Chapter-5

ANALYSIS AND SOFTWARE DEVELOPMENT FOR THE DESIGN OF 4-PARAMETERS TRV SYNTHETIC TEST CIRCUIT

5.1 Analysis and Mathematical Modeling of Multi-frequency TRV synthetic Test Circuit

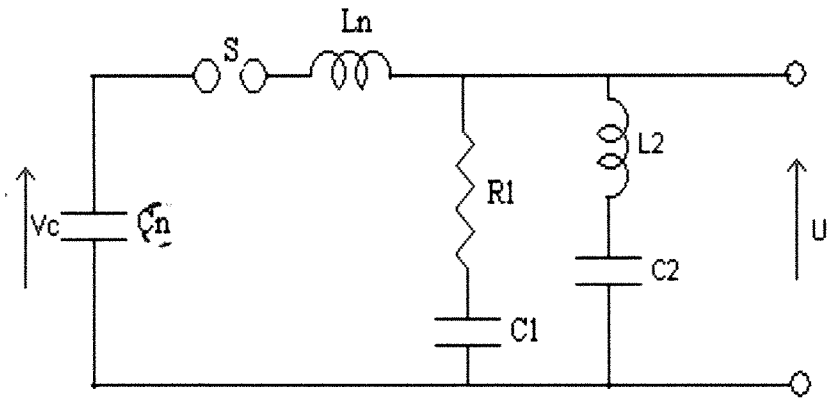


Fig.5.1 Multi frequency TRV synthetic test circuit

The circuit shown in Fig.5.1 permits to produce 4– parameters transient recovery voltages (TRV) according to IEC standards. Vc is the charging voltage. Cn, C1, C2, Ln, L2 and R1 are the circuit components. The magnitude and the frequency of the transient recovery voltage depend on the voltage to which the capacitor Cn is charged and the values of circuit components. u is the transient recovery voltage. C1, C2, Ln, L2 and R1 are to control TRV and RRRV.

The expression for the transient recovery voltage is as follows:

$$u(s) = -\frac{CnVc}{s} \cdot \frac{(1+sR1C1)(1+s^2L2C2)}{s^4LnCnL2C2C1 + s^3R1CnC1C2(Ln+L2) + s^2\left[LnCn(C1+C2) + L2C2(Cn+C1)\right] + sR1C1(Cn+C2) + Cn+C1+C2}$$

The time expression of the transient recovery voltage is complex, but by making some hypotheses, it is possible to obtain some fundamental information concerning the TRV generated by this configuration[12].

Indeed, a simple analysis of the position of the poles of the above mentioned expression reveals the existence of 2 frequencies:

High Frequency Circuit

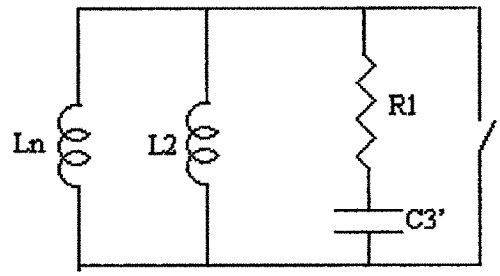


Fig.5.2. High frequency circuit

The high frequency voltage wave arises from the free oscillation of the circuit shown in Figure 5.2. The value of high frequency depends upon the circuit components C3', Ln and L2.

$$C3' = C1 \times \frac{Cn + C2}{Cn + C1 + C2}$$

$$Leq = LnX\ L2 = \frac{Ln \times L2}{Ln + L2}$$

$$fn_1 = \frac{1}{2\pi\sqrt{Leq \times C3'}}$$

$$\therefore t_{m1} = \frac{10^3}{2 \times fn_1} \qquad \text{------} \quad \text{------} \quad \text{------} \qquad (5.1)$$

Where

fn_1 = high frequency oscillation of the voltage wave, kHz

t_{m1} = time to reach peak of high frequency voltage wave, μs

Low Frequency Circuit

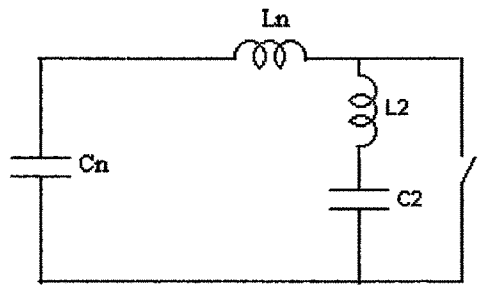


Fig.5.3 Low frequency circuit

The low frequency voltage wave corresponds to the natural oscillation of the circuit represented by Figure 5.3. This low frequency circuit consists of circuit components Cn, C2, Ln and L2.

Low frequency $$fn_2 = \frac{1}{2\pi\sqrt{(Ln+L2).\frac{Cn\times C2}{Cn+C2}}}$$

$$\therefore t_{m2} = \frac{10^3}{2\times fn_2} \qquad \text{------ ------ ------} \qquad (5.2)$$

Where

fn_2 = low frequency oscillation of the voltage wave, kHz

t_{m2} = time to reach peak of low frequency voltage wave, μs

The TRV can then be considered as a result of the oscillations of both low frequency and high frequency circuits.

5.2 Program / Software development for finding circuit components

For the design optimization of 4-parameters TRV control circuits the independent variables x_1, x_2, x_3, x_4 and x_5 may be chosen as follows:

x_1 = Capacitance of the main capacitor bank , Cn in μF

x_2 = Capacitance of TRV capacitor bank-I, C1 in μF

x_3 = Capacitance of TRV capacitor bank-II, C2 in μF

x_4 = Inductance of reactor Ln in mH

x_5 = Inductance of reactor L2 in mH.

The objective function chosen:

Minimize the value of capacitance (hence energy required or size of the capacitor banks) of capacitor Banks Cn, C1 and C2 for the same test conditions (same TRV parameters for a particular rating of circuit-breakers)

The constraints function gi (x_1, x_2, x_3, x_4, x_5) consists of the following:

$g_1 = tm_1$ = time to reach peak of high frequency voltage wave, in μs.

$g_2 = tm_2$ = time to reach peak of low frequency voltage wave, in μs.

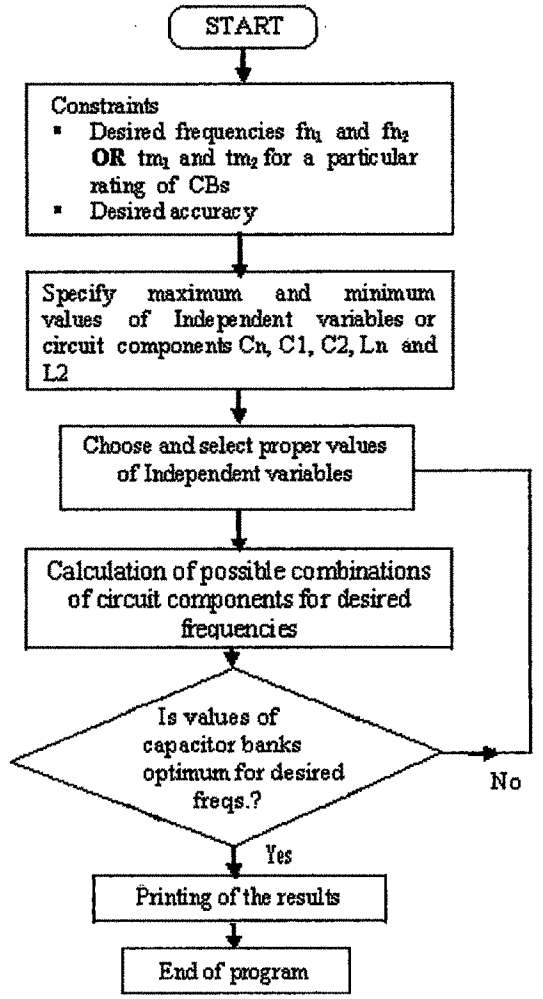


Fig.5.4 Flowchart for finding optimized circuit components

In order to find the possible combinations of circuit components and to optimize the values of capacitance of capacitor banks for the desired frequencies tm_1 and tm_2 of a particular rating of circuit-breaker, program has been developed by using MATLAB M-file. Design optimization is done to reduce the values of capacitance of capacitor banks and hence reduce the energy required, size and cost of the capacitor banks.

Program/software is also developed with the help of VISUAL BASIC 6 software to find all possible combinations of the circuit components and also to optimize the circuit components for the desired frequencies tm_1 and tm_2 for a particular rating of circuit-breaker. This software is user friendly and speed is very fast, just by one click it

will show all the possible combinations of circuit components for the desired frequencies.

Algorithm

Objective Function:

Minimize(optimize) the value of capacitance of Capacitor Banks Cn, C1 and C2 for a desired frequencies (for the same test conditions) as per IEC for a particular rating of circuit-breaker.

- Enter the desired frequencies (tm_1 and tm_2) for a particular rating of circuit-breaker
- Specify the maximum and minimum values of the following independent variables or circuit components:
  Main Capacitor Bank: Cn
  TRV Capacitor Banks: C_1 and C_2
  Reactors: Ln and L_2
- calculate all possible combinations of circuit components for the desired frequencies
- The values of TRV Capacitor Banks can be determined by using the following equations:

$$C_1 = \frac{(Cn+C_2)}{4\pi^2 fn_1^2 Leq(Cn+C_2)-1}$$

$$C_2 = \frac{Cn}{4\pi^2 fn_2^2 (Ln+L_2)Cn-1}$$

- Find the optimal values of capacitor banks Cn, C_1 and C_2.

The flowchart for finding optimal circuit components is shown in Fig.5.4.

5.3 Testing of Program/Software developed by using MATLAB for finding circuit components to test 420kV rating circuit breakers

The developed program/software is tested for finding all possible and optimized circuit components to test 420kV rating circuit-breakers for terminal as well as short line fault test duty condition according to IEC standards.

(A) Finding all possible and optimized circuit components for desired frequencies fn_1 and fn_2 (tm_1 and tm_2) of a terminal fault test duty TRV for a 420kV rating circuit-breakers (as per 4-parameters TRV envelope defined by IEC standards shown in Fig.3.9, case-I)

Input data

Minimum value of Cn: 32e-6
Maximum value of Cn: 40e-6
Step of Cn: 2e-6

Minimum value of C1: 0.4e-6
Maximum value of C1: 0.8e-6
Step of C1: 0.1e-6

Minimum value of C2: 1e-6
Maximum value of C2: 3e-6
Step of C2: 0.2e-6

Minimum value of Ln: 16e-3
Maximum value of Ln: 20e-3
Step of Ln: 1e-3

Minimum value of L2: 12e-3
Maximum value of L2: 17e-3
Step of L2: 1e-3

Tm1: 227e-6
Tm2: 690e-6
DISPLAY OF ALL POSIBLE COMBINATION
##

Cn = 3.200000e-005	Ln = 1.600000e-002	L2 = 1.200000e-002	C2 = 1.820853e-006
C1 = 7.789285e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.200000e-005	Ln = 1.600000e-002	L2 = 1.300000e-002	C2 = 1.754623e-006
C1 = 7.439688e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.200000e-005	Ln = 1.600000e-002	L2 = 1.400000e-002	C2 = 1.693041e-006
C1 = 7.140573e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.200000e-005	Ln = 1.600000e-002	L2 = 1.500000e-002	C2 = 1.635635e-006
C1 = 6.881740e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.200000e-005	Ln = 1.600000e-002	L2 = 1.600000e-002	C2 = 1.581994e-006
C1 = 6.655566e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	

