CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The speed of a numerical algorithm in Current Transformer using MATLAB Version 7 is very sensitive to whether or not vectorized operations are used.

This section presents some basic considerations to writing efficient MATLAB routines. It is possible, of course, to become obsessed with performance simulation and programming time in order to save a few seconds of execution time. The ideas presented below require little extra effort, yet can yield significant speed improvements. Once user understands how to use these procedures they will become natural parts of the MATLAB programming style.

4.2 GUI MATLAB Simulations

4.2.1 Current Transformer Core 1 - Transformer Biases Differential Algorithm

According to manufacturer AREVA KBCH, the CT requirement required for knee point voltage can be calculated from the equation 4.1 (Areva, 2002).

$$Vk \geq 24\, In\, (Rct + 2Rl + Rb) \tag{4.1}$$

Given the Primary Data input:

The system Voltage, Vs = 275kV
The Rated Fault Level, If = 40kV
The CT Ratio = 600/1
The Class type = PX
The magnetizing current, Io=40mA at ½ Vk

The CT secondary resistance should be calculated According to TNB Technical Guideline 2.14, Sh.14 – The Rct ≅ 0.4Ω per 100 turns (TNBE, 2003). Therefore

The CT secondary winding resistance, Rct = 2.4Ω

According TNB Technical Guideline 2.13, Sh.12, and the lead resistance is assumed for Cc is 4mm sq cross section copper Multicore conductor given for 275kV and the estimated distance for calculation purposes Ic is 250m. The copper Multicore conductor resistance/km, Cr is 4.61Ω/km (TNBE, 2003).

The lead Resistance between CTs and relay, RL = 2 x 4.61 x 0.25

= 2.305Ω

The relay resistance, Rb = 1Ω

The required the Knee point Voltage used equation 4.2:

$$Vk \geq 24\ In\ (Rct + 2Rl + Rb) \tag{4.2}$$

$$Vk \geq 24 \times 1\ (2.4 + 2.305 + 1)$$

$$Vk \geq 136.92V\ @\ 600/1A$$

From the clauses 14.1.2.5, the CT burden shall be sufficient and able to cater for all its loads, and shall be more than 15VA with minimum ALF 20 (TNB, 2002).

TNB Technical Guideline 2.13 is a rule of thumb, for class X current transfer. The burden VA requirement may be estimated by the following equation 4.3:

$$VA = (Vk/ALF) - Rct \tag{4.3}$$

$$VA = 4.45VA$$

To comply the requirement from Clauses 14.1.2.5, VA shall be 15VA

Hence,

$$VA = (Vk/20) - Rct$$
$$Vk = 20\ (VA + Rct)$$
$$Vk = 20(15 + 2.4)$$
$$Vk = 348V\ @\ 600/1A$$

The Source impedance, $Zs = Vs/\sqrt{3} \times If$ (4.4)

$$Zs = 275000/\sqrt{3} \times 40000$$
$$Zs = 3.969\Omega$$

The fault current calculated at the 275kV side,

$$I_F = (Vs/\ \sqrt{3})\ /Zs \qquad (4.5)$$
$$I_F = (275000/\ \sqrt{3})\ /3.969$$
$$I_F = 40{,}002.85A$$

Dimensioning of the CTs for the transformer biased differential for 275kV side, the requirement for the relay KBCH 130 is extracted. For over dimensioning factor, $K_{TF} \geq 0.75$ (4ms saturation free time) in the event of internal faults.

From the equation 2.10, the corresponding rated accuracy limit factor is then

$$ALF' = I_F\ /\ I_N.\ K_{TF}$$
$$ALF' = (40{,}002.85/600) \times 0.75$$
$$ALF' = 50.0035$$

The corresponding rated CT burden is then

$$Pi = I_N.\ Rct\ = 1 \times 2.4 = 2.4VA$$
$$Pb = I_N \times (Rl + Rb) = 1 \times (2.305 + 1) = 3.305$$
$$P_N = \text{CT rated Burden} = 15$$

From the equation 2.11, the required Nominal Accuracy Limit Factor is then,

$$ALF = (Pi + P_B / P_i + P_N).\ ALF'$$
$$ALF = (2.4 + 3.305)/ (2.4 + 15) \times 50.0035$$
$$ALF = 16.395$$

From the equation 3.12, the internal EMF that arise when this rated accuracy limit factor flows then corresponds to the saturation voltage of the CT

$$E_{al} = ALF.\ I_{2N}.\ (R_{CT} + R_B)$$
$$E_{al} = 16.395\ (2.4 + 3.305)$$
$$E_{al} = 93.533V$$

Apply equation 4.3, the actual burden required for this Current Transformer

$$VA = (Vk/ALF) - Rct$$
$$VA = (93.533/16.395) - 2.4$$
$$VA = 3.3049$$

Therefore, the calculation of Vknee point voltage ad ALF show that requirement for CT are adequate.

4.2.2 Current Transformer Core 2 Transformer High Impedance Algorithm

According to manufacturer MCAG34, The CT requirement for knee point voltage can be calculated (Areva, 2001).

$$Vk = 3 \times Ims \times (Rct + Rl) \tag{4.6}$$

Given the Primary Data input:

The system Voltage, Vs = 275kV

The Rated Fault Level, If = 40kV

The CT Ratio = 1200/600/1

The Class type = PX

The magnetizing current, Io=40mA at ½ Vk

The CT secondary resistance should be calculated According to TNB Technical Guideline 2.14, Sh.14 – The Rct ≅ 0.4Ω per 100 turns (TNBE, 2003). Therefore

The CT highest ratio secondary winding resistance, Rct = 4.8Ω @ 1200A

The CT lowest ratio secondary winding resistance, Rct = 2.4Ω @ 600A

The lead resistance between CTs and relay, RL = 2 x 4.61 x 0.25

= 2.305Ω

The relay resistance, Rb = 1Ω

The maximum primary full load Current, Ip = MVA / √3 x Vs

$Ip = 240 \times 10^6 / \sqrt{3} \times 275 \times 10^3$

Ip = 503.87A

The maximum Secondary Full load Current, Is_H= Ip/Highest Ratio

Is_H=503.89/1200

Is_H = 0.42A @ 1200A

The maximum Secondary Full load Current, Is_L= Ip/ Lowest Ratio

Is_L=503.89/600

Is_L=0.84A @ 600A

The ext. fault Current, Iefc=16x Is_H

$Iefc_H$=15 x 0.42 = 6.3A @ 1200A

$Iefc_L$= 15 x 0.84 = 13.A @ 600A

The minimum preferred value in TNB guidelines for Vk ≥ 2Vs (TNB, 2002)

From equation 4.6, the required the Knee point Voltage is at highest Ratio

$Vk = 3\ Ims \times (Rct + Rl)$ @ 1200A

$Vk = 3 \times 6.72 \times (4.8 + 2.305)$

$Vk = 143.23V$ @ 1200A

From equation 4.6, the required the Knee point Voltage is at lowest Ratio

$Vk = 3\ Ims \times (Rct + Rl)$ @ 600A

$Vk = 3 \times 13.44 \times (2.4 + 2.305)$

$Vk = 189.70\ V$ @ 600A

From the clauses 14.1.2.5, The CT burden shall be sufficient and able to cater for all its loads, and shall be more than 15VA with minimum ALF 20 (TNB, 2002).

Apply equation 4.3, the burden in VA,

$VA = (Vk/20) - Rct$

$VA = 2.361VA$ @ 1200A

$VA = 7.085VA$ @ 600A

Apply equation 4.4, the Source impedance,

$Zs = Vs/\sqrt{3} \times If = 275000/\sqrt{3} \times 40000$

$Zs = 3.969\Omega$

Apply equation 4.5, the fault current calculated at the 275/132kV side,

$I_F = (Vs/\sqrt{3})/Zs$

$I_F = (275000/\sqrt{3})/3.969$

$I_F = 40{,}002.8A$

Dimensioning of the CTs for the transformer biases differential for 275kV side, the requirement for the relay MCAG 34 is extracted. For over dimensioning factor, $K_{TF} \geq 0.75$ (4ms saturation free time) in the event of internal faults.

