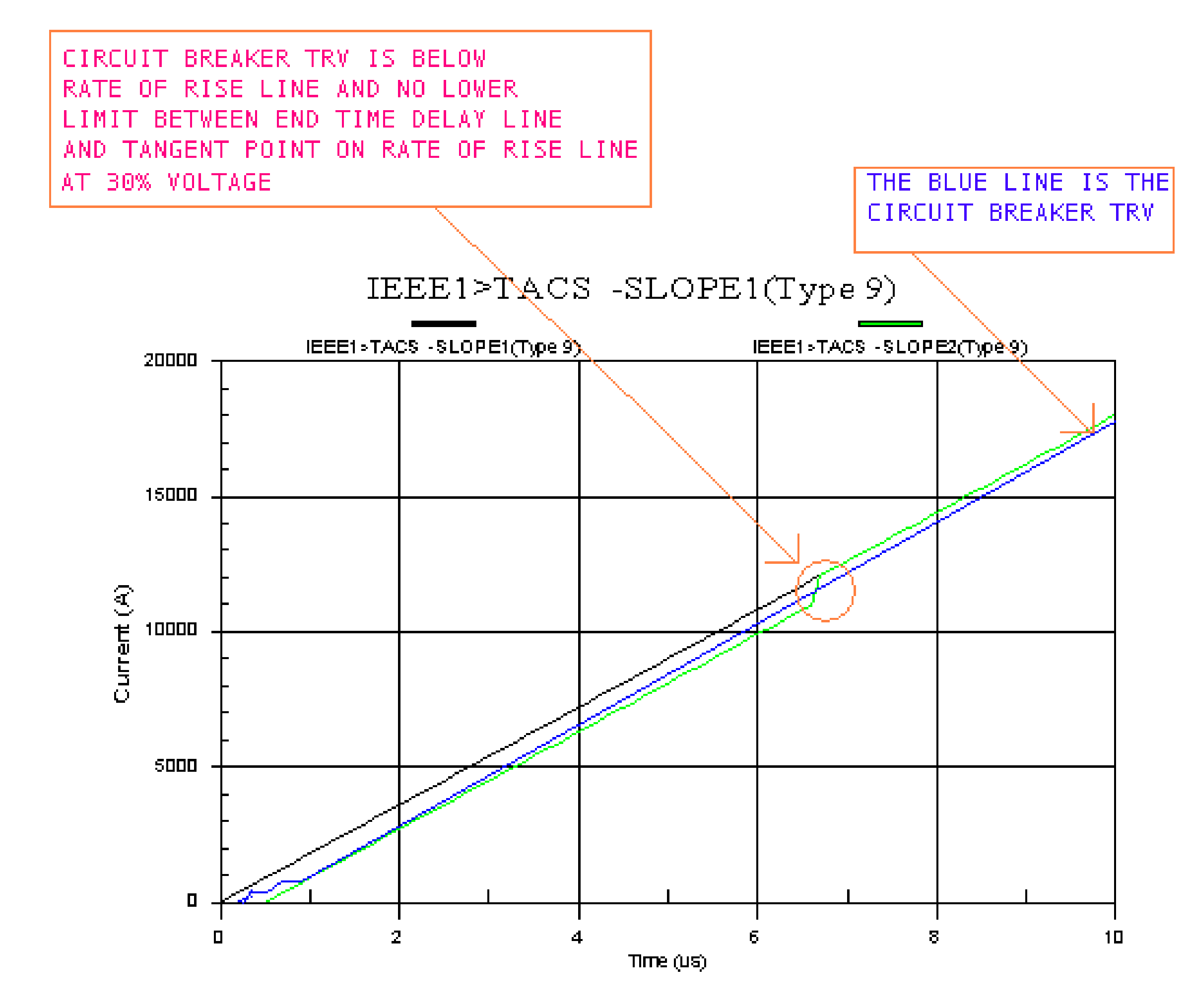
4 Parameter Function of IEC 56



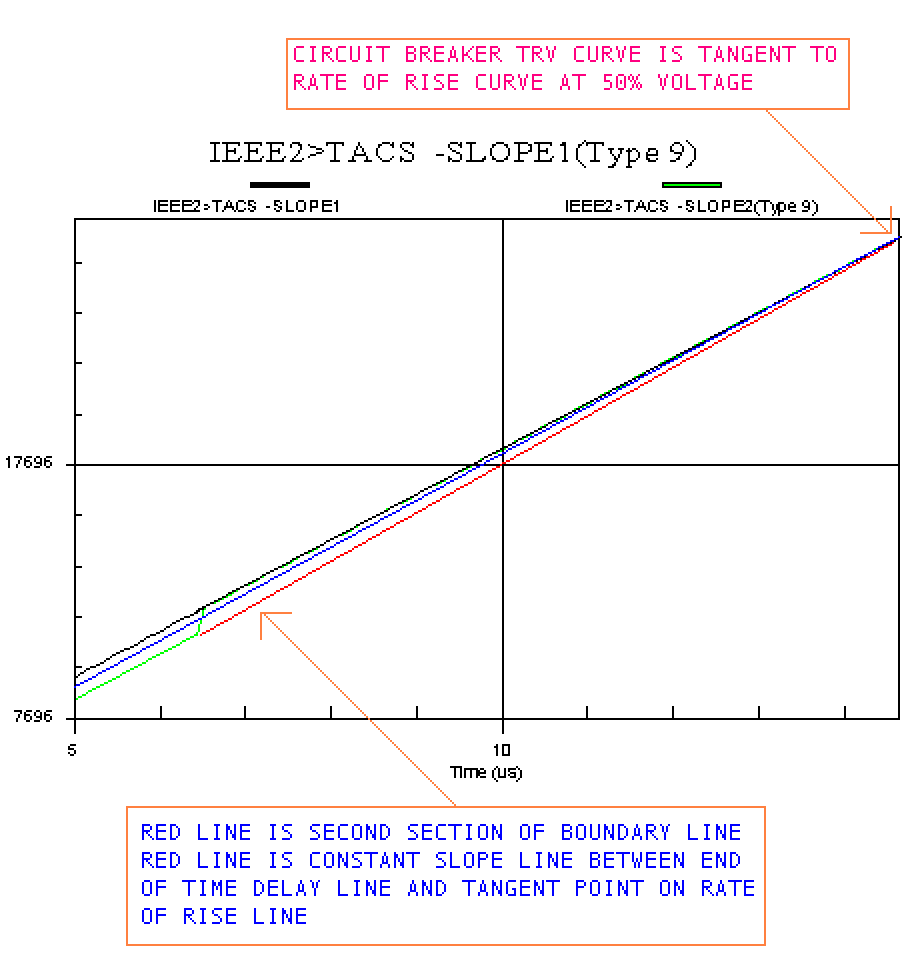
Possible Solutions to Problem

- IEC Reference Waveshape
- Delay Line to E2
- Delay Line to %1 T2 and then ROR Line
- Delay Line to %1 T2 and then Slope to ROR Line at %2 T2
- Delay Line to %1 T2, then Slope to ROR Line at %2 T2, then Curve to E2 at T2