Cn = 3.200000e-005 Ln = 1.600000e-002 L2 = 1.700000e-002 C2 = 1.531761e-006
C1 = 6.456237e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 3.200000e-005 Ln = 1.700000e-002 L2 = 1.200000e-002 C2 = 1.754623e-006
C1 = 7.588844e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.700000e-002 L2 = 1.300000e-002 C2 = 1.693041e-006
C1 = 7.239586e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.700000e-002 L2 = 1.400000e-002 C2 = 1.635635e-006
C1 = 6.940763e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.700000e-002 L2 = 1.500000e-002 C2 = 1.581994e-006
C1 = 6.682186e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.700000e-002 L2 = 1.600000e-002 C2 = 1.531761e-006
C1 = 6.456237e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.700000e-002 L2 = 1.700000e-002 C2 = 1.484619e-006
C1 = 6.257107e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 3.200000e-005 Ln = 1.800000e-002 L2 = 1.200000e-002 C2 = 1.693041e-006
C1 = 7.410855e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.800000e-002 L2 = 1.300000e-002 C2 = 1.635635e-006
C1 = 7.061900e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.800000e-002 L2 = 1.400000e-002 C2 = 1.581994e-006
C1 = 6.763338e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.800000e-002 L2 = 1.500000e-002 C2 = 1.531761e-006
C1 = 6.504989e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.800000e-002 L2 = 1.600000e-002 C2 = 1.484619e-006
C1 = 6.279241e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.800000e-002 L2 = 1.700000e-002 C2 = 1.440292e-006
C1 = 6.080289e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 3.200000e-005 Ln = 1.900000e-002 L2 = 1.200000e-002 C2 = 1.635635e-006
C1 = 7.251746e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.900000e-002 L2 = 1.300000e-002 C2 = 1.581994e-006
C1 = 6.903062e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.900000e-002 L2 = 1.400000e-002 C2 = 1.531761e-006
C1 = 6.604735e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.900000e-002 L2 = 1.500000e-002 C2 = 1.484619e-006
C1 = 6.346591e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.900000e-002 L2 = 1.600000e-002 C2 = 1.440292e-006
C1 = 6.121023e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 1.900000e-002 L2 = 1.700000e-002 C2 = 1.398535e-006
C1 = 5.922232e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 3.200000e-005 Ln = 2.000000e-002 L2 = 1.200000e-002 C2 = 1.581994e-006
C1 = 7.108663e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 2.000000e-002 L2 = 1.300000e-002 C2 = 1.531761e-006
C1 = 6.760225e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 2.000000e-002 L2 = 1.400000e-002 C2 = 1.484619e-006
C1 = 6.462110e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 2.000000e-002 L2 = 1.500000e-002 C2 = 1.440292e-006
C1 = 6.204151e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 2.000000e-002 L2 = 1.600000e-002 C2 = 1.398535e-006
C1 = 5.978746e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.200000e-005 Ln = 2.000000e-002 L2 = 1.700000e-002 C2 = 1.359131e-006
C1 = 5.780099e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 3.400000e-005	Ln = 1.600000e-002	L2 = 1.200000e-002	C2 = 1.814779e-006
C1 = 7.779310e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.600000e-002	L2 = 1.300000e-002	C2 = 1.748981e-006
C1 = 7.430552e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.600000e-002	L2 = 1.400000e-002	C2 = 1.687788e-006
C1 = 7.132124e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.600000e-002	L2 = 1.500000e-002	C2 = 1.630732e-006
C1 = 6.873865e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.600000e-002	L2 = 1.600000e-002	C2 = 1.577407e-006
C1 = 6.648176e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.600000e-002	L2 = 1.700000e-002	C2 = 1.527460e-006
C1 = 6.449262e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.700000e-002	L2 = 1.200000e-002	C2 = 1.748981e-006
C1 = 7.579338e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.700000e-002	L2 = 1.300000e-002	C2 = 1.687788e-006
C1 = 7.230902e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.700000e-002	L2 = 1.400000e-002	C2 = 1.630732e-006
C1 = 6.932753e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.700000e-002	L2 = 1.500000e-002	C2 = 1.577407e-006
C1 = 6.674737e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.700000e-002	L2 = 1.600000e-002	C2 = 1.527460e-006
C1 = 6.449262e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.700000e-002	L2 = 1.700000e-002	C2 = 1.480578e-006
C1 = 6.250537e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.800000e-002	L2 = 1.200000e-002	C2 = 1.687788e-006
C1 = 7.401756e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.800000e-002	L2 = 1.300000e-002	C2 = 1.630732e-006
C1 = 7.053607e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.800000e-002	L2 = 1.400000e-002	C2 = 1.577407e-006
C1 = 6.755707e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.800000e-002	L2 = 1.500000e-002	C2 = 1.527460e-006
C1 = 6.497908e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.800000e-002	L2 = 1.600000e-002	C2 = 1.480578e-006
C1 = 6.272624e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.800000e-002	L2 = 1.700000e-002	C2 = 1.436489e-006
C1 = 6.074068e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.900000e-002	L2 = 1.200000e-002	C2 = 1.630732e-006
C1 = 7.243002e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.900000e-002	L2 = 1.300000e-002	C2 = 1.577407e-006
C1 = 6.895112e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.900000e-002	L2 = 1.400000e-002	C2 = 1.527460e-006
C1 = 6.597435e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.900000e-002	L2 = 1.500000e-002	C2 = 1.480578e-006
C1 = 6.339831e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.900000e-002	L2 = 1.600000e-002	C2 = 1.436489e-006
C1 = 6.114718e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	
Cn = 3.400000e-005	Ln = 1.900000e-002	L2 = 1.700000e-002	C2 = 1.394949e-006
C1 = 5.916314e-007	Tm1 = 2.270000e-004	Tm2 = 6.900000e-004 |	

Cn = 3.400000e-005 Ln = 2.000000e-002 L2 = 1.200000e-002 C2 = 1.577407e-006
C1 = 7.100233e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.400000e-005 Ln = 2.000000e-002 L2 = 1.300000e-002 C2 = 1.527460e-006
C1 = 6.752577e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.400000e-005 Ln = 2.000000e-002 L2 = 1.400000e-002 C2 = 1.480578e-006
C1 = 6.455102e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.400000e-005 Ln = 2.000000e-002 L2 = 1.500000e-002 C2 = 1.436489e-006
C1 = 6.197674e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.400000e-005 Ln = 2.000000e-002 L2 = 1.600000e-002 C2 = 1.394949e-006
C1 = 5.972716e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.400000e-005 Ln = 2.000000e-002 L2 = 1.700000e-002 C2 = 1.355744e-006
C1 = 5.774449e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 3.600000e-005 Ln = 1.600000e-002 L2 = 1.200000e-002 C2 = 1.809414e-006
C1 = 7.770406e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.600000e-002 L2 = 1.300000e-002 C2 = 1.743997e-006
C1 = 7.422397e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.600000e-002 L2 = 1.400000e-002 C2 = 1.683146e-006
C1 = 7.124585e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.600000e-002 L2 = 1.500000e-002 C2 = 1.626398e-006
C1 = 6.866839e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.600000e-002 L2 = 1.600000e-002 C2 = 1.573352e-006
C1 = 6.641584e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.600000e-002 L2 = 1.700000e-002 C2 = 1.523657e-006
C1 = 6.443040e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 3.600000e-005 Ln = 1.700000e-002 L2 = 1.200000e-002 C2 = 1.743997e-006
C1 = 7.570854e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.700000e-002 L2 = 1.300000e-002 C2 = 1.683146e-006
C1 = 7.223152e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.700000e-002 L2 = 1.400000e-002 C2 = 1.626398e-006
C1 = 6.925606e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.700000e-002 L2 = 1.500000e-002 C2 = 1.573352e-006
C1 = 6.668091e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.700000e-002 L2 = 1.600000e-002 C2 = 1.523657e-006
C1 = 6.443040e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.700000e-002 L2 = 1.700000e-002 C2 = 1.477005e-006
C1 = 6.244676e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 3.600000e-005 Ln = 1.800000e-002 L2 = 1.200000e-002 C2 = 1.683146e-006
C1 = 7.393636e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.800000e-002 L2 = 1.300000e-002 C2 = 1.626398e-006
C1 = 7.046209e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.800000e-002 L2 = 1.400000e-002 C2 = 1.573352e-006
C1 = 6.748899e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.800000e-002 L2 = 1.500000e-002 C2 = 1.523657e-006
C1 = 6.491592e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.800000e-002 L2 = 1.600000e-002 C2 = 1.477005e-006
C1 = 6.266722e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.800000e-002 L2 = 1.700000e-002 C2 = 1.433125e-006
C1 = 6.068519e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 3.600000e-005 Ln = 1.900000e-002 L2 = 1.200000e-002 C2 = 1.626398e-006
C1 = 7.235201e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.900000e-002 L2 = 1.300000e-002 C2 = 1.573352e-006
C1 = 6.888021e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.900000e-002 L2 = 1.400000e-002 C2 = 1.523657e-006
C1 = 6.590924e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.900000e-002 L2 = 1.500000e-002 C2 = 1.477005e-006
C1 = 6.333802e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.900000e-002 L2 = 1.600000e-002 C2 = 1.433125e-006
C1 = 6.109095e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 1.900000e-002 L2 = 1.700000e-002 C2 = 1.391777e-006
C1 = 5.911038e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 3.600000e-005 Ln = 2.000000e-002 L2 = 1.200000e-002 C2 = 1.573352e-006
C1 = 7.092714e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 2.000000e-002 L2 = 1.300000e-002 C2 = 1.523657e-006
C1 = 6.745757e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 2.000000e-002 L2 = 1.400000e-002 C2 = 1.477005e-006
C1 = 6.448852e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 2.000000e-002 L2 = 1.500000e-002 C2 = 1.433125e-006
C1 = 6.191897e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 2.000000e-002 L2 = 1.600000e-002 C2 = 1.391777e-006
C1 = 5.967338e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.600000e-005 Ln = 2.000000e-002 L2 = 1.700000e-002 C2 = 1.352748e-006
C1 = 5.769411e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

==========

==========

Cn = 3.800000e-005 Ln = 1.600000e-002 L2 = 1.200000e-002 C2 = 1.804640e-006
C1 = 7.762409e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.600000e-002 L2 = 1.300000e-002 C2 = 1.739562e-006
C1 = 7.415075e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.600000e-002 L2 = 1.400000e-002 C2 = 1.679015e-006
C1 = 7.117816e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.600000e-002 L2 = 1.500000e-002 C2 = 1.622540e-006
C1 = 6.860531e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.600000e-002 L2 = 1.600000e-002 C2 = 1.569741e-006
C1 = 6.635666e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.600000e-002 L2 = 1.700000e-002 C2 = 1.520270e-006
C1 = 6.437455e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 3.800000e-005 Ln = 1.700000e-002 L2 = 1.200000e-002 C2 = 1.739562e-006
C1 = 7.563236e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.700000e-002 L2 = 1.300000e-002 C2 = 1.679015e-006
C1 = 7.216195e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.700000e-002 L2 = 1.400000e-002 C2 = 1.622540e-006
C1 = 6.919190e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.700000e-002 L2 = 1.500000e-002 C2 = 1.569741e-006
C1 = 6.662126e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.700000e-002 L2 = 1.600000e-002 C2 = 1.520270e-006
C1 = 6.437455e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.700000e-002 L2 = 1.700000e-002 C2 = 1.473822e-006
C1 = 6.239417e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 3.800000e-005 Ln = 1.800000e-002 L2 = 1.200000e-002 C2 = 1.679015e-006
C1 = 7.386346e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.800000e-002 L2 = 1.300000e-002 C2 = 1.622540e-006
C1 = 7.039568e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.800000e-002 L2 = 1.400000e-002 C2 = 1.569741e-006
C1 = 6.742789e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.800000e-002 L2 = 1.500000e-002 C2 = 1.520270e-006
C1 = 6.485923e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.800000e-002 L2 = 1.600000e-002 C2 = 1.473822e-006
C1 = 6.261425e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.800000e-002 L2 = 1.700000e-002 C2 = 1.430128e-006
C1 = 6.063541e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 3.800000e-005 Ln = 1.900000e-002 L2 = 1.200000e-002 C2 = 1.622540e-006
C1 = 7.228199e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.900000e-002 L2 = 1.300000e-002 C2 = 1.569741e-006
C1 = 6.881656e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.900000e-002 L2 = 1.400000e-002 C2 = 1.520270e-006
C1 = 6.585081e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.900000e-002 L2 = 1.500000e-002 C2 = 1.473822e-006
C1 = 6.328392e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.900000e-002 L2 = 1.600000e-002 C2 = 1.430128e-006
C1 = 6.104050e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 1.900000e-002 L2 = 1.700000e-002 C2 = 1.388950e-006
C1 = 5.906304e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 3.800000e-005 Ln = 2.000000e-002 L2 = 1.200000e-002 C2 = 1.569741e-006
C1 = 7.085966e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 2.000000e-002 L2 = 1.300000e-002 C2 = 1.520270e-006
C1 = 6.739636e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 2.000000e-002 L2 = 1.400000e-002 C2 = 1.473822e-006
C1 = 6.443243e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 2.000000e-002 L2 = 1.500000e-002 C2 = 1.430128e-006
C1 = 6.186714e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 2.000000e-002 L2 = 1.600000e-002 C2 = 1.388950e-006
C1 = 5.962513e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 3.800000e-005 Ln = 2.000000e-002 L2 = 1.700000e-002 C2 = 1.350078e-006
C1 = 5.764892e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 4.000000e-005 Ln = 1.600000e-002 L2 = 1.200000e-002 C2 = 1.800365e-006
C1 = 7.755189e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.600000e-002 L2 = 1.300000e-002 C2 = 1.735589e-006
C1 = 7.408464e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.600000e-002 L2 = 1.400000e-002 C2 = 1.675313e-006
C1 = 7.111705e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.600000e-002 L2 = 1.500000e-002 C2 = 1.619084e-006
C1 = 6.854838e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.600000e-002 L2 = 1.600000e-002 C2 = 1.566506e-006
C1 = 6.630325e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.600000e-002 L2 = 1.700000e-002 C2 = 1.517235e-006
C1 = 6.432416e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 4.000000e-005 Ln = 1.700000e-002 L2 = 1.200000e-002 C2 = 1.735589e-006
C1 = 7.556358e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.700000e-002 L2 = 1.300000e-002 C2 = 1.675313e-006
C1 = 7.209914e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.700000e-002 L2 = 1.400000e-002 C2 = 1.619084e-006
C1 = 6.913398e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.700000e-002 L2 = 1.500000e-002 C2 = 1.566506e-006
C1 = 6.656742e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.700000e-002 L2 = 1.600000e-002 C2 = 1.517235e-006
C1 = 6.432416e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.700000e-002 L2 = 1.700000e-002 C2 = 1.470970e-006
C1 = 6.234671e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 4.000000e-005 Ln = 1.800000e-002 L2 = 1.200000e-002 C2 = 1.675313e-006
C1 = 7.379765e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.800000e-002 L2 = 1.300000e-002 C2 = 1.619084e-006
C1 = 7.033573e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.800000e-002 L2 = 1.400000e-002 C2 = 1.566506e-006
C1 = 6.737274e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.800000e-002 L2 = 1.500000e-002 C2 = 1.517235e-006
C1 = 6.480807e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.800000e-002 L2 = 1.600000e-002 C2 = 1.470970e-006
C1 = 6.256646e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.800000e-002 L2 = 1.700000e-002 C2 = 1.427442e-006
C1 = 6.059049e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 4.000000e-005 Ln = 1.900000e-002 L2 = 1.200000e-002 C2 = 1.619084e-006
C1 = 7.221879e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.900000e-002 L2 = 1.300000e-002 C2 = 1.566506e-006
C1 = 6.875912e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.900000e-002 L2 = 1.400000e-002 C2 = 1.517235e-006
C1 = 6.579807e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.900000e-002 L2 = 1.500000e-002 C2 = 1.470970e-006
C1 = 6.323510e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.900000e-002 L2 = 1.600000e-002 C2 = 1.427442e-006
C1 = 6.099498e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.900000e-002 L2 = 1.700000e-002 C2 = 1.386417e-006
C1 = 5.902032e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 4.000000e-005 Ln = 2.000000e-002 L2 = 1.200000e-002 C2 = 1.566506e-006
C1 = 7.079875e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 2.000000e-002 L2 = 1.300000e-002 C2 = 1.517235e-006
C1 = 6.734112e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 2.000000e-002 L2 = 1.400000e-002 C2 = 1.470970e-006
C1 = 6.438182e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 2.000000e-002 L2 = 1.500000e-002 C2 = 1.427442e-006
C1 = 6.182038e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 2.000000e-002 L2 = 1.600000e-002 C2 = 1.386417e-006
C1 = 5.958160e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 2.000000e-002 L2 = 1.700000e-002 C2 = 1.347683e-006
C1 = 5.760814e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
##########