From the equation 2.10, the corresponding rated accuracy limit factor is then

$$ALF' = I_F / I_N . K_{TF}$$
$$ALF' = (40{,}002.8/1200) \times 0.75$$
$$ALF' = 25 \ @ \ 1200A$$
$$ALF' = (40{,}002.8/600) \times 0.75$$
$$ALF' = 50.0035 \ @ \ 600A$$

The corresponding CT rated burden is then

$$Pi = I_N . Rct = 1 \times 4.8 = 4.8VA \ @ \ 1200A$$
$$Pi = I_N . Rct = 1 \times 2.4 = 2.4VA \ @ \ 600A$$
$$Pb=I_N \times (Rl + Rb) = 1 \times (2.305 + 0.5) = 2.805$$
$$P_N = \text{CT rated Burden} = 15$$

From the equation 2.11, the required Nominal Accuracy Limit Factor is then,

$$ALF = (Pi + P_B / P_i + P_N). ALF'$$
$$ALF = (4.8 + 2.805)/ (4.8 + 15) \times 25$$
$$ALF = 9.602 @ \ 1200A$$
$$ALF = (2.4 + 2.805)/ (2.4 + 15) \times 50.0035$$
$$ALF = 14.958 @ \ 600A$$

From the equation 3.12, the internal EMF that arise when this rated accuracy limit factor flows then corresponds to the saturation voltage of the CT

$$E_{al} = ALF. I_{2N}. (R_{CT} + R_B)$$
$$E_{al} = 9.602 \ (4.8 + 2.805)$$
$$E_{al} = 73.023V @ \ 1200A$$

$$E_{al} = 14.958\ (2.4 + 2.805)$$
$$E_{al} = 77.856V @\ 600A$$

Apply equation 4.3, the actual burden required for this Current Transformer

$$VA = (Vk/ALF) - Rct$$
$$VA = (73.023/9.602) - 4.8$$
$$VA = 2.805 @\ 1200A$$
$$VA = (77.856/14.958) - 2.4$$
$$VA = 2.8049 @\ 600A$$

Therefore, the calculation of Burden, Vknee point voltage and ALF show that requirement for CT is adequate.

4.2.3 Current Transformer Core 3 Back up Distance Algorithm

According to manufacturer AREVA P441, the CT requirement required for knee point voltage can be calculated from the equation (4.7) (Areva, 2001).

$$Vk = (VA \times ALF)/In + (Rct \times ALF \times In) \tag{4.7}$$

Given the Primary Data input:

The system Voltage, Vs = 275kV
The Rated Fault Level, If = 40kV
The CT Ratio = 600/1
The VA Rating = 30VA
The Class type = 5P20
The magnetizing current, Io=40mA at ½ Vk

The CT secondary resistance should be calculated According to TNB Technical Guideline 2.14, Sh.14 – The Rct ≅ 0.4Ω per 100 turns (TNBE, 2003). Therefore

The CT secondary winding resistance, Rct = 2.4Ω

The lead Resistance between CTs and relay, $RL = 2 \times 4.61 \times 0.25$

$= 2.305\Omega$

The CB fail relay resistance = 0.3Ω

The Recorder resistance = 0.5Ω

The Low Impedance BBP = 0.1Ω

The Total relay resistance, $Rb = 0.3\Omega+0.5\Omega+0.1\Omega$

$=0.9\Omega$

Maximum Voltage across the CT's terminals during short circuit

$$=If \times (Rct + RL + Rb)$$

$$= (40KA/600) \times (2.4 + 2.305 + 0.9)$$

$$=373.67V$$

Apply equation 4.7, the required the Knee point Voltage is

$$Vk= (VA \times ALF)/In + (Rct \times ALF \times In)$$

$$Vk \geq (30 \times 20)/1 + (2.4 \times 20 \times 1)$$

$$Vk \geq 648V \ @ \ 600/1A$$

From the clauses 14.1.2.5, The CT burden shall be sufficient and able to cater for all its loads, and shall be more than 15VA with minimum ALF 20 (TNB, 2002).

Apply the equation 4.3, the burden in VA,

$$VA = (Vk/20) - Rct$$

$$VA = 30VA$$

Apply equation 4.4, the Source impedance,

$$Zs = Vs/\sqrt{3} \times If = 275000/\sqrt{3} \times 40000$$

$$Zs = 3.969\Omega$$

Apply equation 4.5, the fault current calculated at the 275/132kV side,

$$I_F = (Vs/ \sqrt{3}) /Zs$$

$$I_F = (275000/ \sqrt{3}) /3.969$$

$$I_F =40{,}002.8A$$

Dimensioning of the CTs for the transformer biased differential for 275kV side, the requirement for the relay P441 is extracted. For over dimensioning factor, $K_{TF} \geq 0.75$ (4ms saturation free time) in the event of internal faults.

From the equation 2.10, the corresponding rated accuracy limit factor is then

$$ALF' = I_F / I_N.\ K_{TF}$$

$$ALF' = (40{,}002.8/600) \text{ x } 0.75$$

$$ALF' = 50.0035$$

The corresponding rated accuracy limit factor is then

$$Pi = I_N.\ Rct = 1 \text{ x } 2.4 = 2.4VA$$

$$Pb=I_N \text{ x } (Rl +Rb) = 1 \text{ x } (2.305 +0.9) = 3.205$$

$$P_N = \text{CT rated Burden} = 30$$

From the equation 2.11, the required Nominal Accuracy Limit Factor is then,

$$ALF = (Pi +P_B / P_i + P_N).\ ALF'$$

$$ALF = (2.4 + 3.205)/ (2.4 +30) \text{ x } 50.0035$$

$$ALF = 8.650$$

From the equation 3.12, the internal EMF that arise when this rated accuracy limit factor flows then corresponds to the saturation voltage of the CT

$$E_{al} = ALF.\ I_{2N}.\ (R_{CT} + R_B)$$

$$E_{al} = 8.650(2.4 + 3.205)$$

$$E_{al} = 48.483V$$

Apply equation 4.3, the Actual Burden required for this Current Transformer

$$VA = (Vk/ALF) - Rct$$

$$VA = (48.483/8.650) - 2.4$$

$$VA = 3.205$$

So therefore the burden, Vknee point Voltage and The ALF are calculated and show that the requirements for Current Transformer are Adequate.

4.2.4 Current Transformer Core 4 and 5 High Impedance BusBar Algorithm

According to manufacturer MCAG34, The CT requirement for knee point voltage can be calculated (Areva, 2001).

$$Vk = 3 \text{ x } Ims \text{ x } (Rct + Rl) \tag{4.8}$$

Given the Primary Data input:

The system Voltage, Vs = 275kV

The Rated Fault Level, If = 40kV

The CT Ratio = 4000/1A

The Class type = PX

The magnetizing current, Io=10mA at ½ Vk

The CT secondary resistance should be calculated According to TNB Technical Guideline 2.14, Sh.14 – The Rct ≅ 0.4Ω per 100 turns (TNBE, 2003). Therefore

The CT Highest ratio secondary winding resistance, Rct = 16Ω

The lead Resistance between CTs and relay, RL = 2 x 4.61 x 0.25

= 2.305Ω

The Maximum Secondary Full load Current, I_{SF}= Ip/Highest Ratio

Is_F=40000/4000

Is_F=10A

The maximum voltage across CT terminal, Vs=I_{SF} x (R_{CT} + R_L)

Vs=10 x (16 + 2.305)

Vs=183.05V

The minimum preferred value in TNB guidelines for Vk ≥ 2Vs (TNB, 2002)

The required the Knee point Voltage is at highest Ratio

Vk = 2Vs

Vk = 2 x 183.05

Vk = 366.1V

From the clauses 14.1.2.5, The CT burden shall be sufficient and able to cater for all its loads, and shall be more than 15VA with minimum ALF 20 (TNB, 2002).