Delay Line to %1 T2 and then ROR Line



Delay Line to %1 T2 and then Slope to %2 T2 ROR Line



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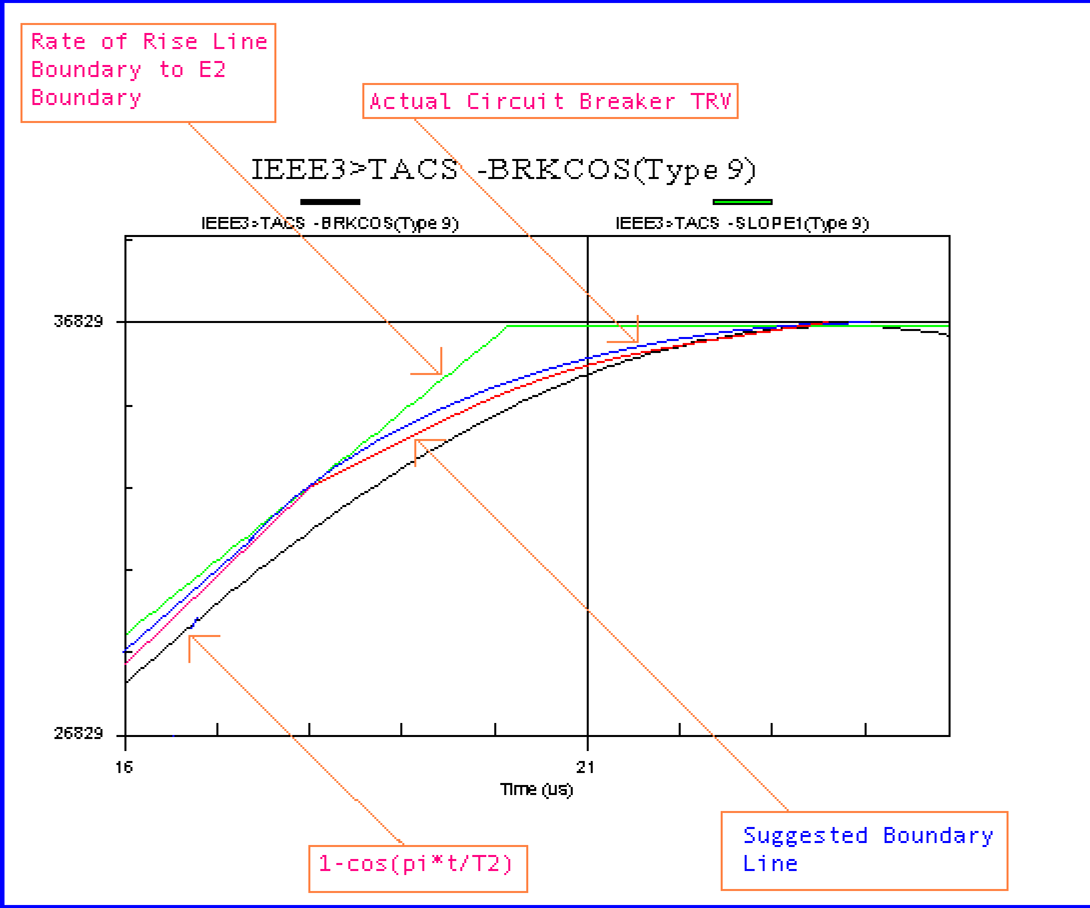
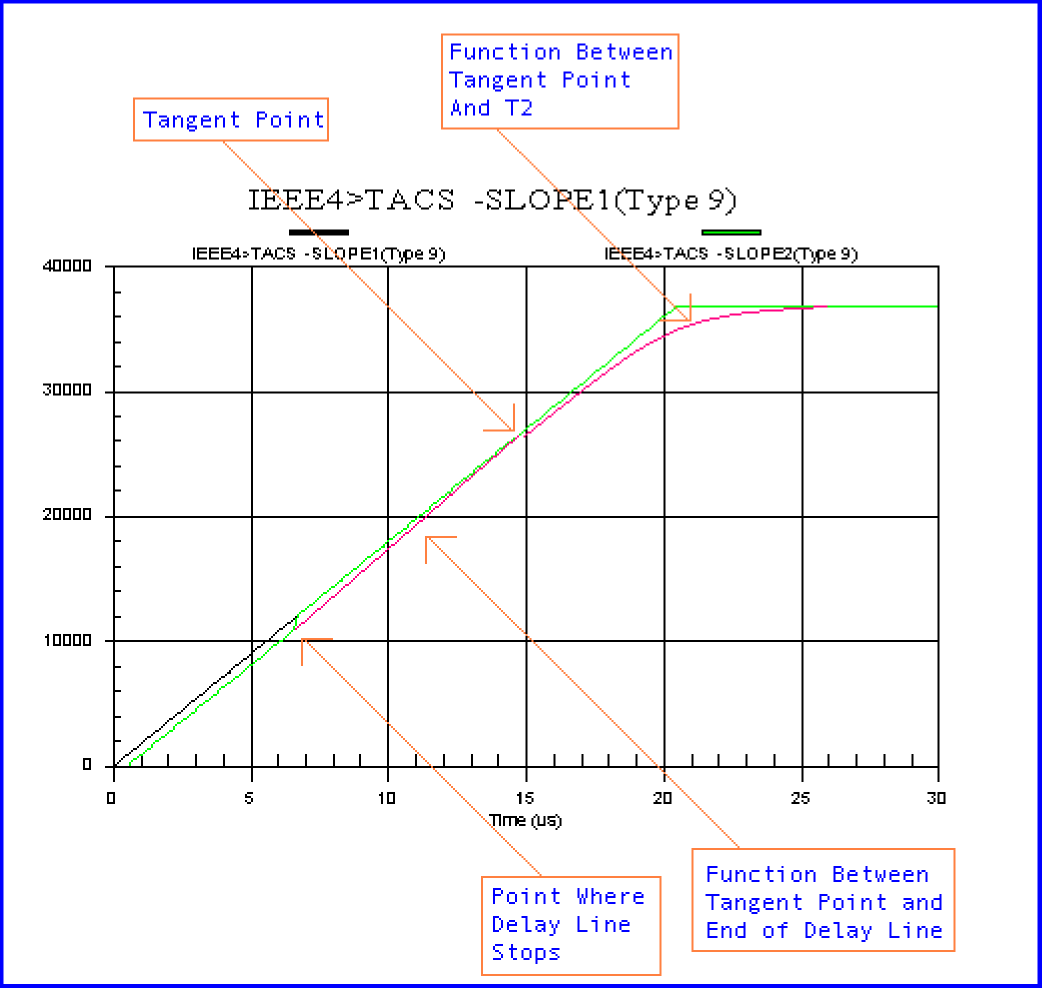
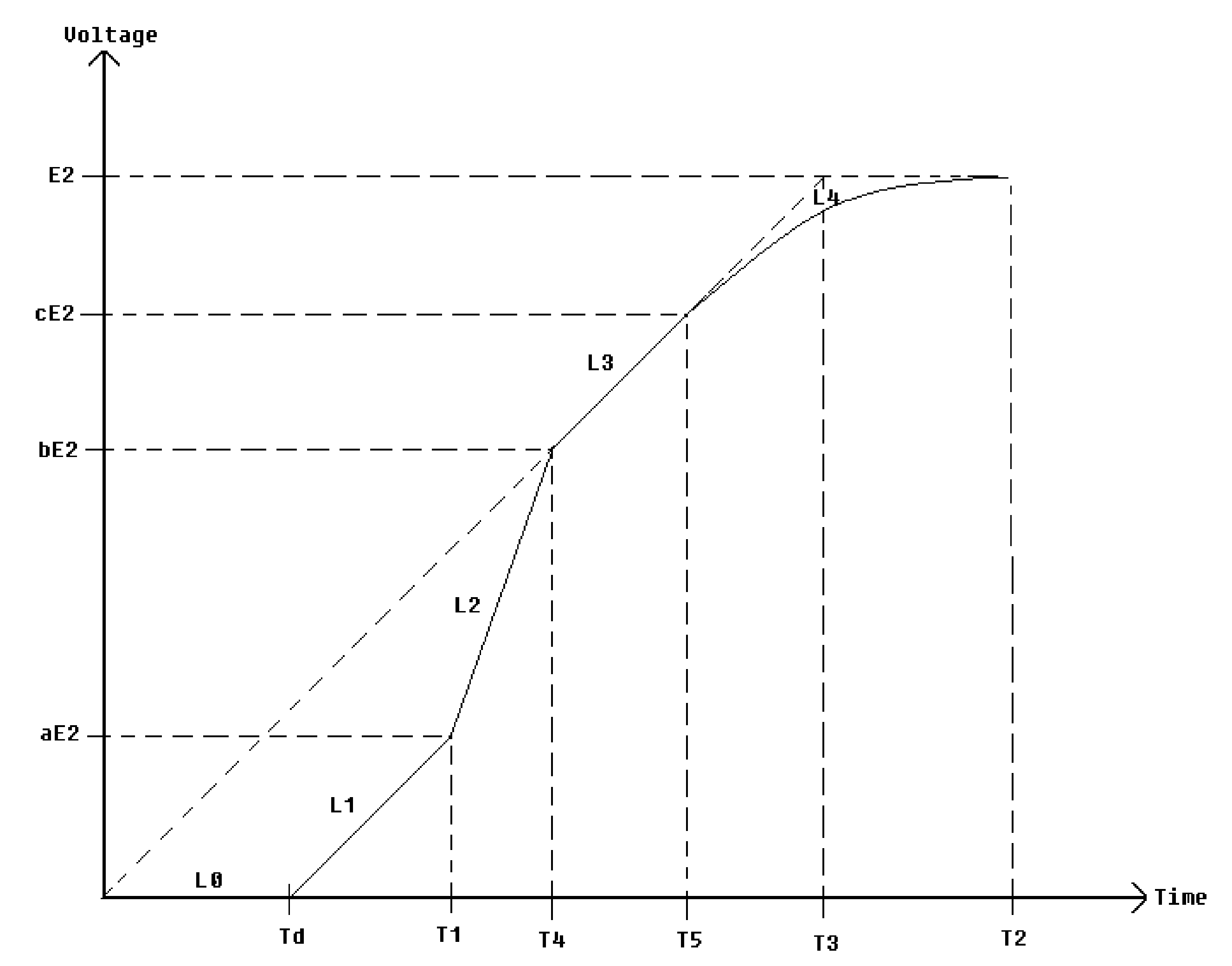
Delay Line to %1 T2, then Slope to ROR Line at %2 T2, then Curve to E2 at T2