Cn = 4.000000e-005 Ln = 1.700000e-002 L2 = 1.200000e-002 C2 = 1.735589e-006
C1 = 7.556358e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.700000e-002 L2 = 1.300000e-002 C2 = 1.675313e-006
C1 = 7.209914e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.700000e-002 L2 = 1.400000e-002 C2 = 1.619084e-006
C1 = 6.913398e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.700000e-002 L2 = 1.500000e-002 C2 = 1.566506e-006
C1 = 6.656742e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.700000e-002 L2 = 1.600000e-002 C2 = 1.517235e-006
C1 = 6.432416e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.700000e-002 L2 = 1.700000e-002 C2 = 1.470970e-006
C1 = 6.234671e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 4.000000e-005 Ln = 1.800000e-002 L2 = 1.200000e-002 C2 = 1.675313e-006
C1 = 7.379765e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.800000e-002 L2 = 1.300000e-002 C2 = 1.619084e-006
C1 = 7.033573e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.800000e-002 L2 = 1.400000e-002 C2 = 1.566506e-006
C1 = 6.737274e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.800000e-002 L2 = 1.500000e-002 C2 = 1.517235e-006
C1 = 6.480807e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.800000e-002 L2 = 1.600000e-002 C2 = 1.470970e-006
C1 = 6.256646e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.800000e-002 L2 = 1.700000e-002 C2 = 1.427442e-006
C1 = 6.059049e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 4.000000e-005 Ln = 1.900000e-002 L2 = 1.200000e-002 C2 = 1.619084e-006
C1 = 7.221879e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.900000e-002 L2 = 1.300000e-002 C2 = 1.566506e-006
C1 = 6.875912e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.900000e-002 L2 = 1.400000e-002 C2 = 1.517235e-006
C1 = 6.579807e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.900000e-002 L2 = 1.500000e-002 C2 = 1.470970e-006
C1 = 6.323510e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.900000e-002 L2 = 1.600000e-002 C2 = 1.427442e-006
C1 = 6.099498e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 1.900000e-002 L2 = 1.700000e-002 C2 = 1.386417e-006
C1 = 5.902032e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Cn = 4.000000e-005 Ln = 2.000000e-002 L2 = 1.200000e-002 C2 = 1.566506e-006
C1 = 7.079875e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 2.000000e-002 L2 = 1.300000e-002 C2 = 1.517235e-006
C1 = 6.734112e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 2.000000e-002 L2 = 1.400000e-002 C2 = 1.470970e-006
C1 = 6.438182e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 2.000000e-002 L2 = 1.500000e-002 C2 = 1.427442e-006
C1 = 6.182038e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 2.000000e-002 L2 = 1.600000e-002 C2 = 1.386417e-006
C1 = 5.958160e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Cn = 4.000000e-005 Ln = 2.000000e-002 L2 = 1.700000e-002 C2 = 1.347683e-006
C1 = 5.760814e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

##########

OPTIMIZATION

Enter the value of Cn for optimization: 32e-6

Optimized C1
Cn = 3.200000e-005 Ln = 1.600000e-002 L2 = 1.700000e-002 C2 = 1.531761e-006
C1 = 6.456237e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Optimized C2
Cn = 3.200000e-005 Ln = 1.600000e-002 L2 = 1.700000e-002 C2 = 1.531761e-006
C1 = 6.456237e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Optimized C1
Cn = 3.200000e-005 Ln = 1.700000e-002 L2 = 1.700000e-002 C2 = 1.484619e-006
C1 = 6.257107e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Optimized C2
Cn = 3.200000e-005 Ln = 1.700000e-002 L2 = 1.700000e-002 C2 = 1.484619e-006
C1 = 6.257107e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Optimized C1
Cn = 3.200000e-005 Ln = 1.800000e-002 L2 = 1.700000e-002 C2 = 1.440292e-006
C1 = 6.080289e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Optimized C2
Cn = 3.200000e-005 Ln = 1.800000e-002 L2 = 1.700000e-002 C2 = 1.440292e-006
C1 = 6.080289e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Optimized C1
Cn = 3.200000e-005 Ln = 1.900000e-002 L2 = 1.700000e-002 C2 = 1.398535e-006
C1 = 5.922232e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Optimized C2
Cn = 3.200000e-005 Ln = 1.900000e-002 L2 = 1.700000e-002 C2 = 1.398535e-006
C1 = 5.922232e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

Optimized C1
Cn = 3.200000e-005 Ln = 2.000000e-002 L2 = 1.700000e-002 C2 = 1.359131e-006
C1 = 5.780099e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |
Optimized C2
Cn = 3.200000e-005 Ln = 2.000000e-002 L2 = 1.700000e-002 C2 = 1.359131e-006
C1 = 5.780099e-007 Tm1 = 2.270000e-004 Tm2 = 6.900000e-004 |

(B) Finding all possible and optimized circuit components for desired frequencies fn_1 and fn_2 (tm_1 and tm_2) of a terminal fault test duty TRV for a 420kV rating circuit-breakers (as per 4-parameters TRV envelope defined by IEC standards shown in Fig.3.10, case-II)

Input data

Minimum value of Cn: 32e-6

Maximum value of Cn: 40e-6

Step of Cn: 2e-6

Minimum value of C1: 0.4e-6

Maximum value of C1: 0.8e-6

Step of C1: 0.1e-6

Minimum value of C2: 2e-6

Maximum value of C2: 4e-6

Step of C2: 0.25e-6

Minimum value of Ln: 14e-3

Maximum value of Ln: 18e-3

Step of Ln: 1e-3

Minimum value of L2: 5e-3

Maximum value of L2: 9e-3

Step of L2: 1e-3

Tm1: 167e-6

Tm2: 800e-6

OPTIMIZATION ###

Enter the value of Cn for optimization: 32e-6

Optimized C1

Cn = 3.200000e-005	Ln = 1.400000e-002	L2 = 9.000000e-003	C2 = 3.091774e-006
C1 = 5.235058e-007	Tm1 = 1.670000e-004	Tm2 = 8.000000e-004 |	

Optimized C2

Cn = 3.200000e-005	Ln = 1.400000e-002	L2 = 9.000000e-003	C2 = 3.091774e-006
C1 = 5.235058e-007	Tm1 = 1.670000e-004	Tm2 = 8.000000e-004 |	

Optimized C1

Cn = 3.200000e-005	Ln = 1.500000e-002	L2 = 9.000000e-003	C2 = 2.951070e-006
C1 = 5.096806e-007	Tm1 = 1.670000e-004	Tm2 = 8.000000e-004 |	

Optimized C2

Cn = 3.200000e-005	Ln = 1.500000e-002	L2 = 9.000000e-003	C2 = 2.951070e-006
C1 = 5.096806e-007	Tm1 = 1.670000e-004	Tm2 = 8.000000e-004 |	

```
 Optimized C1
Cn = 3.200000e-005      Ln = 1.600000e-002      L2 = 9.000000e-003      C2 = 2.822615e-006
C1 = 4.975911e-007      Tm1 = 1.670000e-004     Tm2 = 8.000000e-004 |
 Optimized C2
Cn = 3.200000e-005      Ln = 1.600000e-002      L2 = 9.000000e-003      C2 = 2.822615e-006
C1 = 4.975911e-007      Tm1 = 1.670000e-004     Tm2 = 8.000000e-004 |
-------------------------------------------------------------------------------------------------------------------------------
-------------------------------------------------
 Optimized C1
Cn = 3.200000e-005      Ln = 1.700000e-002      L2 = 9.000000e-003      C2 = 2.704876e-006
C1 = 4.869296e-007      Tm1 = 1.670000e-004     Tm2 = 8.000000e-004 |
 Optimized C2
Cn = 3.200000e-005      Ln = 1.700000e-002      L2 = 9.000000e-003      C2 = 2.704876e-006
C1 = 4.869296e-007      Tm1 = 1.670000e-004     Tm2 = 8.000000e-004 |
-------------------------------------------------------------------------------------------------------------------------------
-------------------------------------------------
 Optimized C1
Cn = 3.200000e-005      Ln = 1.800000e-002      L2 = 9.000000e-003      C2 = 2.596567e-006
C1 = 4.774573e-007      Tm1 = 1.670000e-004     Tm2 = 8.000000e-004 |

 Optimized C2
Cn = 3.200000e-005      Ln = 1.800000e-002      L2 = 9.000000e-003      C2 = 2.596567e-006
C1 = 4.774573e-007      Tm1 = 1.670000e-004     Tm2 = 8.000000e-004 |
-------------------------------------------------------------------------------------------------------------------------------
>>
```

(C) Finding all possible and optimized circuit components for desired frequencies fn_1 and fn_2 (tm_1 and tm_2) of a short line fault test duty TRV for a 420kV rating circuit-breakers (as per 4-parameters TRV envelope defined by IEC standards shown in Fig.3.9, case-I)