Apply equation 4.3, the burden in VA,

VA = (Vk/ALF) -Rct

VA= 11.4575VA

Apply equation 4.4, the Source impedance, Zs = Vs/√3 x If = 275000/√3 x 40000

Zs = 3.969Ω

Apply equation 4.5, the fault current calculated at the 275kV side,

I_F = (Vs/ √3) /Zs

I_F = (275000/ √3) /3.969

I_F =40,002.8A

Dimensioning of the CTs for the transformer biases differential for 275kV side, the requirement for the relay MCAG 34 is extracted. For over dimensioning factor, $K_{TF} \geq 0.75$ (4ms saturation free time) in the event of internal faults.

From the equation 2.10, the corresponding rated accuracy limit factor is then

$$ALF' = I_F / I_N . K_{TF}$$
$$ALF' = (40{,}002.8/4000) \times 0.75$$
$$ALF' = 7.5$$

The corresponding rated accuracy limit factor is then

$$Pi = I_N . Rct = 1 \times 16 = 16VA$$
$$Pb = I_N \times (Rl + Rb) = 1 \times (2.305) = 2.305$$
$$P_N = \text{CT rated Burden} = 15$$

From the equation 2.11, the required Nominal Accuracy Limit Factor is then,

$$ALF = (Pi + P_B / P_i + P_N). ALF'$$
$$ALF = (16 + 2.305)/ (16 + 30) \times 7.5$$
$$ALF = 2.986$$

From the equation 3.12, the internal EMF that arise when this rated accuracy limit factor flows then corresponds to the saturation voltage of the CT

$$E_{al} = ALF. I_{2N}. (R_{CT} + R_B)$$
$$E_{al} = 2.986 (16 + 2.305)$$
$$E_{al} = 54.659$$

Apply equation 4.3, the Actual Burden required for this Current Transformer

$$VA = (Vk/ALF) - Rct$$
$$VA = (54.659/2.986) - 16$$

$$VA= 2.305\ VA$$

So therefore the burden, Vknee point Voltage and The ALF are calculated and show that the requirements for Current Transformer are Adequate

4.3 Simulations Results and Discussions

4.3.1 Current Transformer

This section will explain the steps to run the program and all the important parameter used for simulation output value. The procedure to evaluate the program in MATLAB will be describe explain as below:-

Firstly, the program will show the functions and some of the applications of CT transformer as shown in Figure 4.1. Then click "to be continued" icon as shown in Figure 4.1.

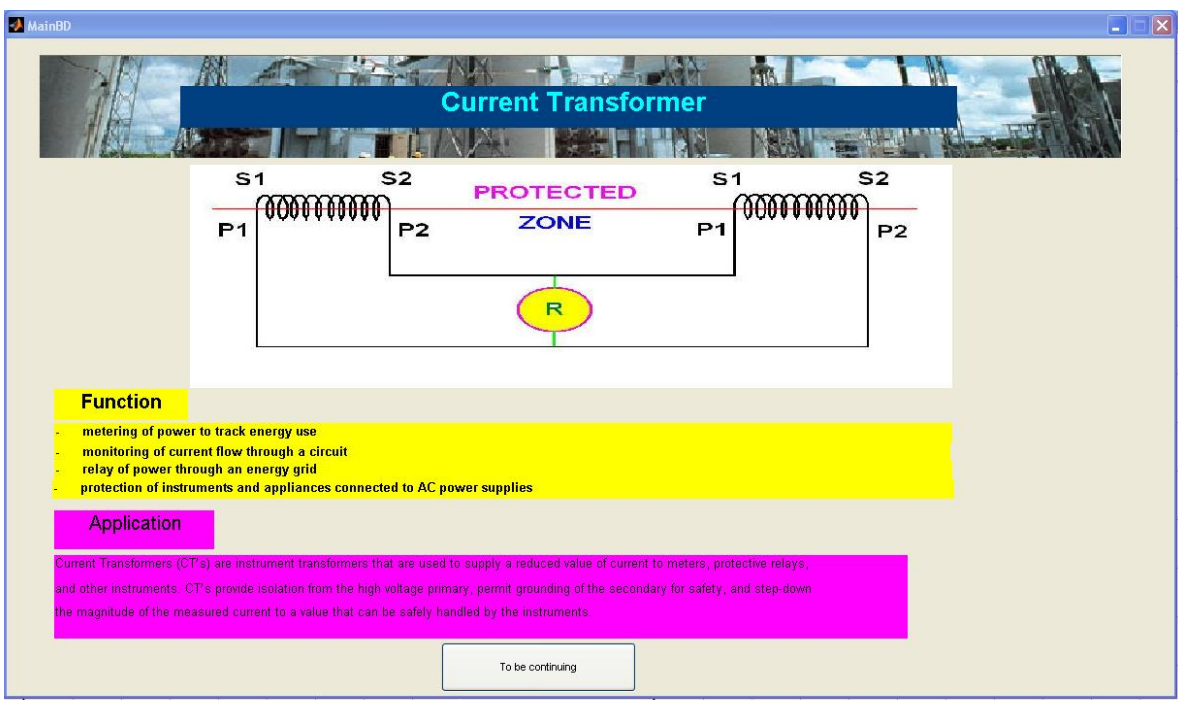

Fig. 4.1 Window of CT Definition

Two equations are display which are the equation for over dimensioning factor and fault Inception angle which shown in Figure 4.2. The user can get this graph by clicking the “Anglel Graph” and “Ktf Graph” icon as shown in Figure 4.2.