Total Suggested Solution



Possible Generic Solution



$$L = L0 + L1 + L2 + L3 + L4$$

$$L0 = 0 \Leftrightarrow 0 \le t \le Td$$

$$L1 = R(t - Td) \Leftrightarrow Td \le t \le T1$$

$$L2 = \left(\frac{bE2 - aE2}{T4 - T1}\right)(t - T1) + aE2 \Leftrightarrow T1 \le t \le T4$$

$$L3 = Rt \Leftrightarrow T4 \le t \le T5$$

$$L4 = (1 - c)E2\left(1 - \cos\left(\frac{\pi}{2}\frac{(t - T5)}{(T2 - T5)} + \frac{\pi}{2}\right)\right) + (2c - 1)E2$$

$$\Leftrightarrow T5 \le t$$

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R is Rate of Rise

$R=E2/T3$

$T3=0.85T2$

Td is defined in the Table

E2 is defined in the Table

T2 is defined in the Table

Add:

a, b, and c to the Table

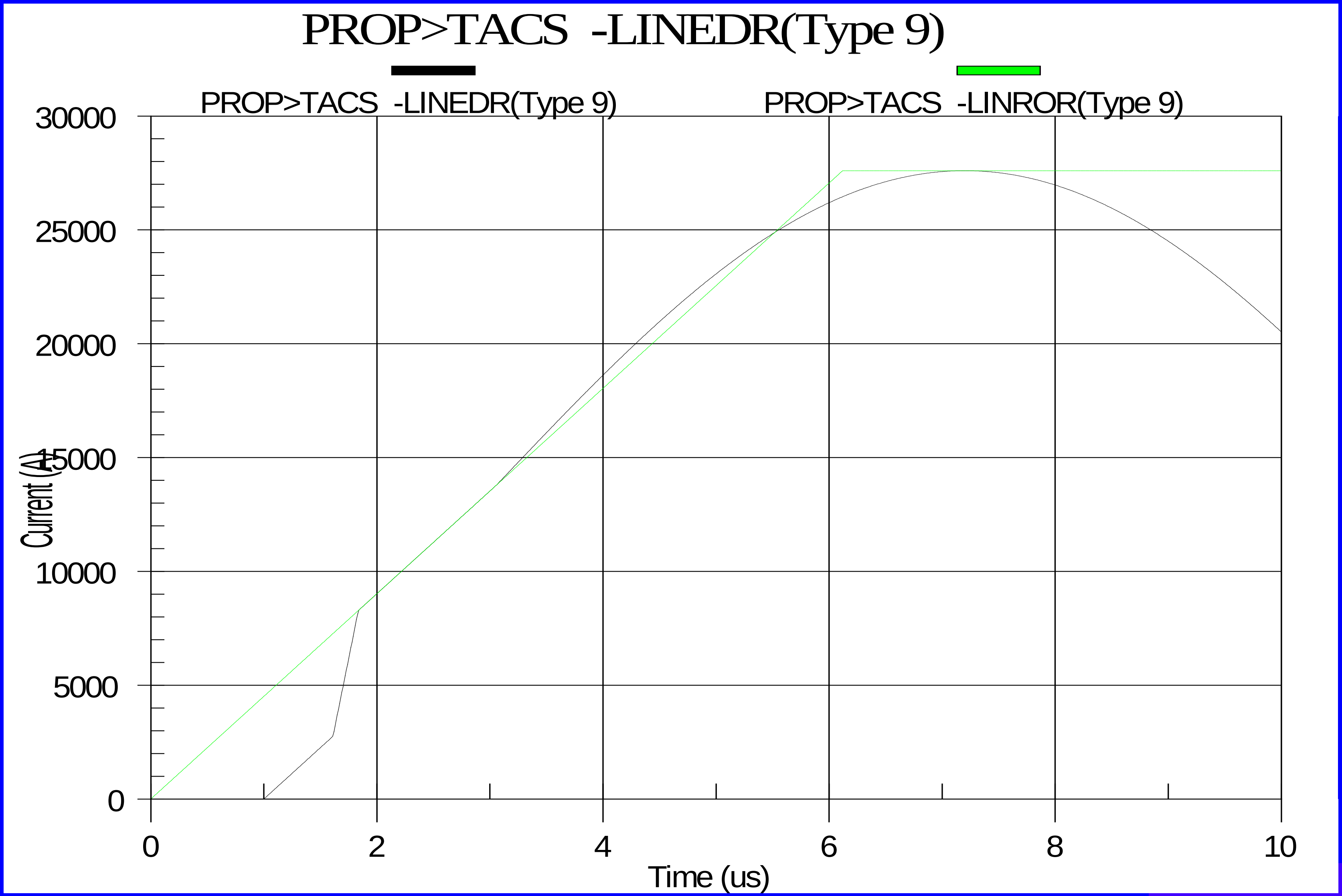
where:

$T1=(aE2/R)+Td$

$T4=bE2/R$

$T5=cE2/R$

Without Limit on Cosine



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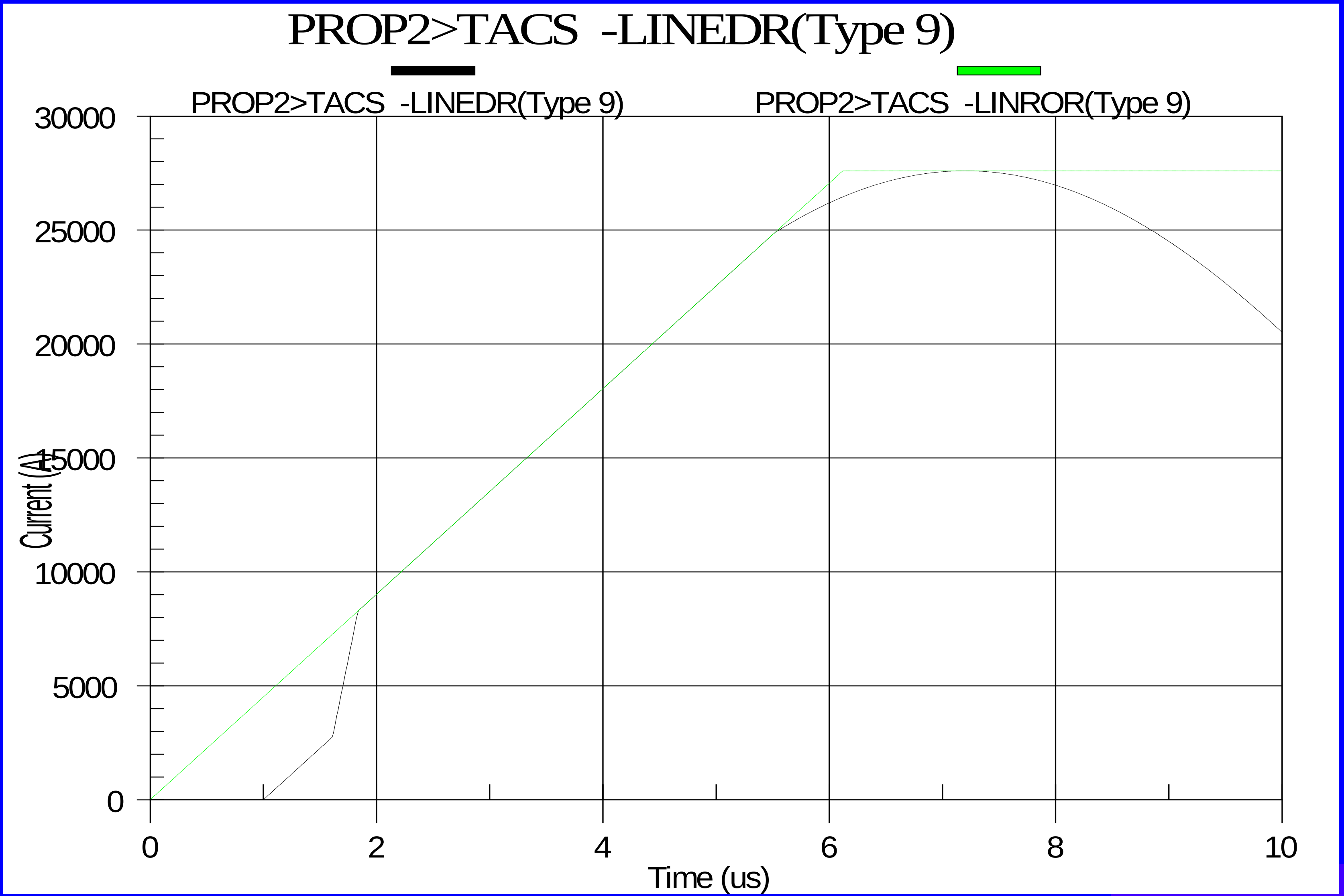
Limit on Cosine



```
TACS HYBRID
C
C       ENTER T2 VALUE (in us)
11TI2          7.2
C       ENTER E2 VALUE (in kv)
11EI2          27.6
C       ENTER THE TIME DELAY (in us)
11TID           1.0
C       ENTER CONSTANT A IN %
11AICON         10.0
C       ENTER CONSTANT B IN %
11BICON         30.0
C       ENTER CONSTANT C IN %
11CICON         50.0
C
99T2      =TI2/1000000.0
99TD      =TID/1000000.0
99E2      =EI2*1000.0
99ACON    =AICON/100.0
99BCON    =BICON/100.0
99CCON    =CICON/100.0
99T3      =0.85*T2
99ROR     =E2/T3
99T1      =(ACON*E2/ROR)+TD
99T4      =BCON*E2/ROR
99T5      =CCON*E2/ROR
C
IF (TIMEX .LT. TD) THEN
98LINEDR  =0.0
ENDIF
IF (TIMEX .GE. TD.AND.TIMEX .LT.T1) THEN
98LINEDR  =ROR*(TIMEX-TD)
ENDIF
IF (TIMEX .GT. T1.AND.TIMEX .LT.T4) THEN
98LINEDR  =((BCON-ACON)*E2/(T4-T1))*(TIMEX-T1)+ACON*E2
ENDIF
IF (TIMEX .GT. T4.AND.TIMEX .LT.T5) THEN
98LINEDR  =ROR*TIMEX
ENDIF
IF (TIMEX.GT.T5)THEN
98TEMP1   =(1-CCON)*E2
98ARGCS   =(PI/2.0)*(TIMEX-T5)/(T2-T5)+PI/2.0
98TEMP2   =TEMP1*(1-COS(ARGCS))
98LINEDR  =TEMP2+((2*CCON)-1.0)*E2
ENDIF
98CHECK   =ROR*TIMEX
IF (LINEDR .GT. CHECK) THEN
98LINEDR  =CHECK
ENDIF
IF (TIMEX .LT. T3) THEN
98LINROR  =ROR*TIMEX
ELSE
98LINROR  =E2
ENDIF
C
C <name1<name2<name3<name4<name5<name6<name7<name8<name9<nam10<nam11<nam12<nam13<
33LINEDRLINROR
C .....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.
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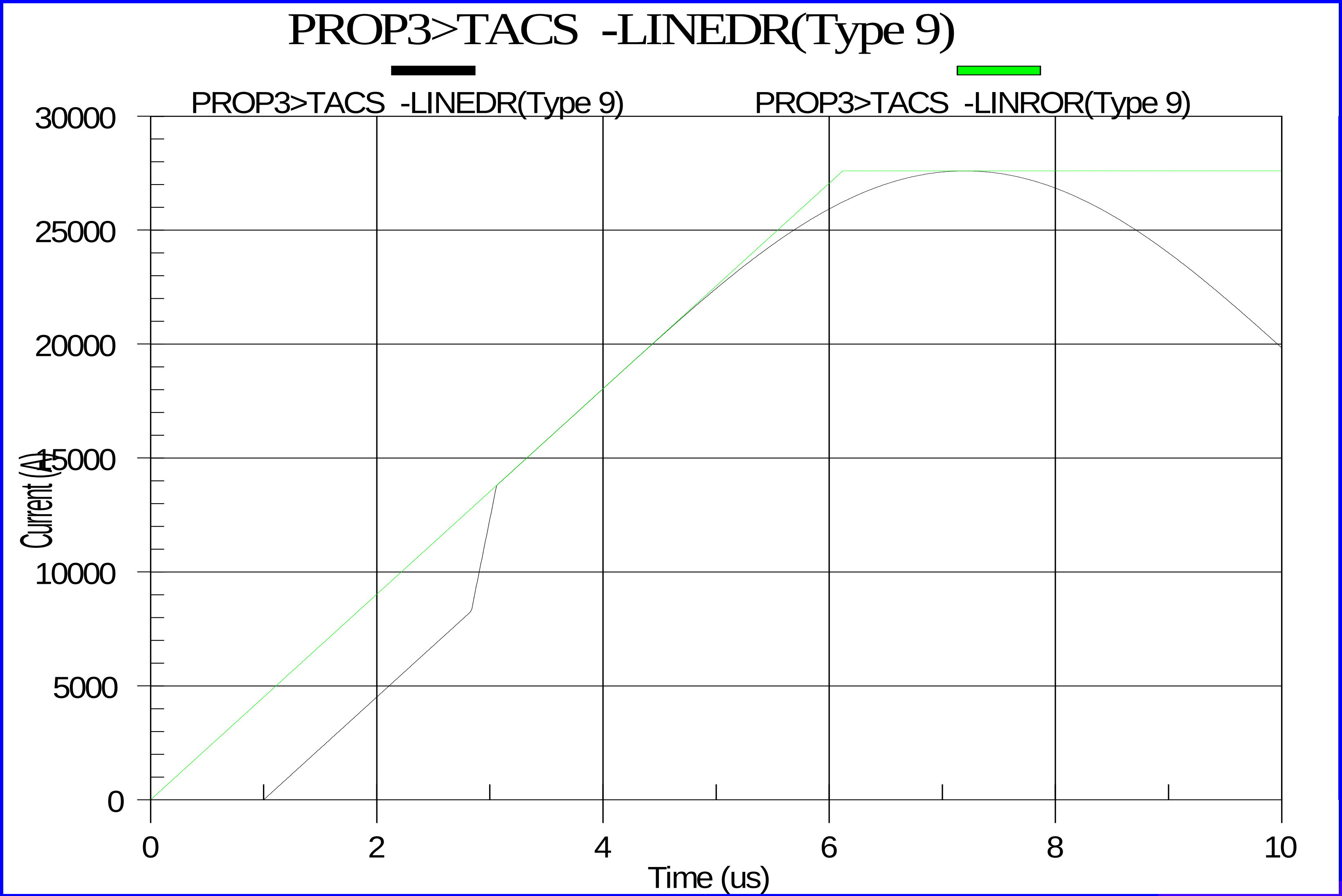
A=30%, B=50%, C=70%



PROP3>TACS -LINEDR(Type 9)
PROP3>TACS -LINEDR(Type 9)
PROP3>TACS -LINROR(Type 9)
30000
25000
20000
15000
10000
5000
0
Current (A)
0
2
4
6
8
10
Time (us)

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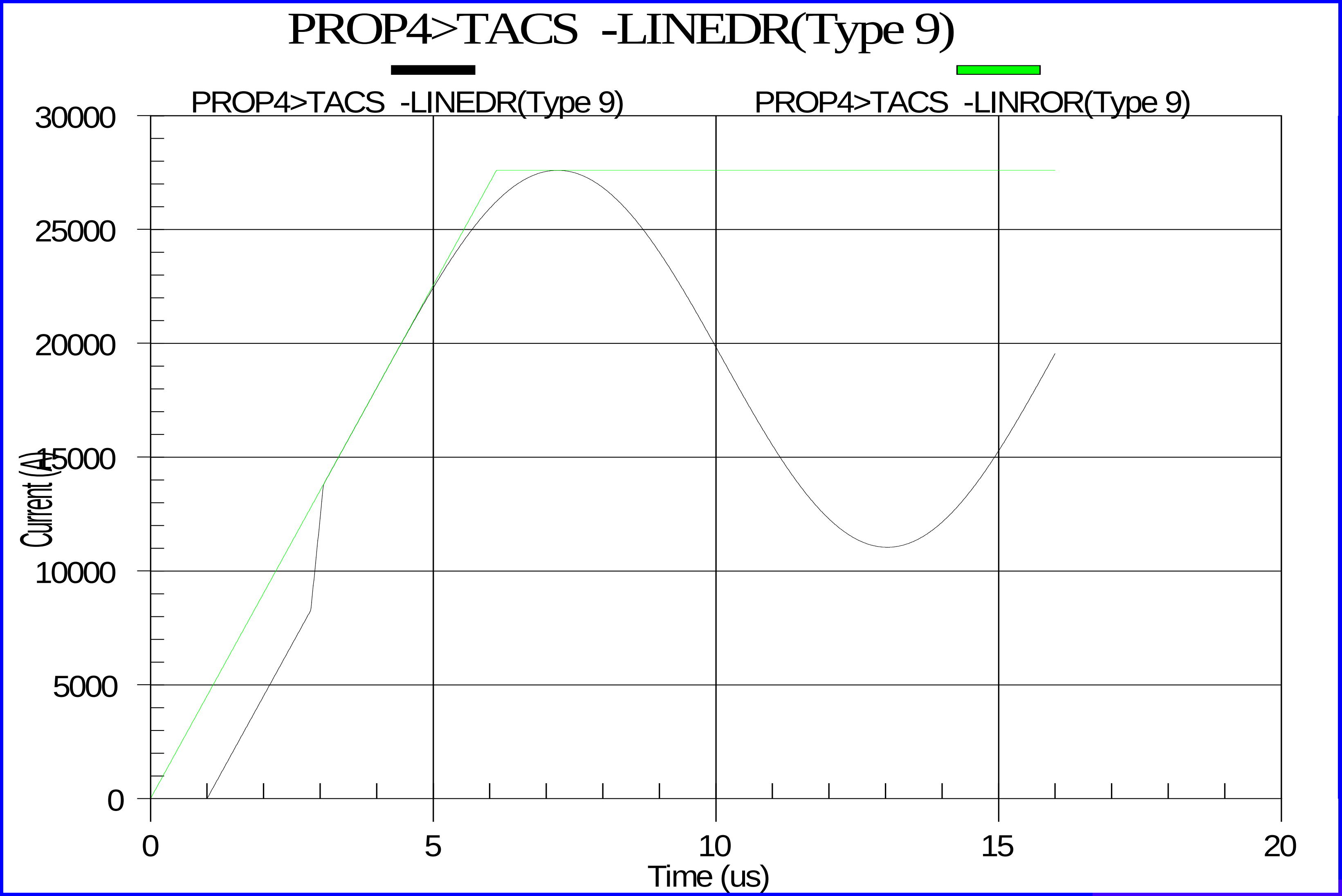