Input Data

Minimum value of Cn: 32e-6

Maximum value of Cn: 40e-6

Step of Cn: 2e-6

Minimum value of C1: 0.4e-6

Maximum value of C1: 0.6e-6

Step of C1: 0.1e-6

Minimum value of C2: 1e-6

Maximum value of C2: 3e-6

Step of C2: 0.25e-6

Minimum value of Ln: 9e-3

Maximum value of Ln: 13e-3

Step of Ln: 1e-3

Minimum value of L2: 7e-3

Maximum value of L2: 11e-3

Step of L2: 1e-3

Tm1: 170e-6

Tm2: 550e-6

OPTIMIZATION

Enter the value of Cn for optimization: 32e-6

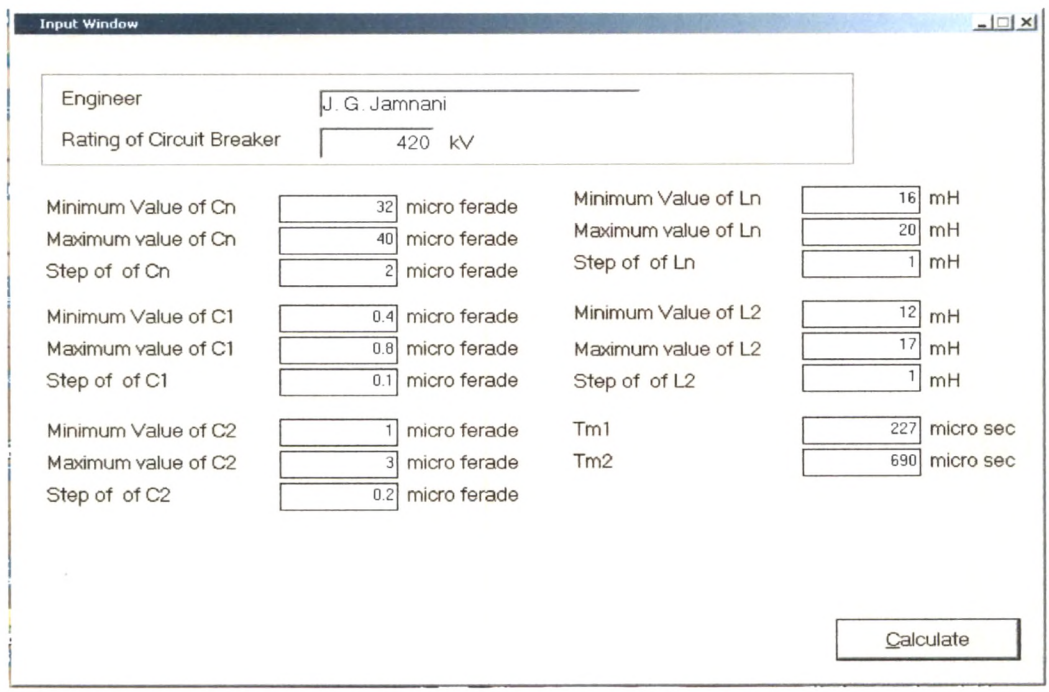
```
 Optimized C1
Cn = 3.200000e-005      Ln = 9.000000e-003      L2 = 1.100000e-002      C2 = 1.609565e-006
C1 = 6.000000e-007      Tm1 = 1.700000e-004     Tm2 = 5.500000e-004 |
 Optimized C2
Cn = 3.200000e-005      Ln = 9.000000e-003      L2 = 1.100000e-002      C2 = 1.609565e-006
C1 = 6.021502e-007      Tm1 = 1.700000e-004     Tm2 = 5.500000e-004 |
-------------------------------------------------------------------------------
 Optimized C1
Cn = 3.200000e-005      Ln = 1.000000e-002      L2 = 1.100000e-002      C2 = 1.529256e-006
C1 = 5.684948e-007      Tm1 = 1.700000e-004     Tm2 = 5.500000e-004 |
 Optimized C2
Cn = 3.200000e-005      Ln = 1.000000e-002      L2 = 1.100000e-002      C2 = 1.529256e-006
C1 = 5.684948e-007      Tm1 = 1.700000e-004     Tm2 = 5.500000e-004 |
-------------------------------------------------------------------------------
 Optimized C1
Cn = 3.200000e-005      Ln = 1.100000e-002      L2 = 1.100000e-002      C2 = 1.456581e-006
C1 = 5.410058e-007      Tm1 = 1.700000e-004     Tm2 = 5.500000e-004 |
 Optimized C2
Cn = 3.200000e-005      Ln = 1.100000e-002      L2 = 1.100000e-002      C2 = 1.456581e-006
C1 = 5.410058e-007      Tm1 = 1.700000e-004     Tm2 = 5.500000e-004 |
-------------------------------------------------------------------------------
 Optimized C1
 Cn = 3.200000e-005     Ln = 1.200000e-002      L2 = 1.100000e-002      C2 = 1.390499e-006
 C1 = 5.181307e-007     Tm1 = 1.700000e-004     Tm2 = 5.500000e-004 |
 Optimized C2
Cn = 3.200000e-005      Ln = 1.200000e-002      L2 = 1.100000e-002      C2 = 1.390499e-006
C1 = 5.181307e-007      Tm1 = 1.700000e-004     Tm2 = 5.500000e-004 |
-------------------------------------------------------------------------------
 Optimized C1
Cn = 3.200000e-005      Ln = 1.300000e-002      L2 = 1.100000e-002      C2 = 1.330153e-006
C1 = 4.987978e-007      Tm1 = 1.700000e-004     Tm2 = 5.500000e-004 |
 Optimized C2
Cn = 3.200000e-005      Ln = 1.300000e-002      L2 = 1.100000e-002      C2 = 1.330153e-006
C1 = 4.987978e-007      Tm1 = 1.700000e-004     Tm2 = 5.500000e-004 |
-------------------------------------------------------------------------------
>>
```

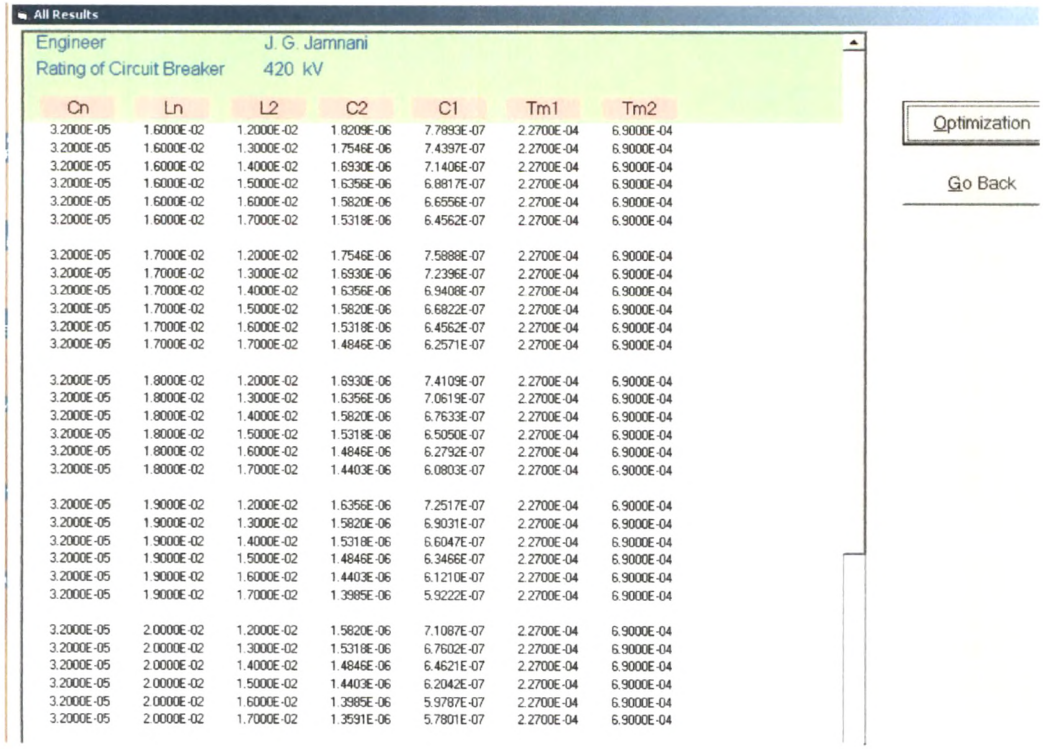
5.4 Testing of Program/Software developed by using VISUAL BASIC 6 for finding circuit components to test 420kV rating circuit breakers

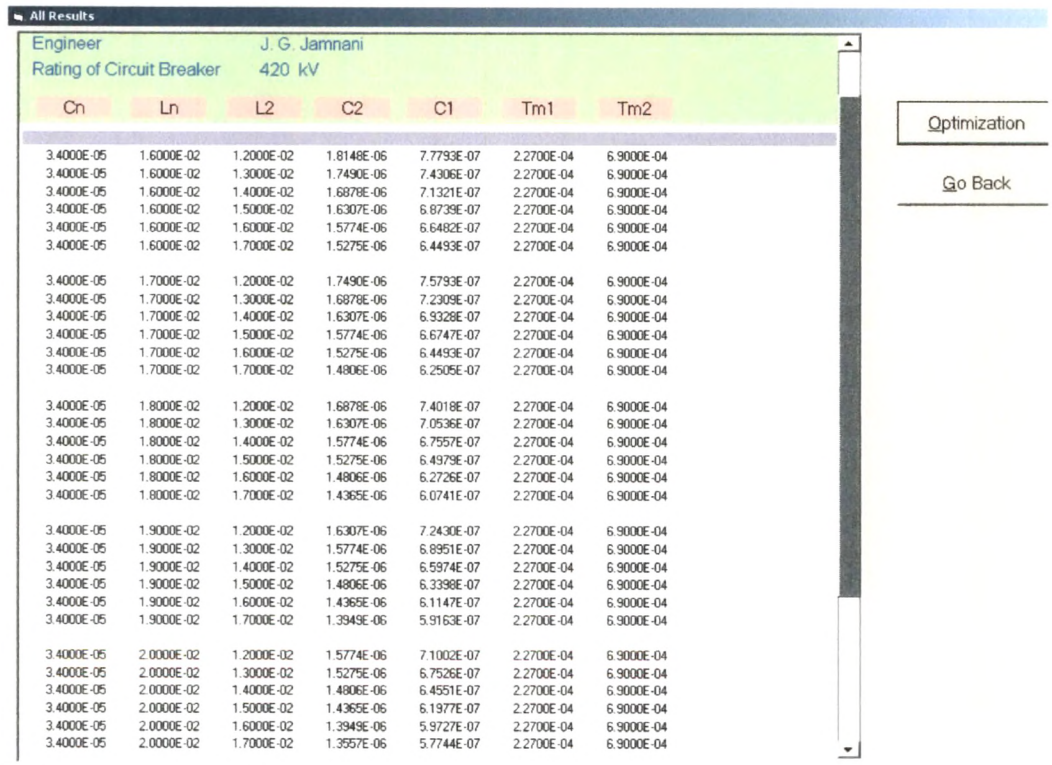
Program/software is also developed with the help of VISUAL BASIC 6 software to find all possible combinations of the circuit components and also to optimize the circuit components for the desired frequencies tm_1 and tm_2 for a particular rating of circuit-breaker. This software is user friendly and speed is very fast, just by one click it will show all the possible combinations of circuit components for the desired frequencies. In order to verify the results obtained by using MATLAB, the developed program/software by using visual basic 6 is tested for finding all possible and optimized circuit components to test 420kV rating circuit-breakers for terminal as well as short line fault test duty condition according to IEC standards.

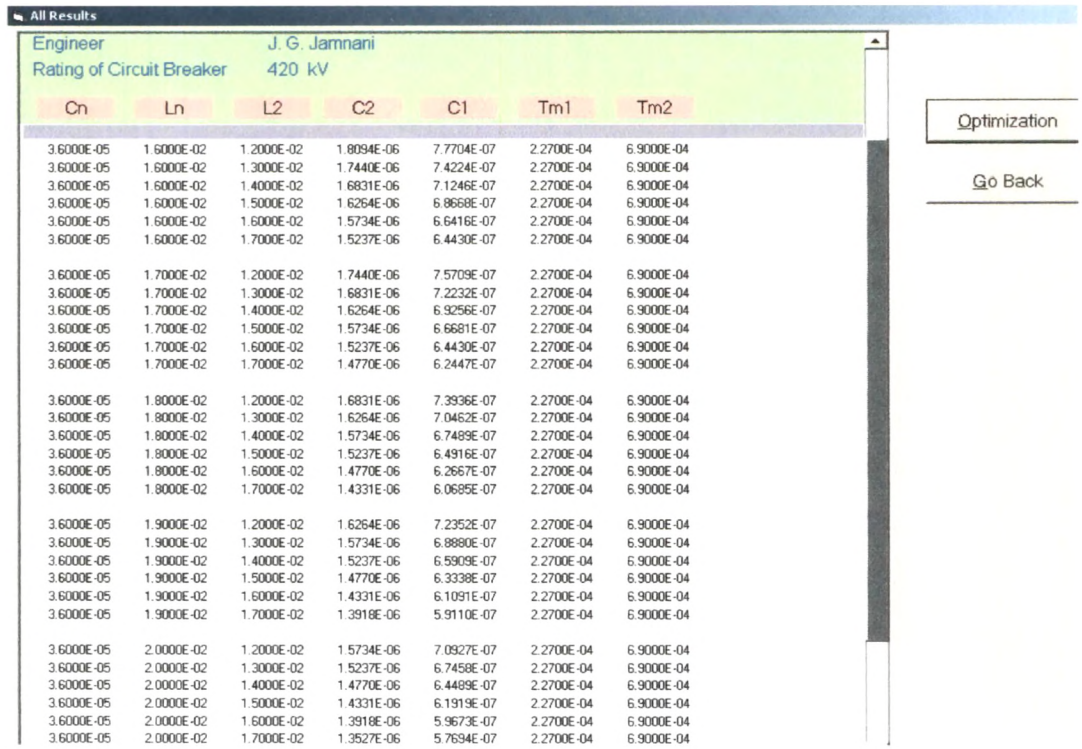
(A) Finding all possible and optimized circuit components for desired frequencies fn_1 and fn_2 (tm_1 and tm_2)

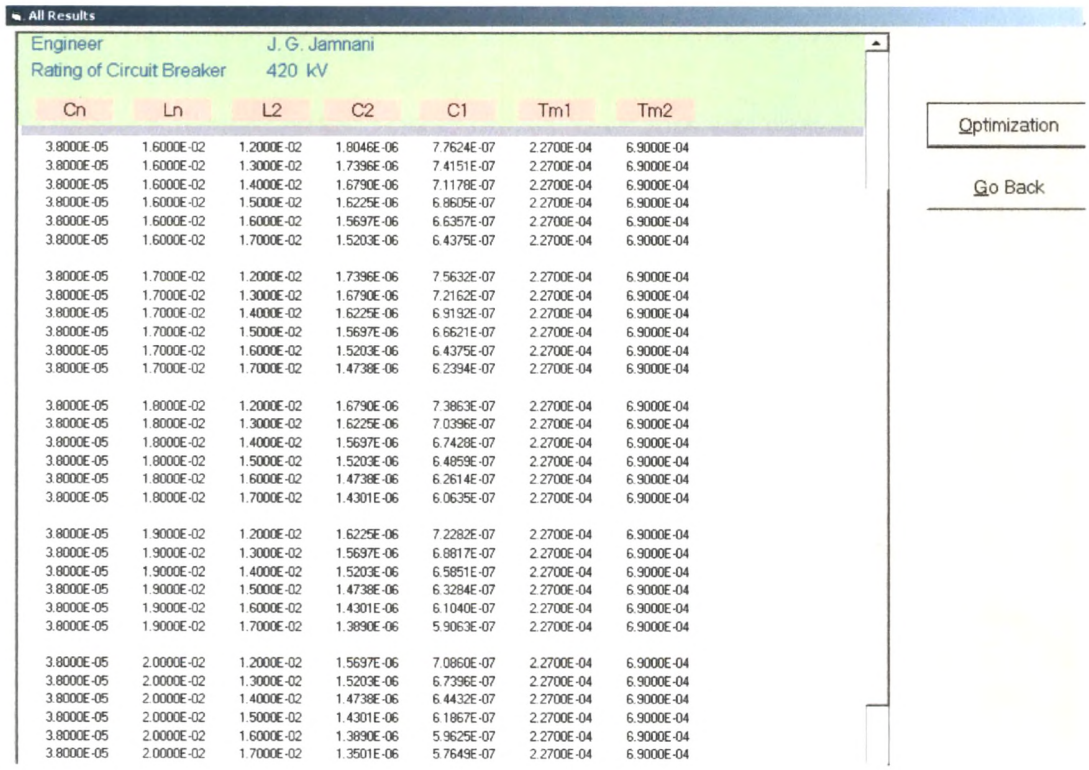
- Rating of circuit-breaker: 420kV
- Type of test duty: Terminal fault
- TRV envelope: 4-parameters TRV envelope defined by IEC standards shown in Fig.3.9, case-I