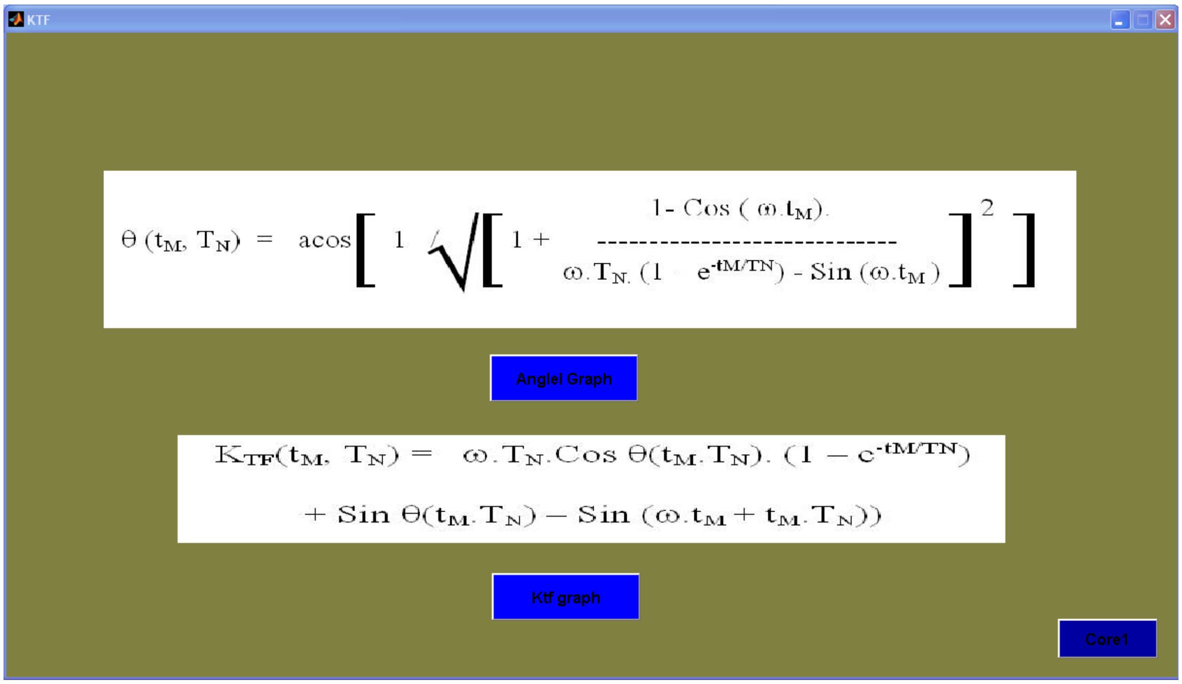

Fig. 4.2 Equation of over dimensioning and Fault Inception Anglel

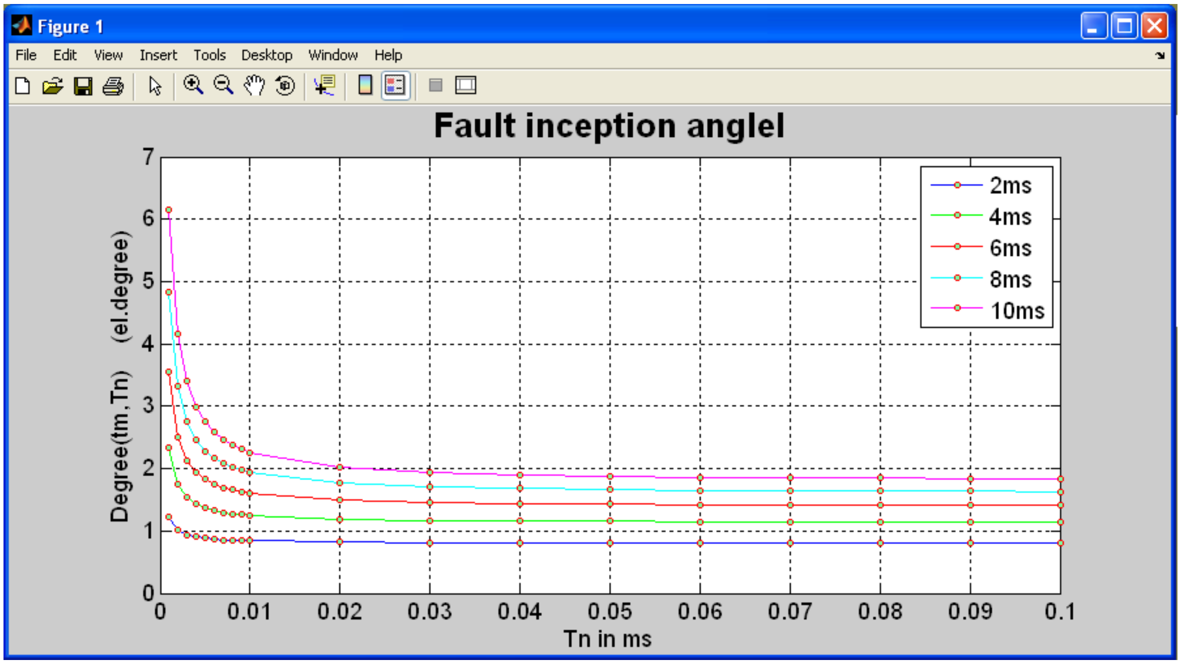

Fig. 4.3 Transient Over dimensioning (K_{TF}) vs System time Constant. (T_N)

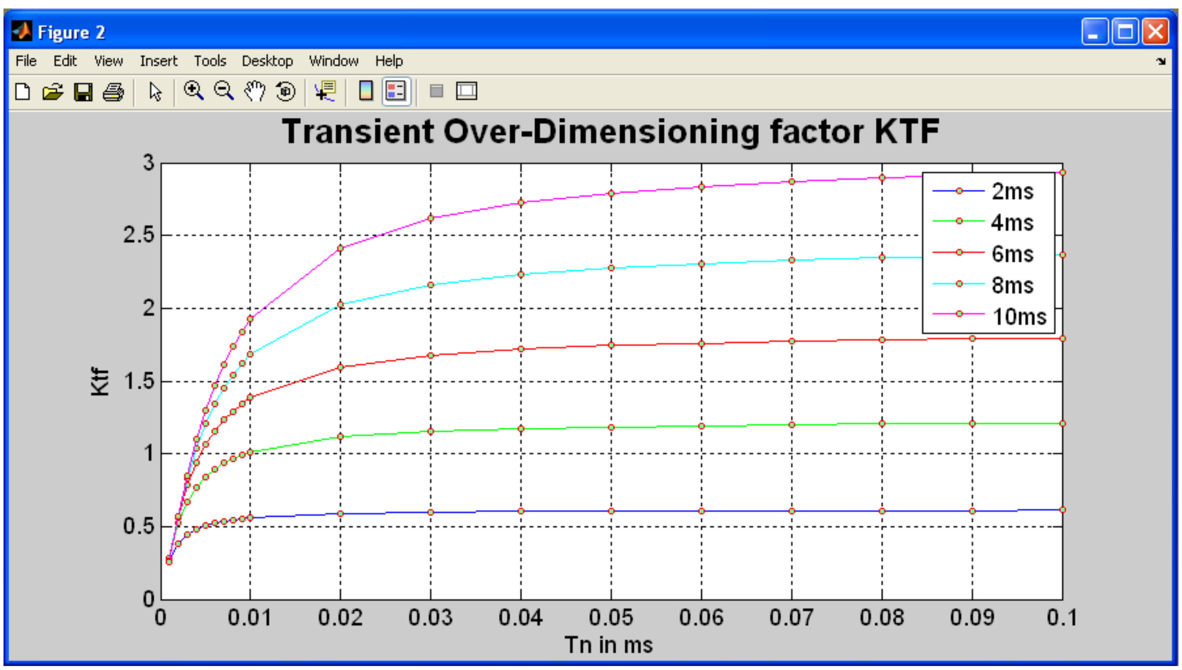

Fig. 4.4 Fault inception anglel (θ) vs System time Constant. (T_N)

The graph shows the value of K_{TF} for internal fault and external fault for every type of fault. In the event of an internal fault close to the terminals, a very large fault current will result while the current in case of external fault is much smaller due to the transformer short circuit impedance. CT dimensioning calculations may be found in the product documentation or engineering guides provided by the protection manufacturer (Gerhard Ziegler, 2005). The value for generator and transformer protection for Internal fault at choose at T $\geq$ 4ms at $K_{TF} \geq 0.75$ are calculated.

STEP 1

Firstly, click “Core 1” icon from Figure 4.2, and Figure 4.5 shows the model of Core I - Transformer Biased Differential protection. Then, key in CT parameters that is input power transformer value given at the transformer rating is 240MVA and the system Voltage is 275KV. The maximum through fault current for external fault, Ikmaz is 40KA and the Nominal frequency input, Freq is 50Hz. For the Existing substation, the maximum fault current rating is equal to the maximum short circuit rating of the existing primary equipment. Therefore in this case, fault current is 40KA. As per requirement Refer to TNB Technical Guideline for 275KV, page 7 show the standard TNB system X/R parameters for current transformer protection transient performance are, X/R is 15. Refer to TNB Technical Guideline for 275KV, page 12 for the purpose for calculation, the lead resistance is assumed, Cc is 4mmsq cross sectional copper multicore conductor and Copper multicore conductor Resistance/Km, Cr is 4.61Ω/km. The Estimated distance for the calculation, L is 10km. As TNB Technical Guideline, page 14, the rated secondary winding resistance R_{CT} is taken at 75^{o}C. The R_{CT} must be selected to ensure adequate cross sectional area of the secondary winding conductor to carry rated current including the secondary rated short time current. The estimate for copper conductor secondary winding, the secondary winding resistance R_{CT} value can be estimated by $R_{CT} \leq 0.2$ to 0.5Ω per 100 turns. As for TNB calculation purpose, The RCT $\cong 0.4\Omega$ per 100 turns. So therefore R/T is 0.004Ω per turn (TNBE, 2003). The Over dimensioning factor for remanence may be as much as 80% , Kr is 0.8 in closed iorn core current transformer. Consequently only 20% flux increases up to saturation would remain (see Figure 3.12) and the Current dimension would be have to be increased by the remanence over dimensioning factor (Gerhard Ziegler, 2005).