Cosine Oscillation



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$$L = L0 + L1 + L2 + L3 + L4$$

$$L0 = 0 \Leftrightarrow 0 \leq t \leq Td$$

$$L1 = R(t - Td) \Leftrightarrow Td \leq t \leq T1$$

$$L2 = \left(\frac{bE2 - aE2}{T4 - T1}\right)(t - T1) + aE2 \Leftrightarrow T1 \leq t \leq T4$$

$$L4 = (1 - c)E2\left(1 - \cos\left(\frac{\pi}{2}\frac{(t - T5)}{(T2 - T5)} + \frac{\pi}{2}\right)\right) + (2c - 1)E2$$

$$\Leftrightarrow T4 \leq t$$

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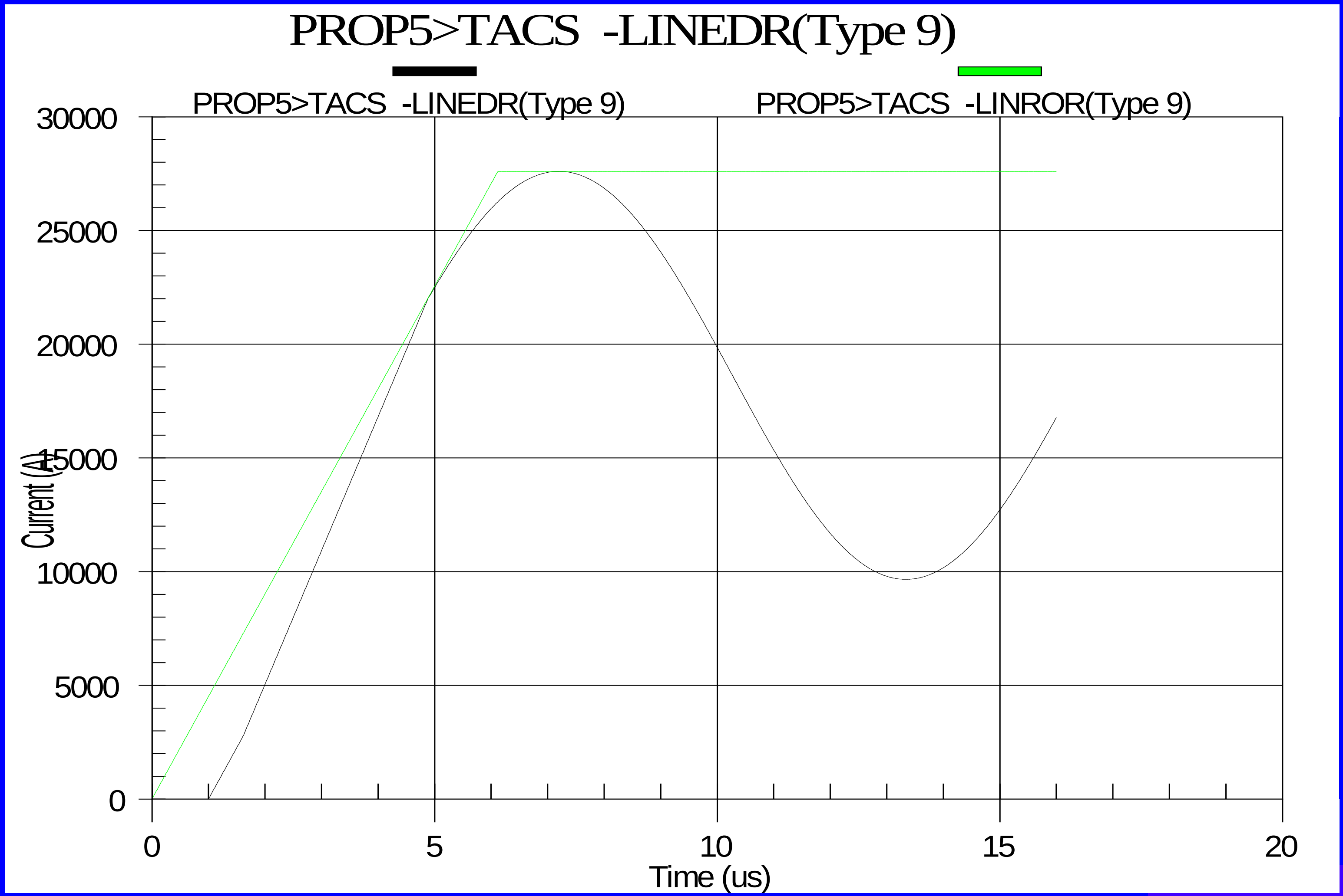
4 Segment Method

a=10%, b=90%, c=67.5%



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```
TACS HYBRID
C
C        ENTER T2 VALUE (in us)
11TI2           7.2
C        ENTER E2 VALUE (in kv)
11EI2           27.6
C        ENTER THE TIME DELAY (in us)
11TID            1.0
C        ENTER CONSTANT A IN %
11AICON          10.0
C        ENTER CONSTANT B IN %
11BICON          80.0
C        ENTER CONSTANT C IN %
11CICON          67.5
C
99T2       =TI2/1000000.0
99TD       =TID/1000000.0
99E2       =EI2*1000.0
99ACON     =AICON/100.0
99BCON     =BICON/100.0
99CCON     =CICON/100.0
99T3       =0.85*T2
99ROR      =E2/T3
99T1       =(ACON*E2/ROR)+TD
99T4       =BCON*E2/ROR
99T5       =CCON*E2/ROR
C
IF (TIMEX .LT. TD) THEN
98LINEDR  =0.0
ENDIF
IF (TIMEX .GE. TD.AND.TIMEX .LT.T1) THEN
98LINEDR  =ROR*(TIMEX-TD)
ENDIF
IF (TIMEX .GT. T1.AND.TIMEX .LT.T4) THEN
98LINEDR  =((BCON-ACON)*E2/(T4-T1))*(TIMEX-T1)+ACON*E2
ENDIF
IF (TIMEX.GT.T4)THEN
98TEMP1   =(1-CCON)*E2
98ARGCS   =(PI/2.0)*(TIMEX-T5)/(T2-T5)+PI/2.0
98TEMP2   =TEMP1*(1-COS(ARGCS))
98LINEDR  =TEMP2+((2*CCON)-1.0)*E2
ENDIF
98CHECK   =ROR*TIMEX
IF (LINEDR .GT. CHECK) THEN
98LINEDR  =CHECK
ENDIF
IF (TIMEX .LT. T3) THEN
98LINROR  =ROR*TIMEX
ELSE
98LINROR  =E2
ENDIF
C
C
<name1<name2<name3<name4<name5<name6<name7<name8<name9<nam10<nam11<nam1
2<nam13<
33LINEDRLINROR
```