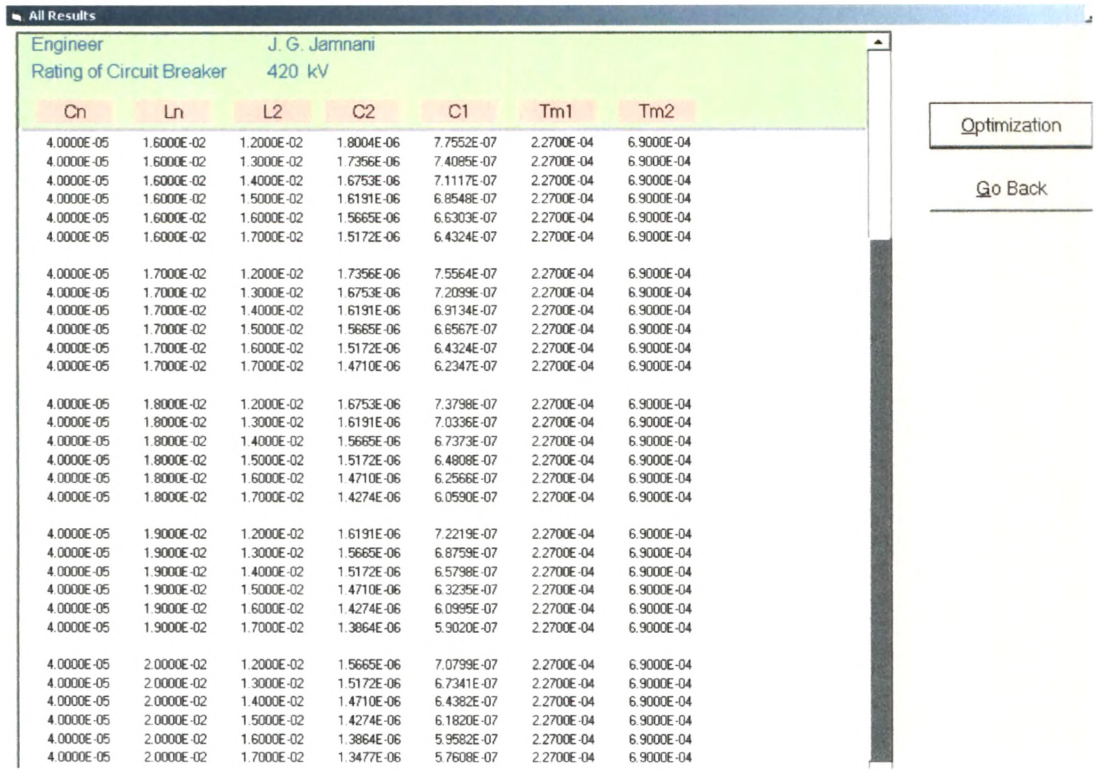


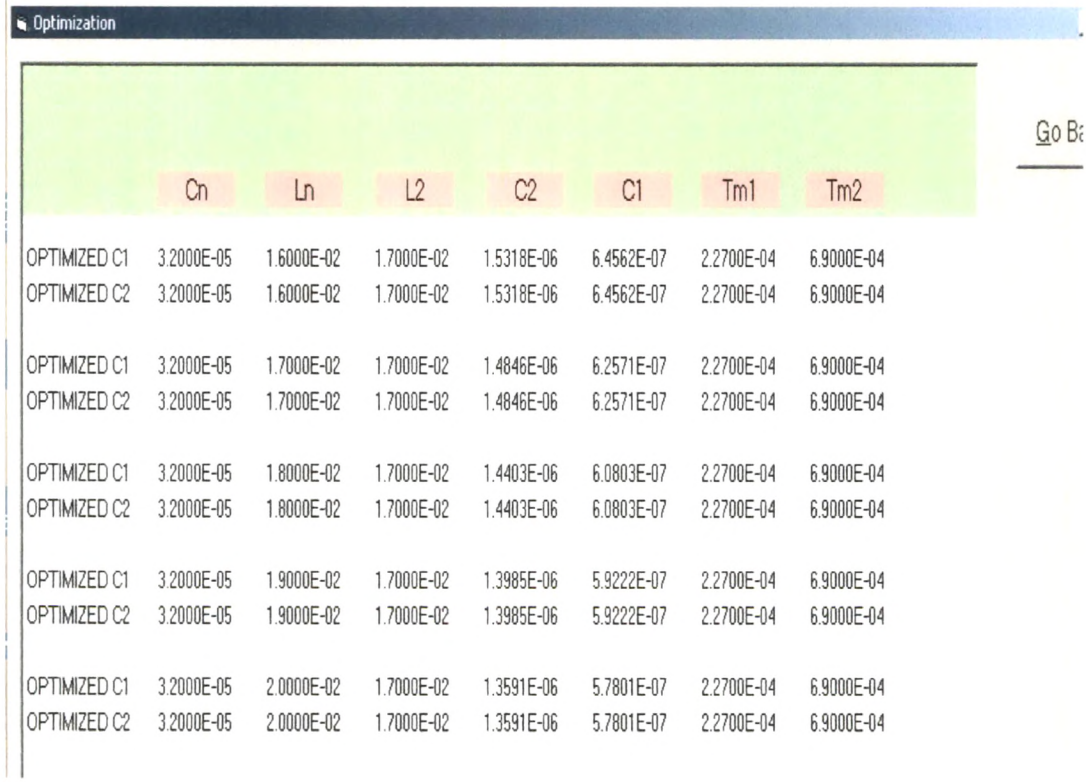

All Results
Engineer J. G. Jamnani
Rating of Circuit Breaker 420 kV
Cn Ln L2 C2 C1 Tm1 Tm2
3.2000E-05 1.6000E-02 1.2000E-02 1.8209E-06 7.7893E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.6000E-02 1.3000E-02 1.7546E-06 7.4397E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.6000E-02 1.4000E-02 1.6930E-06 7.1406E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.6000E-02 1.5000E-02 1.6356E-06 6.8817E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.6000E-02 1.6000E-02 1.5820E-06 6.6556E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.6000E-02 1.7000E-02 1.5318E-06 6.4562E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.7000E-02 1.2000E-02 1.7546E-06 7.5888E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.7000E-02 1.3000E-02 1.6930E-06 7.2396E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.7000E-02 1.4000E-02 1.6356E-06 6.9408E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.7000E-02 1.5000E-02 1.5820E-06 6.6822E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.7000E-02 1.6000E-02 1.5318E-06 6.4562E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.7000E-02 1.7000E-02 1.4846E-06 6.2571E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.8000E-02 1.2000E-02 1.6930E-06 7.4109E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.8000E-02 1.3000E-02 1.6356E-06 7.0619E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.8000E-02 1.4000E-02 1.5820E-06 6.7633E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.8000E-02 1.5000E-02 1.5318E-06 6.5050E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.8000E-02 1.6000E-02 1.4846E-06 6.2792E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.8000E-02 1.7000E-02 1.4403E-06 6.0803E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.9000E-02 1.2000E-02 1.6356E-06 7.2517E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.9000E-02 1.3000E-02 1.5820E-06 6.9031E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.9000E-02 1.4000E-02 1.5318E-06 6.6047E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.9000E-02 1.5000E-02 1.4846E-06 6.3466E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.9000E-02 1.6000E-02 1.4403E-06 6.1210E-07 2.2700E-04 6.9000E-04
3.2000E-05 1.9000E-02 1.7000E-02 1.3985E-06 5.9222E-07 2.2700E-04 6.9000E-04
3.2000E-05 2.0000E-02 1.2000E-02 1.5820E-06 7.1087E-07 2.2700E-04 6.9000E-04
3.2000E-05 2.0000E-02 1.3000E-02 1.5318E-06 6.7602E-07 2.2700E-04 6.9000E-04
3.2000E-05 2.0000E-02 1.4000E-02 1.4846E-06 6.4621E-07 2.2700E-04 6.9000E-04
3.2000E-05 2.0000E-02 1.5000E-02 1.4403E-06 6.2042E-07 2.2700E-04 6.9000E-04
3.2000E-05 2.0000E-02 1.6000E-02 1.3985E-06 5.9787E-07 2.2700E-04 6.9000E-04
3.2000E-05 2.0000E-02 1.7000E-02 1.3591E-06 5.7801E-07 2.2700E-04 6.9000E-04
Optimization
Go Back


All Results
Engineer J. G. Jamnani
Rating of Circuit Breaker 420 kV
Cn Ln L2 C2 C1 Tm1 Tm2
3.4000E-05 1.6000E-02 1.2000E-02 1.8148E-06 7.7793E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.6000E-02 1.3000E-02 1.7490E-06 7.4306E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.6000E-02 1.4000E-02 1.6878E-06 7.1321E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.6000E-02 1.5000E-02 1.6307E-06 6.8739E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.6000E-02 1.6000E-02 1.5774E-06 6.6482E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.6000E-02 1.7000E-02 1.5275E-06 6.4493E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.7000E-02 1.2000E-02 1.7490E-06 7.5793E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.7000E-02 1.3000E-02 1.6878E-06 7.2309E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.7000E-02 1.4000E-02 1.6307E-06 6.9328E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.7000E-02 1.5000E-02 1.5774E-06 6.6747E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.7000E-02 1.6000E-02 1.5275E-06 6.4493E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.7000E-02 1.7000E-02 1.4806E-06 6.2505E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.8000E-02 1.2000E-02 1.6878E-06 7.4018E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.8000E-02 1.3000E-02 1.6307E-06 7.0536E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.8000E-02 1.4000E-02 1.5774E-06 6.7557E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.8000E-02 1.5000E-02 1.5275E-06 6.4979E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.8000E-02 1.6000E-02 1.4806E-06 6.2726E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.8000E-02 1.7000E-02 1.4365E-06 6.0741E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.9000E-02 1.2000E-02 1.6307E-06 7.2430E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.9000E-02 1.3000E-02 1.5774E-06 6.8951E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.9000E-02 1.4000E-02 1.5275E-06 6.5974E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.9000E-02 1.5000E-02 1.4806E-06 6.3398E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.9000E-02 1.6000E-02 1.4365E-06 6.1147E-07 2.2700E-04 6.9000E-04
3.4000E-05 1.9000E-02 1.7000E-02 1.3949E-06 5.9163E-07 2.2700E-04 6.9000E-04
3.4000E-05 2.0000E-02 1.2000E-02 1.5774E-06 7.1002E-07 2.2700E-04 6.9000E-04
3.4000E-05 2.0000E-02 1.3000E-02 1.5275E-06 6.7526E-07 2.2700E-04 6.9000E-04
3.4000E-05 2.0000E-02 1.4000E-02 1.4806E-06 6.4551E-07 2.2700E-04 6.9000E-04
3.4000E-05 2.0000E-02 1.5000E-02 1.4365E-06 6.1977E-07 2.2700E-04 6.9000E-04
3.4000E-05 2.0000E-02 1.6000E-02 1.3949E-06 5.9727E-07 2.2700E-04 6.9000E-04
3.4000E-05 2.0000E-02 1.7000E-02 1.3557E-06 5.7744E-07 2.2700E-04 6.9000E-04
Optimization
Go Back