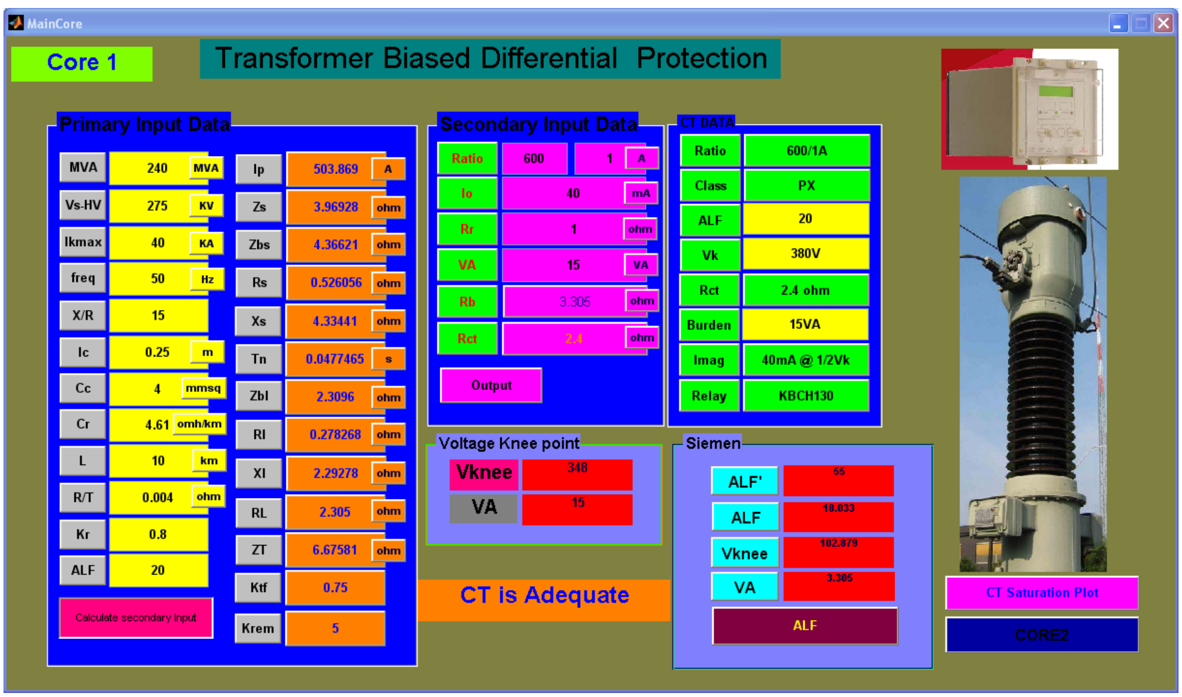

Fig. 4.5 Transformer Biased Differential Protection

Once the user enters primary input parameters, the primary value results are displayed on the program by pressing the icon “Calculate secondary Input”.

Secondly, key in Secondary Input data parameters that is the Vkee point voltage and Burden of the Current Transformer. Therefore as TNB Technical Guidelines, page 26, have specified the CT requirement. For the transformer biased differential protection, the ratio is 600/1 A (TNBE, 2003). The magnetizing current, Io is 40mA and the relay resistance of the KBCH130, Rr is 1Ω. The minimum burden VA requirement is 15VA as TNB COP clauses 14.1.2.5 Accuracy limit factor equal to 20. The VA is 15 and after the user enters secondary input parameters, the value of ”Voltage knee point” result are displayed on the program by pressing icon “Output”.

Third, the user must compare the sum of secondary results with “CT DATA” for CT normalized. By pressing the icon “ALF” the complete result for modeling Core 1 is show in Figure 4.5. The program shows that the “**CT is adequate**”.

Fourth, click icon “CT saturation plot” which design for CT magnetization curve as shown in figure 4.5 and the result say the “Voltage knee point” are located in saturation area as shown in figure 4.6.

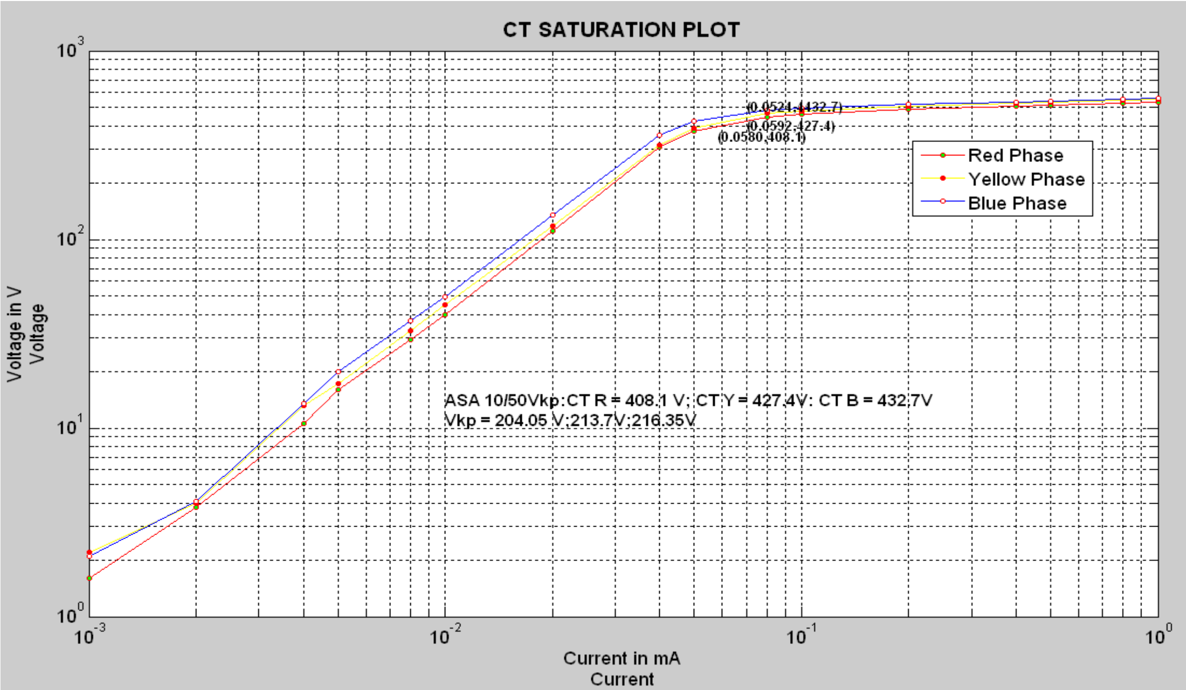

Figure 4.6 Core 1 CT Magnetization Curve; Vkp=204.05V; 213.7V; 216.35V

STEP 2

Finally, the Modeling Simulation for Core 1 has been completed and click the icon "CORE 2". The Figure 4.7 shows the model of Core 2 - Transformer High Impedance protection.

Firstly, use the same progress in Core 1 for Core 2, The requirement is to key in CT parameters Primary input as process as in Core 1. (Refer page 85)