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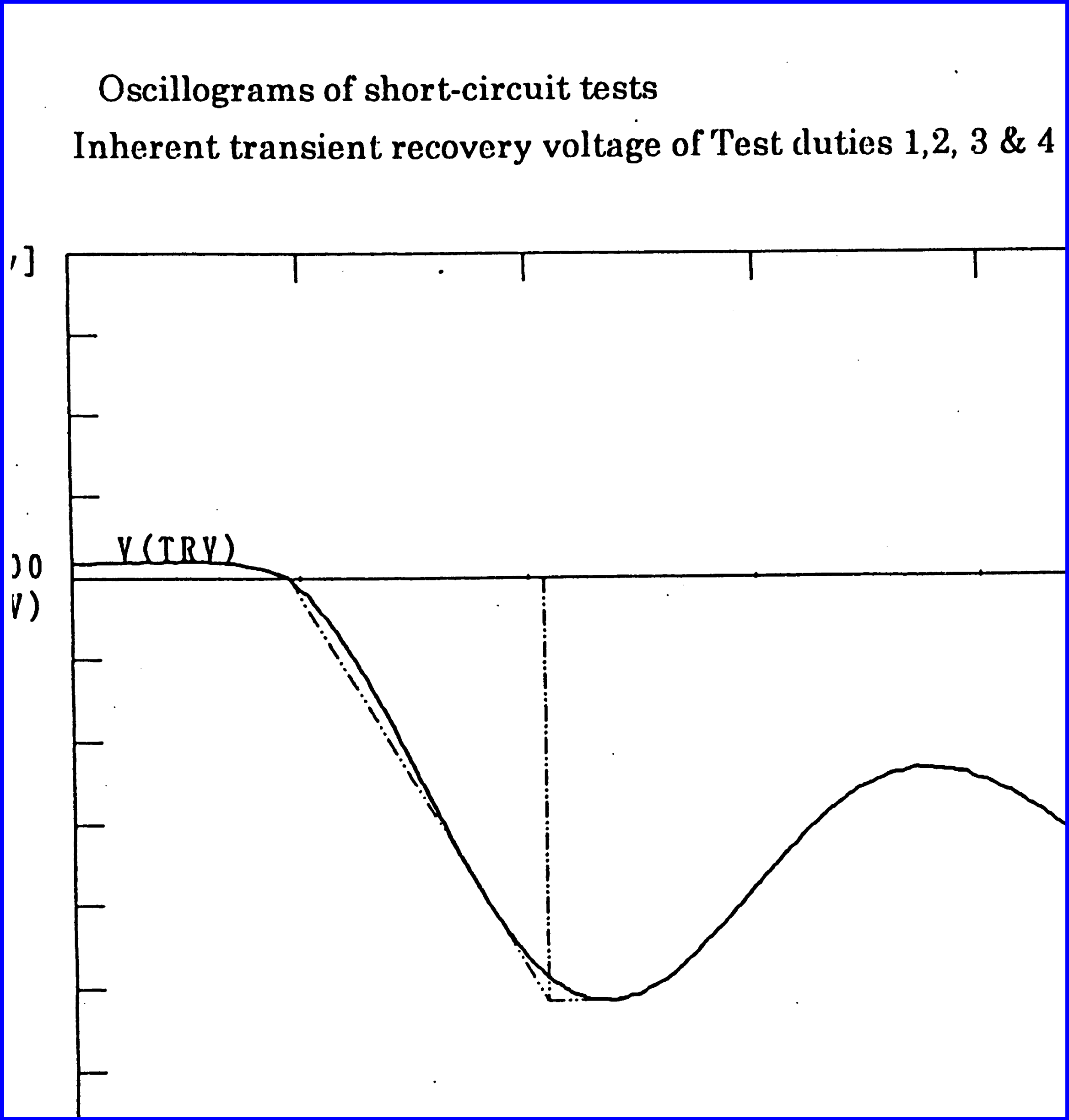
Actual Breaker TRV