All Results
Engineer
J. G. Jamnani
Rating of Circuit Breaker
420 kV
Cn Ln L2 C2 C1 Tm1 Tm2
3.6000E-05 1.6000E-02 1.2000E-02 1.8094E-06 7.7704E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.6000E-02 1.3000E-02 1.7440E-06 7.4224E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.6000E-02 1.4000E-02 1.6831E-06 7.1246E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.6000E-02 1.5000E-02 1.6264E-06 6.8668E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.6000E-02 1.6000E-02 1.5734E-06 6.6416E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.6000E-02 1.7000E-02 1.5237E-06 6.4430E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.7000E-02 1.2000E-02 1.7440E-06 7.5709E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.7000E-02 1.3000E-02 1.6831E-06 7.2232E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.7000E-02 1.4000E-02 1.6264E-06 6.9256E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.7000E-02 1.5000E-02 1.5734E-06 6.6681E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.7000E-02 1.6000E-02 1.5237E-06 6.4430E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.7000E-02 1.7000E-02 1.4770E-06 6.2447E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.8000E-02 1.2000E-02 1.6831E-06 7.3936E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.8000E-02 1.3000E-02 1.6264E-06 7.0462E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.8000E-02 1.4000E-02 1.5734E-06 6.7489E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.8000E-02 1.5000E-02 1.5237E-06 6.4916E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.8000E-02 1.6000E-02 1.4770E-06 6.2667E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.8000E-02 1.7000E-02 1.4331E-06 6.0685E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.9000E-02 1.2000E-02 1.6264E-06 7.2352E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.9000E-02 1.3000E-02 1.5734E-06 6.8880E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.9000E-02 1.4000E-02 1.5237E-06 6.5909E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.9000E-02 1.5000E-02 1.4770E-06 6.3338E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.9000E-02 1.6000E-02 1.4331E-06 6.1091E-07 2.2700E-04 6.9000E-04
3.6000E-05 1.9000E-02 1.7000E-02 1.3918E-06 5.9110E-07 2.2700E-04 6.9000E-04
3.6000E-05 2.0000E-02 1.2000E-02 1.5734E-06 7.0927E-07 2.2700E-04 6.9000E-04
3.6000E-05 2.0000E-02 1.3000E-02 1.5237E-06 6.7458E-07 2.2700E-04 6.9000E-04
3.6000E-05 2.0000E-02 1.4000E-02 1.4770E-06 6.4489E-07 2.2700E-04 6.9000E-04
3.6000E-05 2.0000E-02 1.5000E-02 1.4331E-06 6.1919E-07 2.2700E-04 6.9000E-04
3.6000E-05 2.0000E-02 1.6000E-02 1.3918E-06 5.9673E-07 2.2700E-04 6.9000E-04
3.6000E-05 2.0000E-02 1.7000E-02 1.3527E-06 5.7694E-07 2.2700E-04 6.9000E-04
Optimization
Go Back


All Results
Engineer
J. G. Jamnani
Rating of Circuit Breaker
420 kV
Cn Ln L2 C2 C1 Tm1 Tm2
3.8000E-05 1.6000E-02 1.2000E-02 1.8046E-06 7.7624E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.6000E-02 1.3000E-02 1.7396E-06 7.4151E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.6000E-02 1.4000E-02 1.6790E-06 7.1178E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.6000E-02 1.5000E-02 1.6225E-06 6.8605E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.6000E-02 1.6000E-02 1.5697E-06 6.6357E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.6000E-02 1.7000E-02 1.5203E-06 6.4375E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.7000E-02 1.2000E-02 1.7396E-06 7.5632E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.7000E-02 1.3000E-02 1.6790E-06 7.2162E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.7000E-02 1.4000E-02 1.6225E-06 6.9192E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.7000E-02 1.5000E-02 1.5697E-06 6.6621E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.7000E-02 1.6000E-02 1.5203E-06 6.4375E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.7000E-02 1.7000E-02 1.4738E-06 6.2394E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.8000E-02 1.2000E-02 1.6790E-06 7.3863E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.8000E-02 1.3000E-02 1.6225E-06 7.0396E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.8000E-02 1.4000E-02 1.5697E-06 6.7428E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.8000E-02 1.5000E-02 1.5203E-06 6.4859E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.8000E-02 1.6000E-02 1.4738E-06 6.2614E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.8000E-02 1.7000E-02 1.4301E-06 6.0635E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.9000E-02 1.2000E-02 1.6225E-06 7.2282E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.9000E-02 1.3000E-02 1.5697E-06 6.8817E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.9000E-02 1.4000E-02 1.5203E-06 6.5851E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.9000E-02 1.5000E-02 1.4738E-06 6.3284E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.9000E-02 1.6000E-02 1.4301E-06 6.1040E-07 2.2700E-04 6.9000E-04
3.8000E-05 1.9000E-02 1.7000E-02 1.3890E-06 5.9063E-07 2.2700E-04 6.9000E-04
3.8000E-05 2.0000E-02 1.2000E-02 1.5697E-06 7.0860E-07 2.2700E-04 6.9000E-04
3.8000E-05 2.0000E-02 1.3000E-02 1.5203E-06 6.7396E-07 2.2700E-04 6.9000E-04
3.8000E-05 2.0000E-02 1.4000E-02 1.4738E-06 6.4432E-07 2.2700E-04 6.9000E-04
3.8000E-05 2.0000E-02 1.5000E-02 1.4301E-06 6.1867E-07 2.2700E-04 6.9000E-04
3.8000E-05 2.0000E-02 1.6000E-02 1.3890E-06 5.9625E-07 2.2700E-04 6.9000E-04
3.8000E-05 2.0000E-02 1.7000E-02 1.3501E-06 5.7649E-07 2.2700E-04 6.9000E-04
Optimization
Go Back


All Results
Engineer
J. G. Jamnani
Rating of Circuit Breaker
420 kV
Cn Ln L2 C2 C1 Tm1 Tm2
4.0000E-05 1.6000E-02 1.2000E-02 1.8004E-06 7.7552E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.6000E-02 1.3000E-02 1.7356E-06 7.4085E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.6000E-02 1.4000E-02 1.6753E-06 7.1117E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.6000E-02 1.5000E-02 1.6191E-06 6.8548E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.6000E-02 1.6000E-02 1.5665E-06 6.6303E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.6000E-02 1.7000E-02 1.5172E-06 6.4324E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.7000E-02 1.2000E-02 1.7356E-06 7.5564E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.7000E-02 1.3000E-02 1.6753E-06 7.2099E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.7000E-02 1.4000E-02 1.6191E-06 6.9134E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.7000E-02 1.5000E-02 1.5665E-06 6.6567E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.7000E-02 1.6000E-02 1.5172E-06 6.4324E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.7000E-02 1.7000E-02 1.4710E-06 6.2347E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.8000E-02 1.2000E-02 1.6753E-06 7.3798E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.8000E-02 1.3000E-02 1.6191E-06 7.0336E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.8000E-02 1.4000E-02 1.5665E-06 6.7373E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.8000E-02 1.5000E-02 1.5172E-06 6.4808E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.8000E-02 1.6000E-02 1.4710E-06 6.2566E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.8000E-02 1.7000E-02 1.4274E-06 6.0590E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.9000E-02 1.2000E-02 1.6191E-06 7.2219E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.9000E-02 1.3000E-02 1.5665E-06 6.8759E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.9000E-02 1.4000E-02 1.5172E-06 6.5798E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.9000E-02 1.5000E-02 1.4710E-06 6.3235E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.9000E-02 1.6000E-02 1.4274E-06 6.0995E-07 2.2700E-04 6.9000E-04
4.0000E-05 1.9000E-02 1.7000E-02 1.3864E-06 5.9020E-07 2.2700E-04 6.9000E-04
4.0000E-05 2.0000E-02 1.2000E-02 1.5665E-06 7.0799E-07 2.2700E-04 6.9000E-04
4.0000E-05 2.0000E-02 1.3000E-02 1.5172E-06 6.7341E-07 2.2700E-04 6.9000E-04
4.0000E-05 2.0000E-02 1.4000E-02 1.4710E-06 6.4382E-07 2.2700E-04 6.9000E-04
4.0000E-05 2.0000E-02 1.5000E-02 1.4274E-06 6.1820E-07 2.2700E-04 6.9000E-04
4.0000E-05 2.0000E-02 1.6000E-02 1.3864E-06 5.9582E-07 2.2700E-04 6.9000E-04
4.0000E-05 2.0000E-02 1.7000E-02 1.3477E-06 5.7608E-07 2.2700E-04 6.9000E-04
Optimization
Go Back

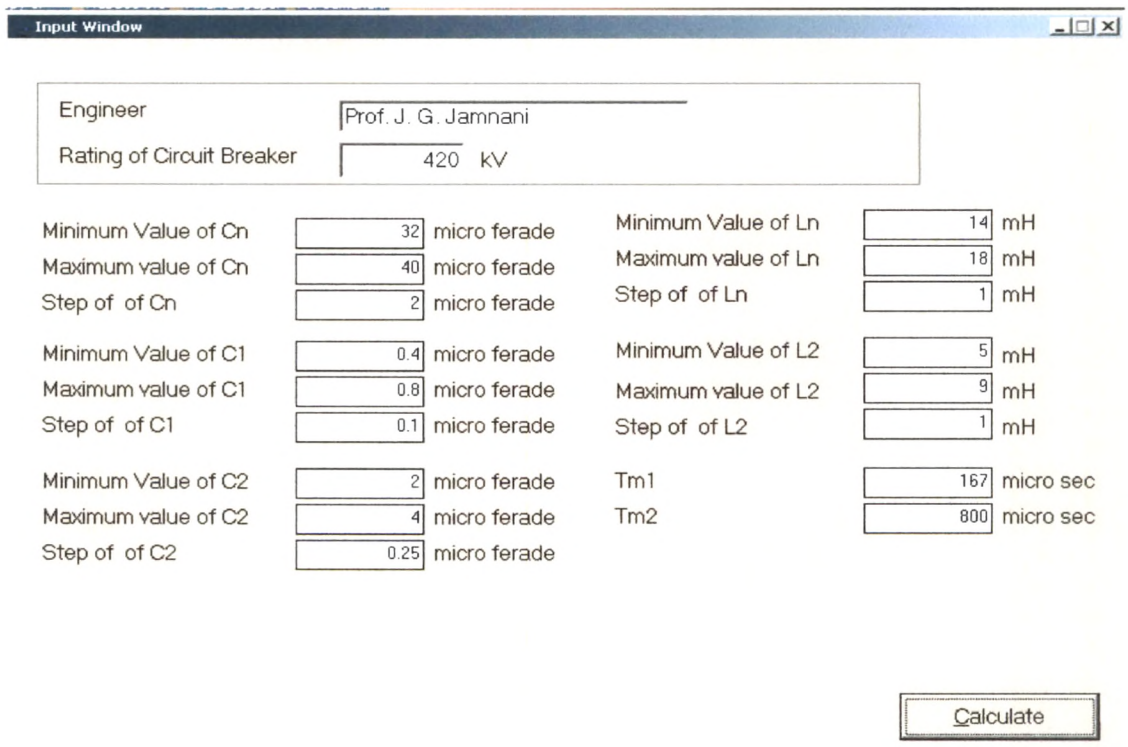

Optimization
Cn Ln L2 C2 C1 Tm1 Tm2
OPTIMIZED C1 3.2000E-05 1.6000E-02 1.7000E-02 1.5318E-06 6.4562E-07 2.2700E-04 6.9000E-04
OPTIMIZED C2 3.2000E-05 1.6000E-02 1.7000E-02 1.5318E-06 6.4562E-07 2.2700E-04 6.9000E-04
OPTIMIZED C1 3.2000E-05 1.7000E-02 1.7000E-02 1.4846E-06 6.2571E-07 2.2700E-04 6.9000E-04
OPTIMIZED C2 3.2000E-05 1.7000E-02 1.7000E-02 1.4846E-06 6.2571E-07 2.2700E-04 6.9000E-04
OPTIMIZED C1 3.2000E-05 1.8000E-02 1.7000E-02 1.4403E-06 6.0803E-07 2.2700E-04 6.9000E-04
OPTIMIZED C2 3.2000E-05 1.8000E-02 1.7000E-02 1.4403E-06 6.0803E-07 2.2700E-04 6.9000E-04
OPTIMIZED C1 3.2000E-05 1.9000E-02 1.7000E-02 1.3985E-06 5.9222E-07 2.2700E-04 6.9000E-04
OPTIMIZED C2 3.2000E-05 1.9000E-02 1.7000E-02 1.3985E-06 5.9222E-07 2.2700E-04 6.9000E-04
OPTIMIZED C1 3.2000E-05 2.0000E-02 1.7000E-02 1.3591E-06 5.7801E-07 2.2700E-04 6.9000E-04
OPTIMIZED C2 3.2000E-05 2.0000E-02 1.7000E-02 1.3591E-06 5.7801E-07 2.2700E-04 6.9000E-04
Go Ba