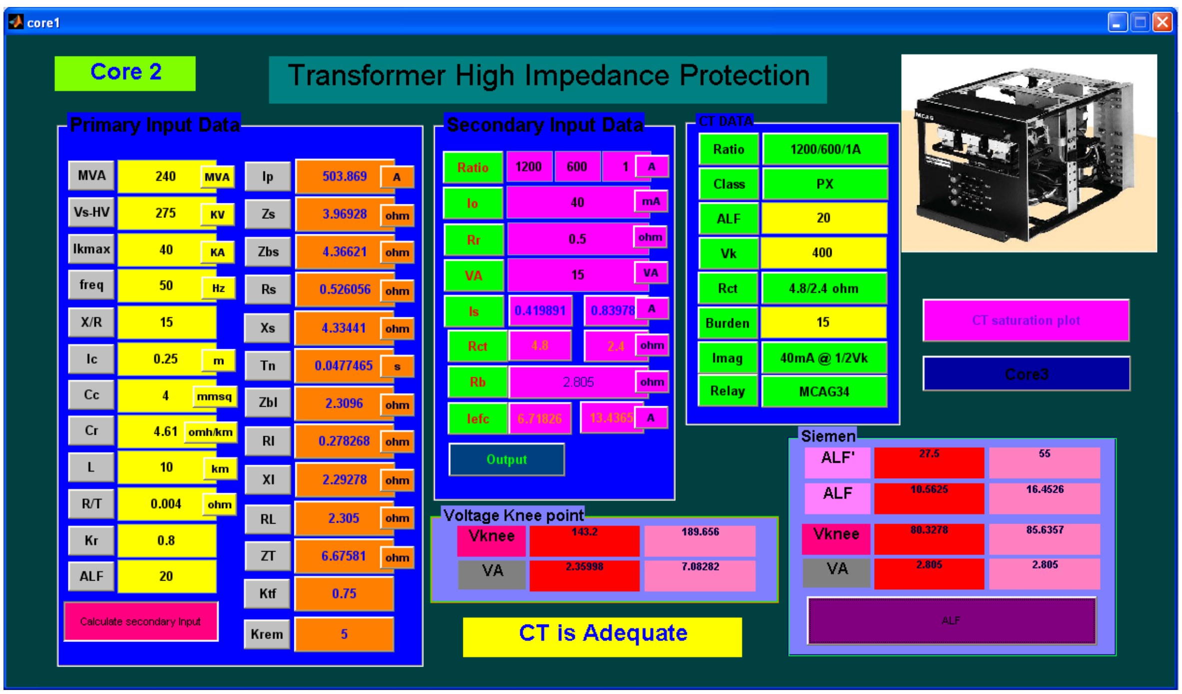

Fig. 4.7 Transformer High Impedance Protection.

Secondly, to key in Secondary Input data parameters for the results of Vkee point voltage and Burden of the Current Transformer. Therefore as TNB Technical Guidelines, page 26, have specified the CT requirement. For the transformer high impedance protection, the ratio is 1200/600/1 A (TNBE, 2003). The magnetizing current, Io is 40mA and the relay resistance of the MCAG34, Rr is 0.5Ω. The minimum burden VA requirement is 15VA as TNB COP clauses 14.1.2.5 Accuracy limit factor equal to 20. The VA is 15. Once the user enters secondary input parameters, the value of ”Voltage knee point” result are displayed on the program by pressing icon “Output” as shown in Figure 4.7.

Third, is to look at comparison the sum of secondary results with “CT DATA” for CT normalized. By pressing the icon “ALF” the complete result for modeling Core 2 is shown in Figure 4.7. The program has to say that the “**CT is adequate**”.

Fourth, click icon “CT saturation plot“ which is the design for CT magnetization curve as shown in Figure 4.7 and the result show the “Voltage knee point” are located in saturation area as shown in Figure 4.8.

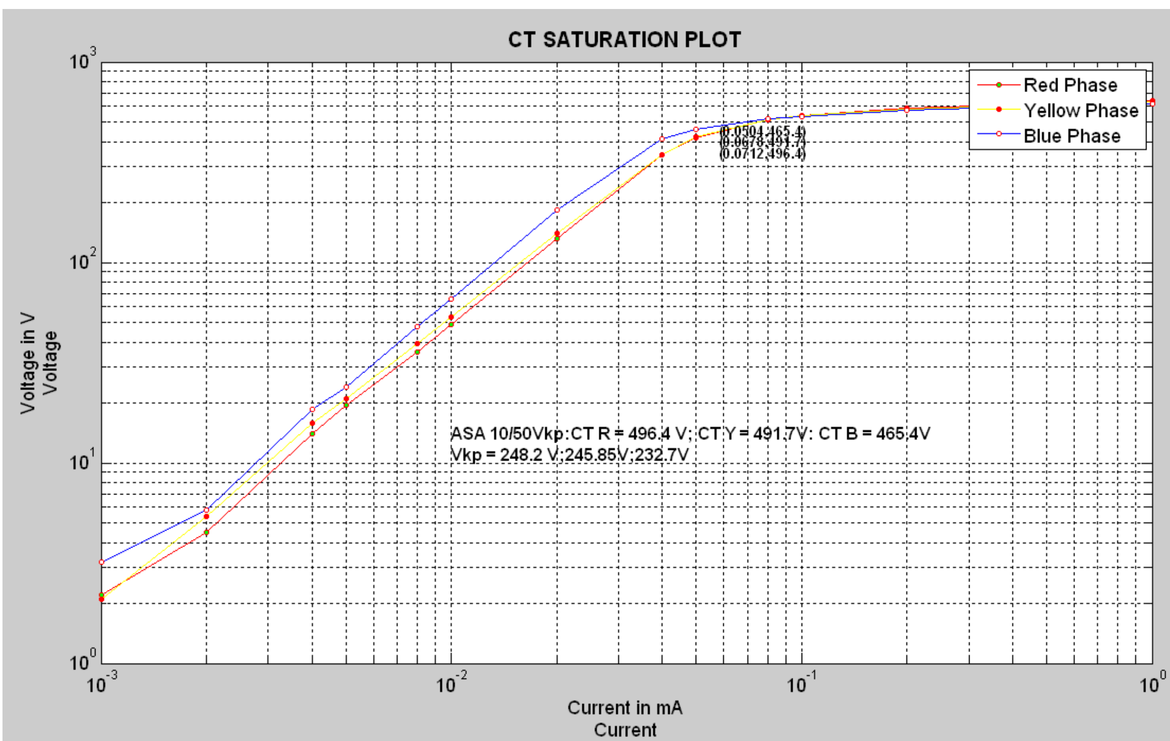

Figure 4.8 Core 2 CT Magnetization Curve; Vkp=248.2V; 245.85V; 232.7V

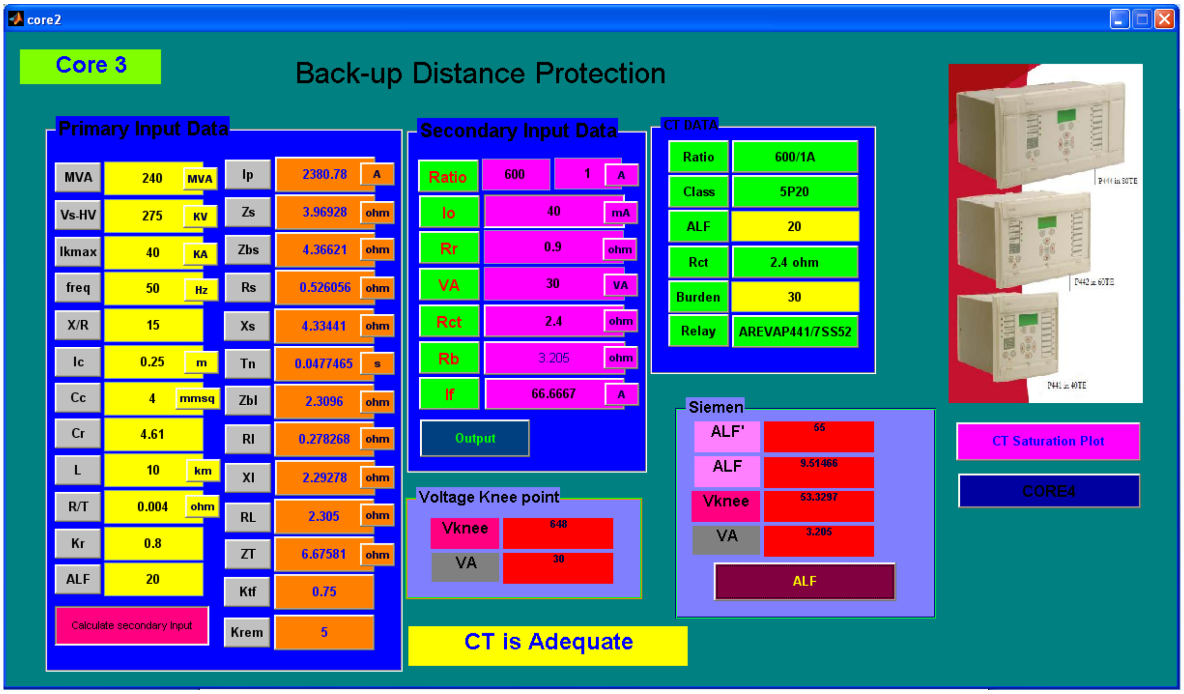

Fig. 4.9 Back-up Distance Protection.