Final Proposed Solution

- Specify a, b, and c for breakpoints in 5 segment curve
- Specify the point that the 1-cosine curve should be centered around
- Calculate the start of last segment based on time in curve instead of start of zero cosine point

Modified Equations

- L0, L1, L2, and L3 remain the same
- Parameters a, b, and c remain the same
- Add parameter d for percent of E2 that the 1-cosine curve is centered around
- Modify L4 by replacing T5 in cosine argument with parameter Tx
- Calculate Tx based on point in wave that 1-cosine centered around dE2 equals cE2

$$L = L0 + L1 + L2 + L3 + L4$$

$$L0 = 0 \Leftrightarrow 0 \le t \le Td$$

$$L1 = R(t - Td) \Leftrightarrow Td \le t \le T1$$

$$L2 = \left(\frac{bE2 - aE2}{T4 - T1} \right)(t - T1) + aE2 \Leftrightarrow T1 \le t \le T4$$

$$L3 = Rt \Leftrightarrow T4 \le t \le T5$$

$$L4 = (1-d)E2\left(1 - \cos\left(\frac{\pi}{2}\frac{(t - Tx)}{(T2 - Tx)} + \frac{\pi}{2}\right)\right) + (2d - 1)E2$$

$$\Leftrightarrow T5 \le t$$

$$Tx = \frac{T2\left(1 - \frac{2}{\pi}\cos^{-1}\frac{d-c}{1-d}\right) - T5}{\frac{2}{\pi}\cos^{-1}\frac{d-c}{1-d}}$$