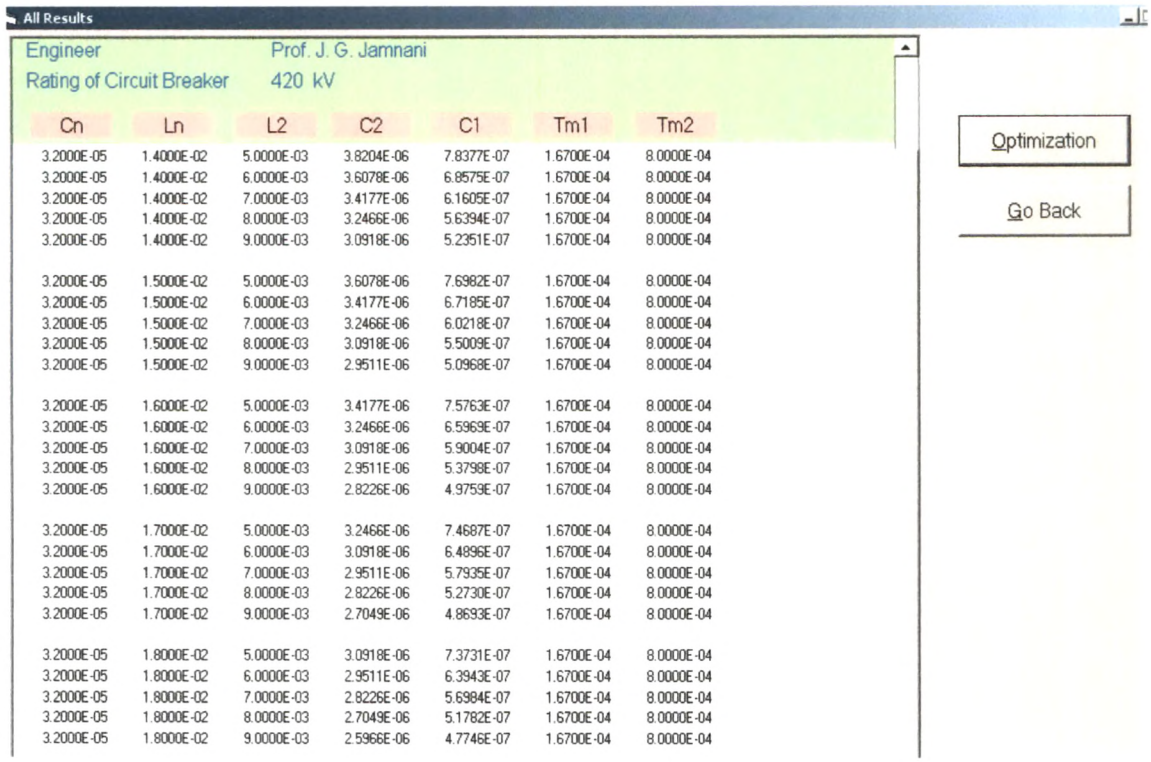
The suitable and optimized circuit components obtained are as follows:

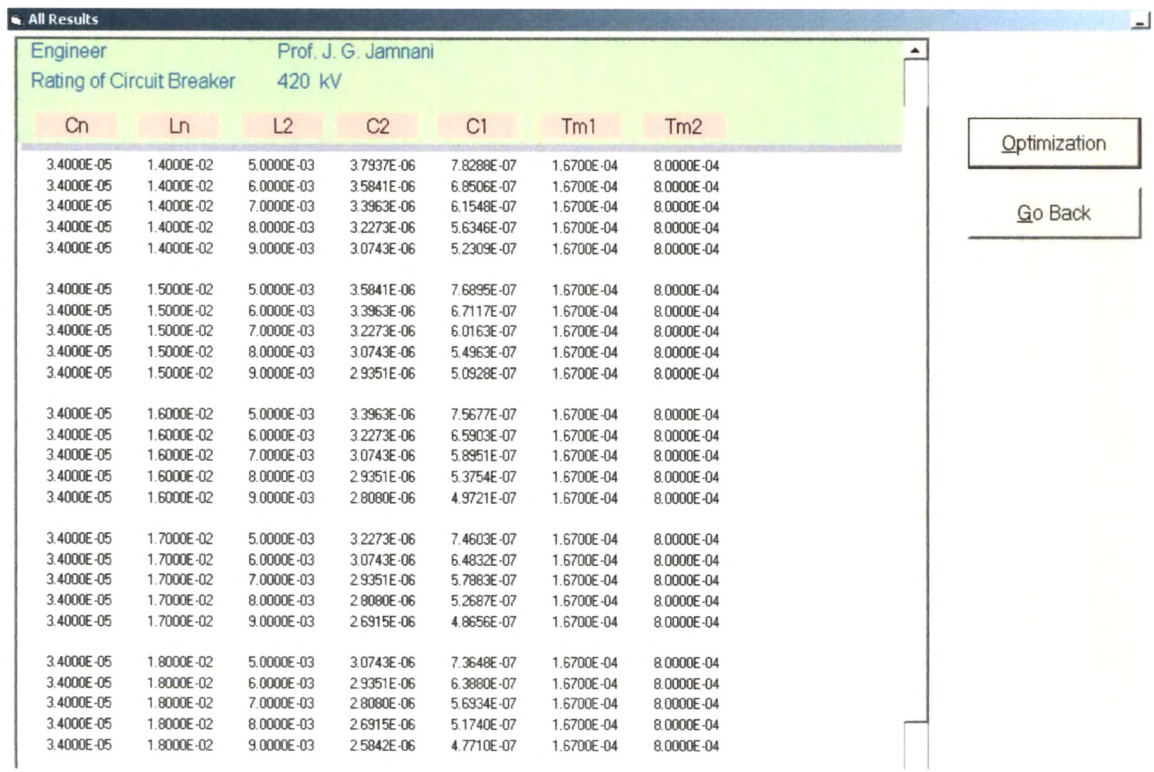
Rating of CB	Circuit components		Terminal Fault Test Duty
420kV			As per case-I
	Capacitor Banks		
	Main Capacitor Bank:	C_n	32 μF
	TRV Capacitor Banks:	C_1	0.6 μF
		C_2	1.4 μF
	Reactors :	L_n	19 mH
		L_2	17 mH

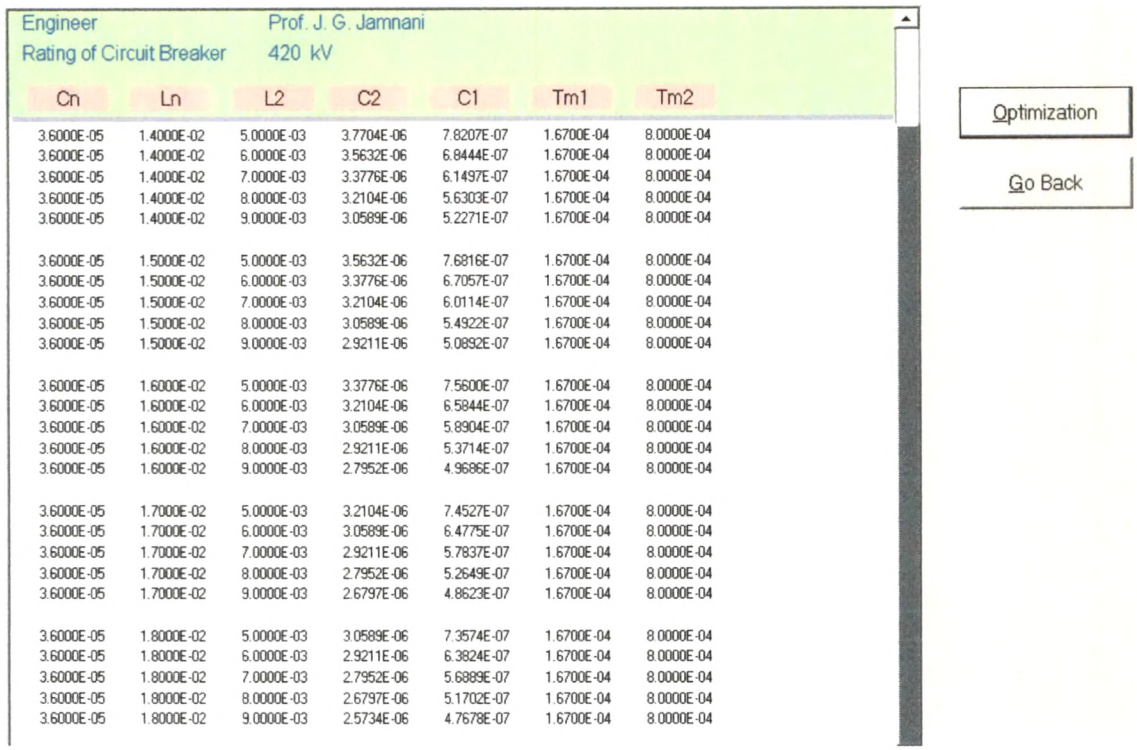
(B) Finding all possible and optimized circuit components for desired frequencies fn_1 and fn_2 (tm_1 and tm_2)

- Rating of circuit-breaker: 420kV
- Type of test duty: Terminal fault
- TRV envelope: 4-parameters TRV envelope defined by IEC standards shown in Fig.3.10, case-II




All Results
Engineer
Prof. J. G. Jamnani
Rating of Circuit Breaker
420 kV
Cn Ln L2 C2 C1 Tm1 Tm2
3.2000E-05 1.4000E-02 5.0000E-03 3.8204E-06 7.8377E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.4000E-02 6.0000E-03 3.6078E-06 6.8575E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.4000E-02 7.0000E-03 3.4177E-06 6.1605E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.4000E-02 8.0000E-03 3.2466E-06 5.6394E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.4000E-02 9.0000E-03 3.0918E-06 5.2351E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.5000E-02 5.0000E-03 3.6078E-06 7.6982E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.5000E-02 6.0000E-03 3.4177E-06 6.7185E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.5000E-02 7.0000E-03 3.2466E-06 6.0218E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.5000E-02 8.0000E-03 3.0918E-06 5.5009E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.5000E-02 9.0000E-03 2.9511E-06 5.0968E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.6000E-02 5.0000E-03 3.4177E-06 7.5763E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.6000E-02 6.0000E-03 3.2466E-06 6.5969E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.6000E-02 7.0000E-03 3.0918E-06 5.9004E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.6000E-02 8.0000E-03 2.9511E-06 5.3798E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.6000E-02 9.0000E-03 2.8226E-06 4.9759E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.7000E-02 5.0000E-03 3.2466E-06 7.4687E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.7000E-02 6.0000E-03 3.0918E-06 6.4896E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.7000E-02 7.0000E-03 2.9511E-06 5.7935E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.7000E-02 8.0000E-03 2.8226E-06 5.2730E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.7000E-02 9.0000E-03 2.7049E-06 4.8693E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.8000E-02 5.0000E-03 3.0918E-06 7.3731E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.8000E-02 6.0000E-03 2.9511E-06 6.3943E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.8000E-02 7.0000E-03 2.8226E-06 5.6984E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.8000E-02 8.0000E-03 2.7049E-06 5.1782E-07 1.6700E-04 8.0000E-04
3.2000E-05 1.8000E-02 9.0000E-03 2.5966E-06 4.7746E-07 1.6700E-04 8.0000E-04
Optimization
Go Back


All Results
Engineer
Prof. J. G. Jamnani
Rating of Circuit Breaker
420 kV
Cn Ln L2 C2 C1 Tm1 Tm2
3.4000E-05 1.4000E-02 5.0000E-03 3.7937E-06 7.8288E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.4000E-02 6.0000E-03 3.5841E-06 6.8506E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.4000E-02 7.0000E-03 3.3963E-06 6.1548E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.4000E-02 8.0000E-03 3.2273E-06 5.6346E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.4000E-02 9.0000E-03 3.0743E-06 5.2309E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.5000E-02 5.0000E-03 3.5841E-06 7.6895E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.5000E-02 6.0000E-03 3.3963E-06 6.7117E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.5000E-02 7.0000E-03 3.2273E-06 6.0163E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.5000E-02 8.0000E-03 3.0743E-06 5.4963E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.5000E-02 9.0000E-03 2.9351E-06 5.0928E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.6000E-02 5.0000E-03 3.3963E-06 7.5677E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.6000E-02 6.0000E-03 3.2273E-06 6.5903E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.6000E-02 7.0000E-03 3.0743E-06 5.8951E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.6000E-02 8.0000E-03 2.9351E-06 5.3754E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.6000E-02 9.0000E-03 2.8080E-06 4.9721E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.7000E-02 5.0000E-03 3.2273E-06 7.4603E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.7000E-02 6.0000E-03 3.0743E-06 6.4832E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.7000E-02 7.0000E-03 2.9351E-06 5.7883E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.7000E-02 8.0000E-03 2.8080E-06 5.2687E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.7000E-02 9.0000E-03 2.6915E-06 4.8656E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.8000E-02 5.0000E-03 3.0743E-06 7.3648E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.8000E-02 6.0000E-03 2.9351E-06 6.3880E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.8000E-02 7.0000E-03 2.8080E-06 5.6934E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.8000E-02 8.0000E-03 2.6915E-06 5.1740E-07 1.6700E-04 8.0000E-04
3.4000E-05 1.8000E-02 9.0000E-03 2.5842E-06 4.7710E-07 1.6700E-04 8.0000E-04
Optimization
Go Back