Finally, the Modeling Simulation for Core 2 has completed and clicked the icon “CORE 3” for back up distance protection. The Figure 4.9 shows the model of Core 3 – Back-up Distance protection.

STEP 3

The process is the same as in Core 1 for Core 3, key in CT parameters Primary input as in Core 1 (Refer page 85).

Then, the user is required to key in Secondary Input data parameters for the results of Vknee point voltage and Burden of the Current Transformer. For the Back-up distance protection, the ratio is 600/1A. The magnetizing current, Io is 40mA and the relay resistance of the AREVA P441/7SS52, Rr is 0.9Ω. The minimum burden VA requirement is 30VA as TNB COP clauses 14.1.2.5 and The VA is 30. Once secondary input parameters is entered the value of ”Voltage knee point” result are displayed on the program by pressing icon “Output” as shown in Figure 4.9.

The comparison of the sum of secondary results with “CT DATA” for CT normalized is compare. By pressing the icon “ALF” the complete result for modeling Core 3 is shown in Figure 4.9. The program states that the “**CT is adequate**”.

Click icon “CT saturation plot” which design for CT magnetization curve as shown in Figure 4.9 and the result shows the “Voltage knee point” is located in saturation area as shown in Figure 4.10.

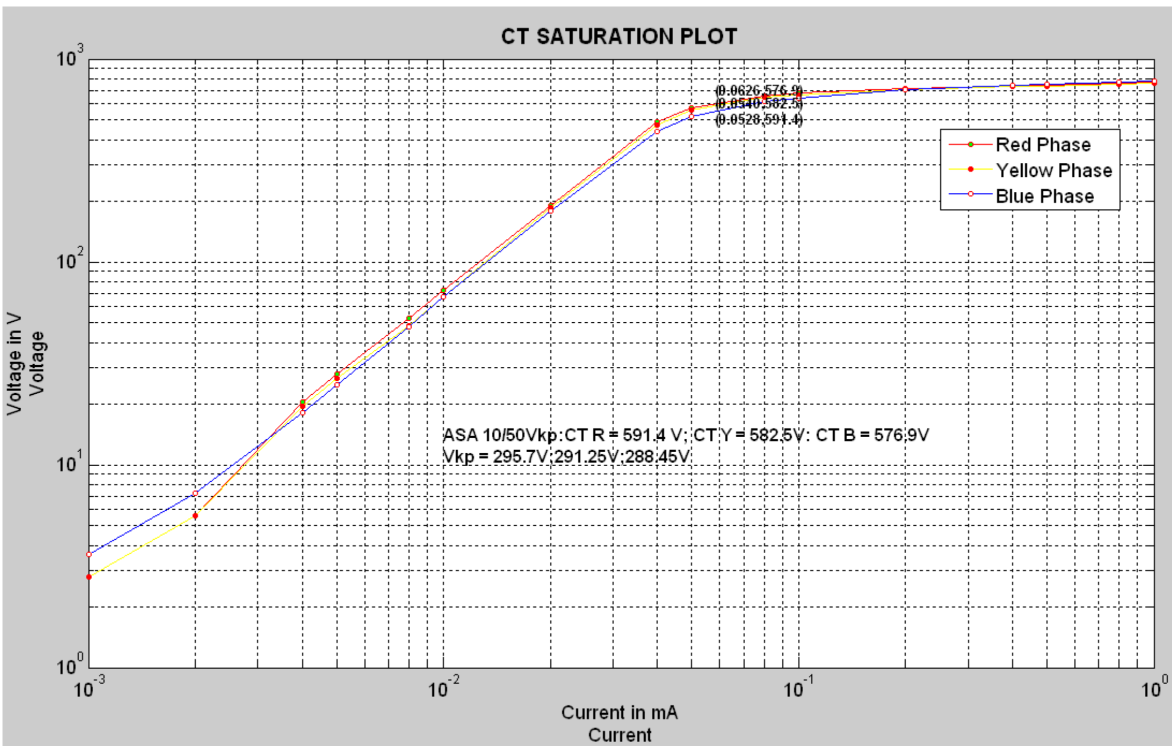

Figure 4.10 Core 3 CT Magnetization Curve; Vkp=295.7V; 291.25V; 288.45V

The Modeling Simulation for Core 3 has been concluded and then click the icon "CORE 4". The Figure 4.11 shows the model of Core 4 & 5 – High Impedance Busbar protection (Main and Check).

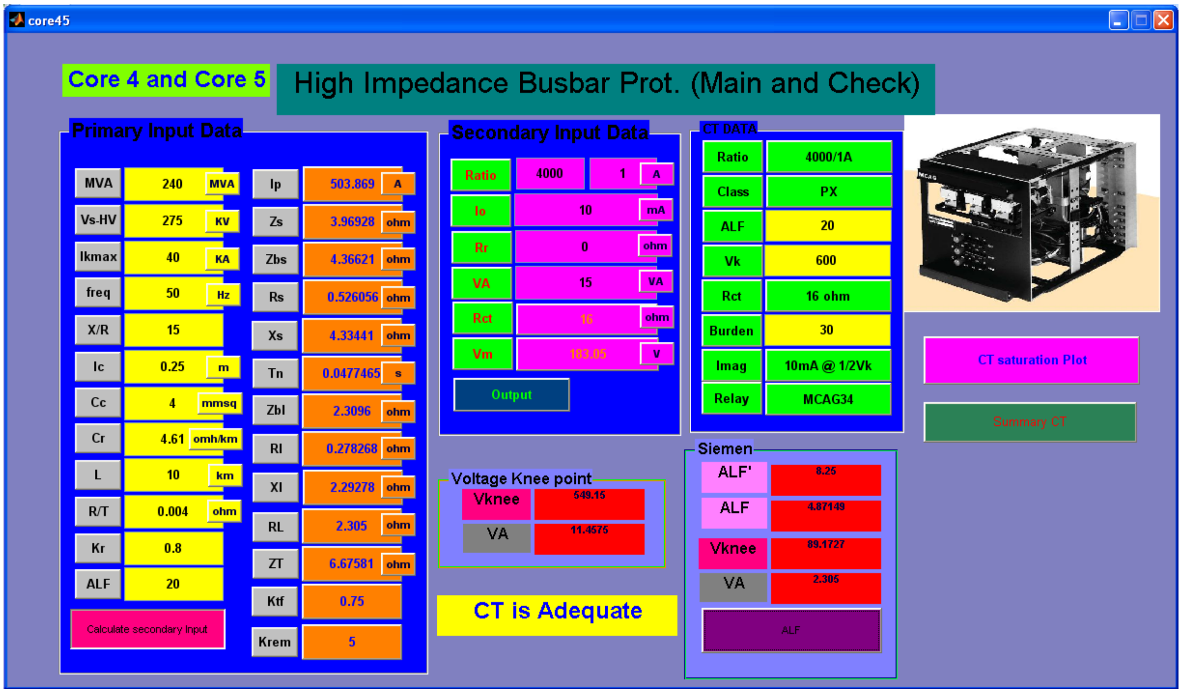

Fig. 4.11 High Impedance Busbar Prot. (Main and Check)

STEP 4

Procedure is the same as in Core 1 for Core 4 & 5, whereby CT parameters Primary input will be keyed in as similarly as in Core 1 (Refer page 85).

Then, the Secondary Input data parameters will be keyed in for the results of Vknee point voltage and Burden of the Current Transformer. As in TNB Technical Guidelines, page 26, specified the CT requirement. For the High Impedance busbar prot, the ratio is 4000/1 A. The magnetizing current, Io is 10mA and the relay resistance of the MCAG34, the minimum burden VA requirement is 30VA as TNB COP clauses 14.1.2.5 and the VA is

15. After completed entry of secondary input parameters, the value of ”Voltage knee point” result are displayed on the program by pressing icon “Output” as shown in Figure 4.11.