R is Rate of Rise

R=E2/T3

T3=0.85T2

Td is defined in the Table

E2 is defined in the Table

T2 is defined in the Table

Add:

a, b, c, and d to the Table

where:

T1=(aE2/R)+Td

T4=bE2/R

T5=cE2/R

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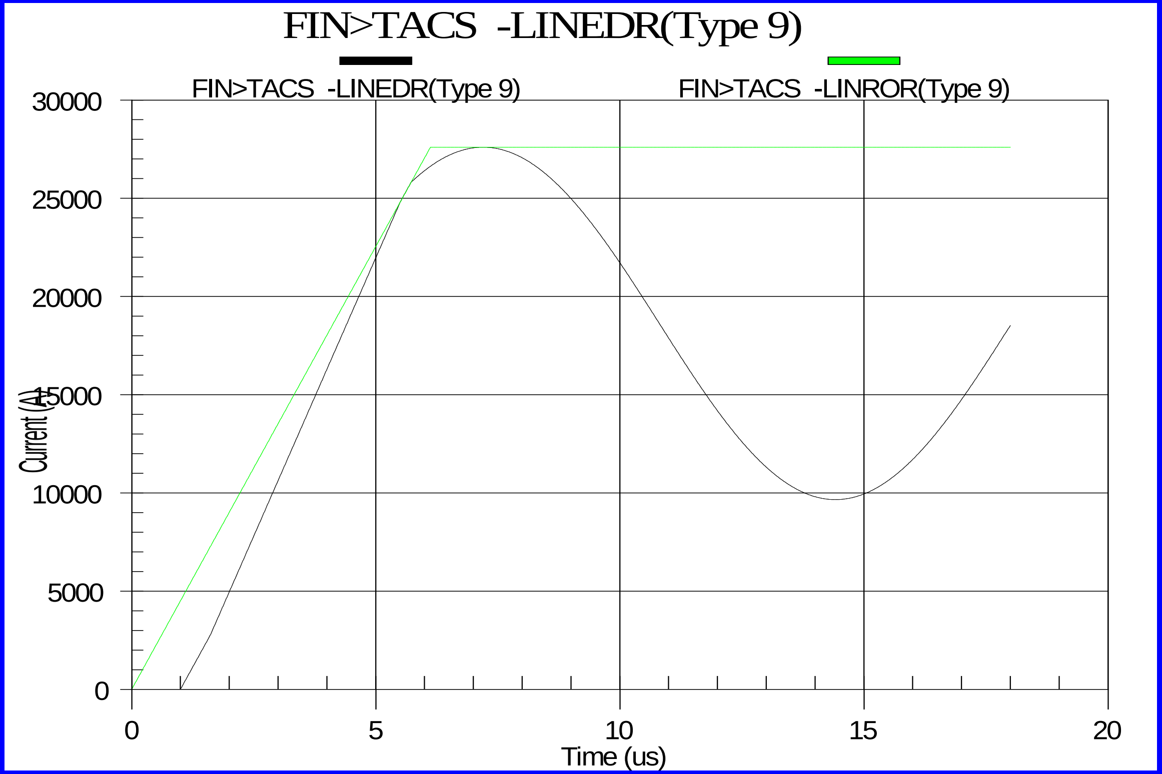
Curve FromC37.013
a=10, d=90, c=90, d=67.5



```
TACS HYBRID
C
C       ENTER T2 VALUE (in us)
11TI2          7.2
C       ENTER E2 VALUE (in kv)
11EI2          27.6
C       ENTER THE TIME DELAY (in us)
11TID           1.0
C       ENTER CONSTANT A IN %
11AICON         10.0
C       ENTER CONSTANT B IN %
11BICON         90.0
C       ENTER CONSTANT C IN % (place to start 1-cos wave)
11CICON         90.0
C       ENTER CONSTANT D IN % (center of 1-cos wave)
11DICON         67.5
99T2      =TI2/1000000.0
99TD      =TID/1000000.0
99E2      =EI2*1000.0
99ACON    =AICON/100.0
99BCON    =BICON/100.0
99CCON    =CICON/100.0
99DCON    =DICON/100.0
99T3      =0.85*T2
99ROR     =E2/T3
99T1      =(ACON*E2/ROR)+TD
99T4      =BCON*E2/ROR
99T5      =CCON*E2/ROR
99DUMV1   =(2.0/PI)*(ACOS(DCON-CCON)/(1-DCON))
99TX      =(1.0/DUMV1)*(T2*(DUMV1-1.0)-T5)
IF (TIMEX .LT. TD) THEN
98LINEDR  =0.0
ENDIF
IF (TIMEX .GE. TD.AND.TIMEX .LT.T1) THEN
98LINEDR  =ROR*(TIMEX-TD)
ENDIF
IF (TIMEX .GT. T1.AND.TIMEX .LT.T4) THEN
98LINEDR  =((BCON-ACON)*E2/(T4-T1))*(TIMEX-T1)+ACON*E2
ENDIF
IF (TIMEX .GT. T4.AND.TIMEX .LT.T5) THEN
98LINEDR  =ROR*TIMEX
ENDIF
IF (TIMEX.GT.T5)THEN
98TEMP1   =(1-DCON)*E2
98ARGCS   =(PI/2.0)*(TIMEX-TX)/(T2-TX)+PI/2.0
98TEMP2   =TEMP1*(1-COS(ARGCS))
98LINEDR  =TEMP2+((2*DCON)-1.0)*E2
ENDIF
98CHECK   =ROR*TIMEX
IF (LINEDR .GT. CHECK) THEN
98LINEDR  =CHECK
ENDIF
IF (TIMEX .LT. T3) THEN
98LINROR  =ROR*TIMEX
ELSE
98LINROR  =E2
ENDIF
C <name1<name2<name3<name4<name5<name6<name7<name8<name9<nam10<nam11<nam12<nam13<
33LINEDRLINRORT2    T5    DCON  CCON  TX
C .....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.....^.
C <Name-<>InitialVal<-
77LINEDR         0.0
C .....^..........^..
```

Conclusions

- Minimum TRV Curves Should Be Specified For C37.013
- 5 Segment Curve Suggested
- Exact Values/Equations Must Be Determined From Test Data
- C37.011 Use of IEC TRV Standard May Have Similar Problem as C37.013 if Minimum TRV Curve Not Specified