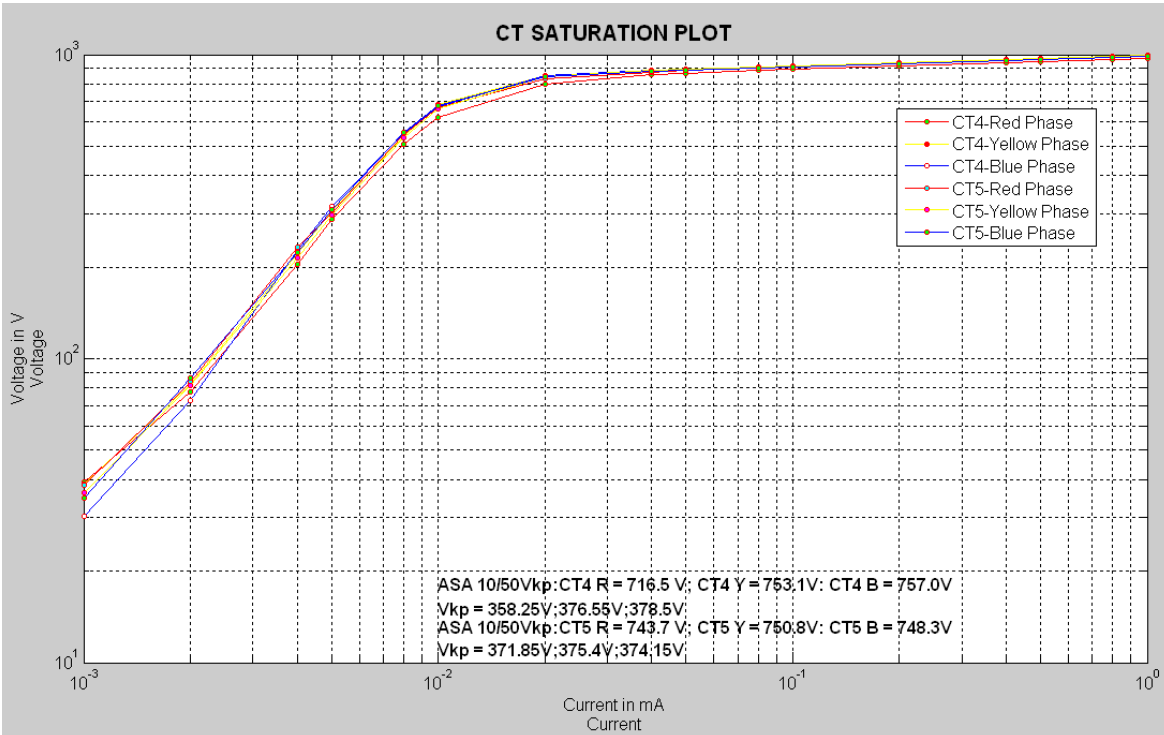

Figure 4.12 Core 4 & 5 CT Magnetization Curve; Vkp=358.25V; 376.55V; 378.5V

The relationship of the sum of secondary results with “CT DATA” for CT normalized are compare. By pressing the icon “ALF” the complete result for modeling Core 4 & 5 is shown in Figure 4.11. The Modeling states that the “**CT is adequate**”.

Then, click icon “CT saturation plot“ which is the design for CT magnetization curve as shown in Figure 4.11 and the result for the “Voltage knee point” are located in saturation area as shown in Figure 4.12.

4.4 Summary

This section describes the calculation of the Actual accuracy limit factor (ALF') for protection type (P) current transformers (CT). Firstly, the calculation of the actual burden of the CT, including connection wires and protection relay impedance, is presented. Secondly, two alternative methods for calculating ALF are shown. All calculation principles and equations are illustrated with calculation and are discussed depending on the CT type input to be applied.

CT selection can play an important role in determining installation options, accuracy and performance of the protection system. The type of protection system and the desired performance characteristics must be taken into consideration when selecting the type of CT to be used. Protection equipment must be considered depending on the type of CT inputs available.

4.5 Conclusions

From the analysis of Current transformer calculation, the equation 2.11 and 3.11 have the better performance and better results as compared to the manual equation as equation 4.1, 4.6, 4.7. Based on the results, the CT data calculation is depending on the requirement and specification. If the CT burden and the Accuracy limit factor show less than the calculated value, then the CT is not specifying the requirement. The analysis shows Core 1, core 2, core 3 and core 4 & 5 are equal.

From the simulation of the CTs protection presented, the following conclusions are derived:

a. In Figure 4.3 and 4.4, in numerical technology algorithm parameter a time, T is used. For the system stability of the internal fault, the time is set to 4ms and the system will be stable if K_{TF} (over dimensioning factor) show less than 0.75. This internal fault is applied for the Generator or transformer protection bay for the calculations purposes.

b. In figure 4.5, Core 1 - Transformer Biased differential, the secondary side input is set as Ratio: 600/1A, Io as 40mA, Rr is 1Ω, VA is 15VA, Rb is 3.305Ω and Rct is 2.4Ω. All these values are calculated and the results are the Voltage knee as 348V and VA=15VA. Using transient calculation the ALF is 16.3937, Vknee is 93.5259V and the VA is 3.305VA. All these values compared with the CT data given is shown in Figure 4.5, the result is say secondary calculation in less than the CT data. It shows that the methods transient does is much better compared to normal manual calculation given by the relay manufacturer. As we see that the Vk is 380V which is higher compared with the Siemen Vknee which is 93.5259V. The class in CT side is PX and we known that Class X is less than equal to 20 as the COP and Siemens, ALF is calculated as 16.3937. It is shows less than 20. So there the Core 1 is equated and stable.

c. In Figure 4.6, Core 2 - Transformer high impedance protection, the secondary side input is set as Ratio: 1200/600/1A, Io as 40mA, Rr is 0.5Ω, VA is 15VA, Rb is 2.305Ω and Rct highest ratio is 4.8Ω. All these values are calculated and the result shows the Voltage knee as 143.2V and VA=2.35998VA. Using transient calculation ALF is 9.60227, Vknee is 73.0253V and the VA is 2.805VA. All these values compared with the CT data given is shown in Figure 4.6, the result shows secondary calculation is less than the CT data. It shows that the methods transient does is much better compared to normal manual calculation given by the relay manufacturer. We see that the Vk 400V is higher compared with the transient value Vknee which is 73.0253V. The class in CT side is PX and we known that Class X is less equal to 20 as the COP and Siemens, ALF calculated is 9.60227. It is shows less than 20. So there the Core 2 is equated and stable.

d. In Figure 4.7, Core 3 – Back-up Distance protection, the secondary side input is set as Ratio: 600/1A, Io as 40mA, Rr is 0.9Ω, VA is 30VA, Rb is 3.305Ω and Rct is 2.4Ω. All these values are calculated and the result shows the Voltage knee as 648V and VA=30VA. Using transient calculation ALF is 8.649, Vknee is 48.4815V and the VA is 3.205VA. All these values compared with the CT data given are shown in Figure 4.7, the result is shows secondary calculation less than the CT data. It shows that the methods of Siemens is much better compared to normal manual calculation which given by the relay manufacturer. As we see that the VA is 30VA is highest compared with the transient value VA which is 3.205VA. The class in CT side is 5P20 and we known that Class 5P20 is equal to 20 as the TNB requirements and Siemens, ALF calculated is 8.649. It is shows less than 20. So there the Core3 is equated and stable.

e. In Figure 4.8, Core 4 and 5 - High impedance Busbar protection, the secondary side input is set as Ratio: 4000/1A, Io as 10mA, VA is 15VA, Rb is 2.305Ω and Rct is 16Ω. All these values are calculated and the result shows the Voltage knee as 549.15V and VA=11.4575VA. Using transient calculation ALF is 2.9845, Vknee is 54.6315V and the VA is 2.305VA. All these values compared with the CT data given is shown in Figure 4.8, the result is secondary calculation is less than the CT data. It shows that the methods transient does is much better compared to normal manual calculation given by the relay manufacturer. We see that the VA is 15VA is higher compared with the transient value VA is 2.305VA. The class in CT side is PX and we known that Class X is less equal to 20 as the TNB requirements and Siemens, ALF calculated is 2.9845. It shows less than 20. So there the Core 3 is equated and stable.