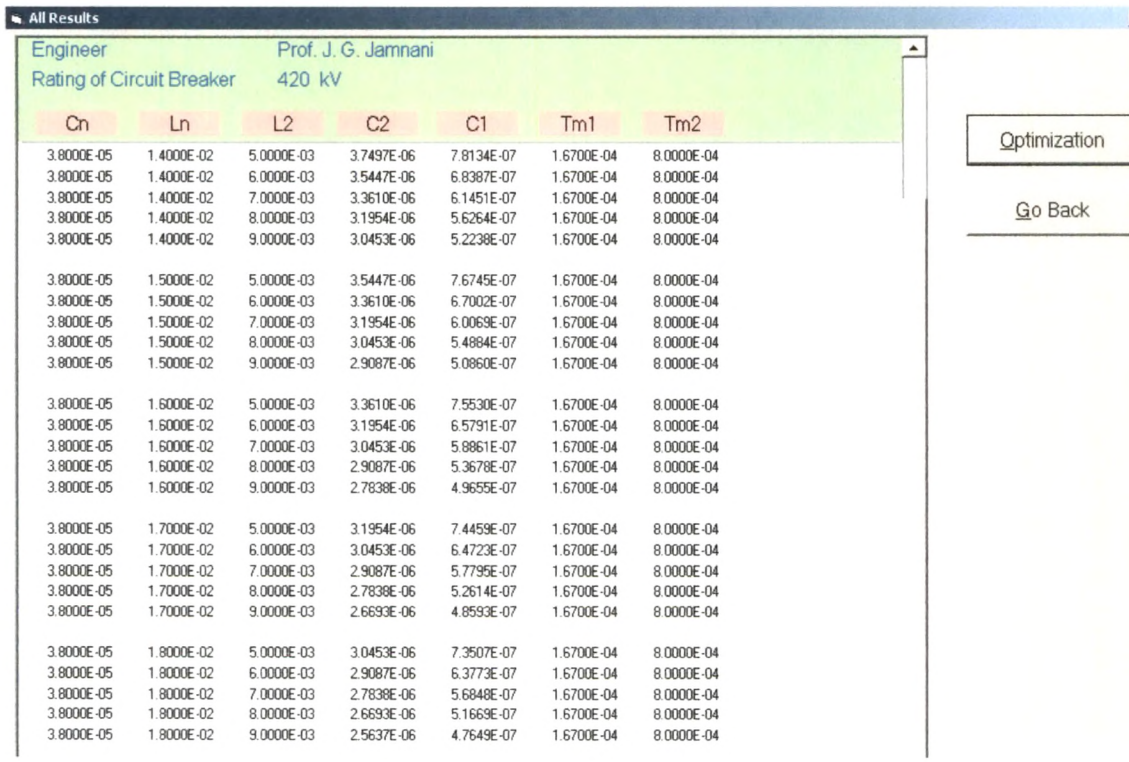
Engineer Prof. J. G. Jamnani

Rating of Circuit Breaker 420 kV

Cn	Ln	L2	C2	C1	Tm1	Tm2
3.6000E-05	1.4000E-02	5.0000E-03	3.7704E-06	7.8207E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.4000E-02	6.0000E-03	3.5632E-06	6.8444E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.4000E-02	7.0000E-03	3.3776E-06	6.1497E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.4000E-02	8.0000E-03	3.2104E-06	5.6303E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.4000E-02	9.0000E-03	3.0589E-06	5.2271E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.5000E-02	5.0000E-03	3.5632E-06	7.6816E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.5000E-02	6.0000E-03	3.3776E-06	6.7057E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.5000E-02	7.0000E-03	3.2104E-06	6.0114E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.5000E-02	8.0000E-03	3.0589E-06	5.4922E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.5000E-02	9.0000E-03	2.9211E-06	5.0892E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.6000E-02	5.0000E-03	3.3776E-06	7.5600E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.6000E-02	6.0000E-03	3.2104E-06	6.5844E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.6000E-02	7.0000E-03	3.0589E-06	5.8904E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.6000E-02	8.0000E-03	2.9211E-06	5.3714E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.6000E-02	9.0000E-03	2.7952E-06	4.9686E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.7000E-02	5.0000E-03	3.2104E-06	7.4527E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.7000E-02	6.0000E-03	3.0589E-06	6.4775E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.7000E-02	7.0000E-03	2.9211E-06	5.7837E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.7000E-02	8.0000E-03	2.7952E-06	5.2649E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.7000E-02	9.0000E-03	2.6797E-06	4.8623E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.8000E-02	5.0000E-03	3.0589E-06	7.3574E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.8000E-02	6.0000E-03	2.9211E-06	6.3824E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.8000E-02	7.0000E-03	2.7952E-06	5.6889E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.8000E-02	8.0000E-03	2.6797E-06	5.1702E-07	1.6700E-04	8.0000E-04
3.6000E-05	1.8000E-02	9.0000E-03	2.5734E-06	4.7678E-07	1.6700E-04	8.0000E-04

Optimization

Go Back



All Results

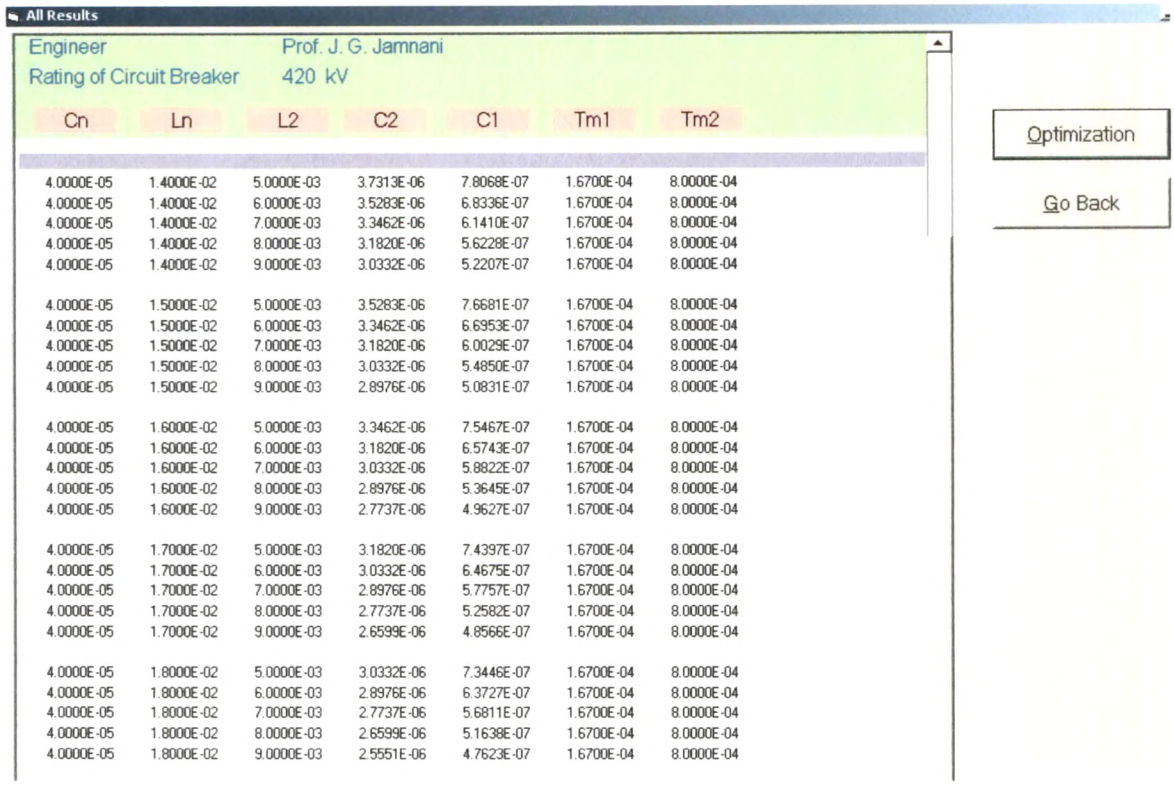
Engineer Prof. J. G. Jamnani

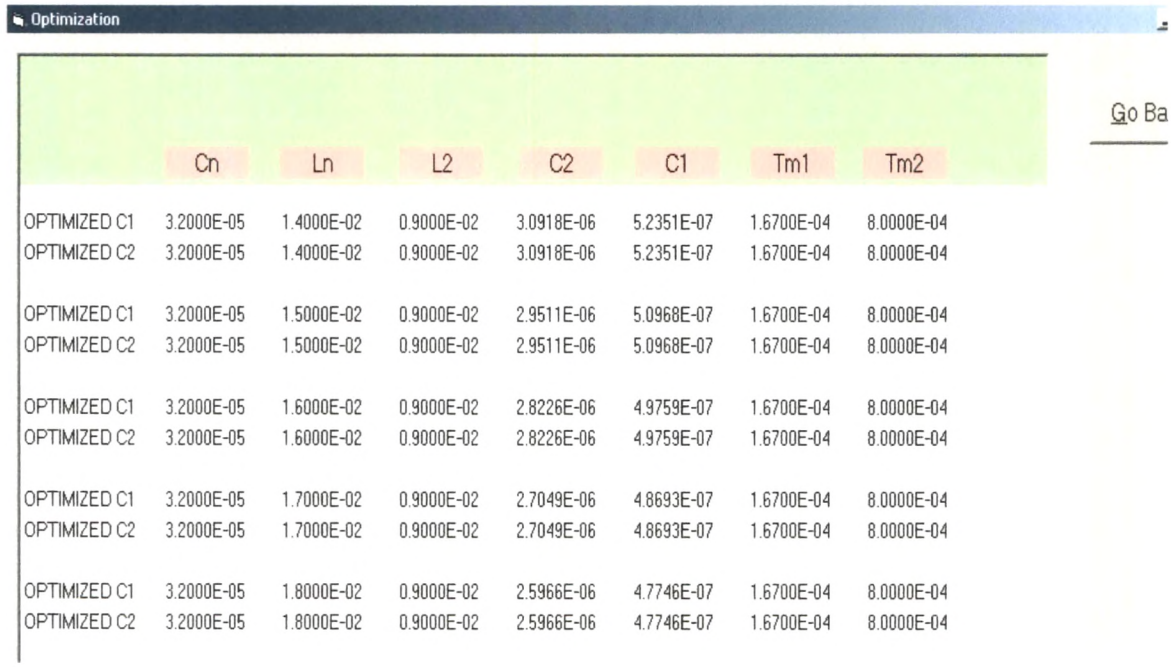
Rating of Circuit Breaker 420 kV

Cn	Ln	L2	C2	C1	Tm1	Tm2
3.8000E-05	1.4000E-02	5.0000E-03	3.7497E-06	7.8134E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.4000E-02	6.0000E-03	3.5447E-06	6.8387E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.4000E-02	7.0000E-03	3.3610E-06	6.1451E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.4000E-02	8.0000E-03	3.1954E-06	5.6264E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.4000E-02	9.0000E-03	3.0453E-06	5.2238E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.5000E-02	5.0000E-03	3.5447E-06	7.6745E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.5000E-02	6.0000E-03	3.3610E-06	6.7002E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.5000E-02	7.0000E-03	3.1954E-06	6.0069E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.5000E-02	8.0000E-03	3.0453E-06	5.4884E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.5000E-02	9.0000E-03	2.9087E-06	5.0860E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.6000E-02	5.0000E-03	3.3610E-06	7.5530E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.6000E-02	6.0000E-03	3.1954E-06	6.5791E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.6000E-02	7.0000E-03	3.0453E-06	5.8861E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.6000E-02	8.0000E-03	2.9087E-06	5.3678E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.6000E-02	9.0000E-03	2.7838E-06	4.9655E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.7000E-02	5.0000E-03	3.1954E-06	7.4459E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.7000E-02	6.0000E-03	3.0453E-06	6.4723E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.7000E-02	7.0000E-03	2.9087E-06	5.7795E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.7000E-02	8.0000E-03	2.7838E-06	5.2614E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.7000E-02	9.0000E-03	2.6693E-06	4.8593E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.8000E-02	5.0000E-03	3.0453E-06	7.3507E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.8000E-02	6.0000E-03	2.9087E-06	6.3773E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.8000E-02	7.0000E-03	2.7838E-06	5.6848E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.8000E-02	8.0000E-03	2.6693E-06	5.1669E-07	1.6700E-04	8.0000E-04
3.8000E-05	1.8000E-02	9.0000E-03	2.5637E-06	4.7649E-07	1.6700E-04	8.0000E-04

Optimization

Go Back


All Results
Engineer
Prof. J. G. Jamnani
Rating of Circuit Breaker
420 kV
Cn
Ln
L2
C2
C1
Tm1
Tm2
4.0000E-05 1.4000E-02 5.0000E-03 3.7313E-06 7.8068E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.4000E-02 6.0000E-03 3.5283E-06 6.8336E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.4000E-02 7.0000E-03 3.3462E-06 6.1410E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.4000E-02 8.0000E-03 3.1820E-06 5.6228E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.4000E-02 9.0000E-03 3.0332E-06 5.2207E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.5000E-02 5.0000E-03 3.5283E-06 7.6681E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.5000E-02 6.0000E-03 3.3462E-06 6.6953E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.5000E-02 7.0000E-03 3.1820E-06 6.0029E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.5000E-02 8.0000E-03 3.0332E-06 5.4850E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.5000E-02 9.0000E-03 2.8976E-06 5.0831E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.6000E-02 5.0000E-03 3.3462E-06 7.5467E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.6000E-02 6.0000E-03 3.1820E-06 6.5743E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.6000E-02 7.0000E-03 3.0332E-06 5.8822E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.6000E-02 8.0000E-03 2.8976E-06 5.3645E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.6000E-02 9.0000E-03 2.7737E-06 4.9627E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.7000E-02 5.0000E-03 3.1820E-06 7.4397E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.7000E-02 6.0000E-03 3.0332E-06 6.4675E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.7000E-02 7.0000E-03 2.8976E-06 5.7757E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.7000E-02 8.0000E-03 2.7737E-06 5.2582E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.7000E-02 9.0000E-03 2.6599E-06 4.8566E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.8000E-02 5.0000E-03 3.0332E-06 7.3446E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.8000E-02 6.0000E-03 2.8976E-06 6.3727E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.8000E-02 7.0000E-03 2.7737E-06 5.6811E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.8000E-02 8.0000E-03 2.6599E-06 5.1638E-07 1.6700E-04 8.0000E-04
4.0000E-05 1.8000E-02 9.0000E-03 2.5551E-06 4.7623E-07 1.6700E-04 8.0000E-04
Optimization
Go Back

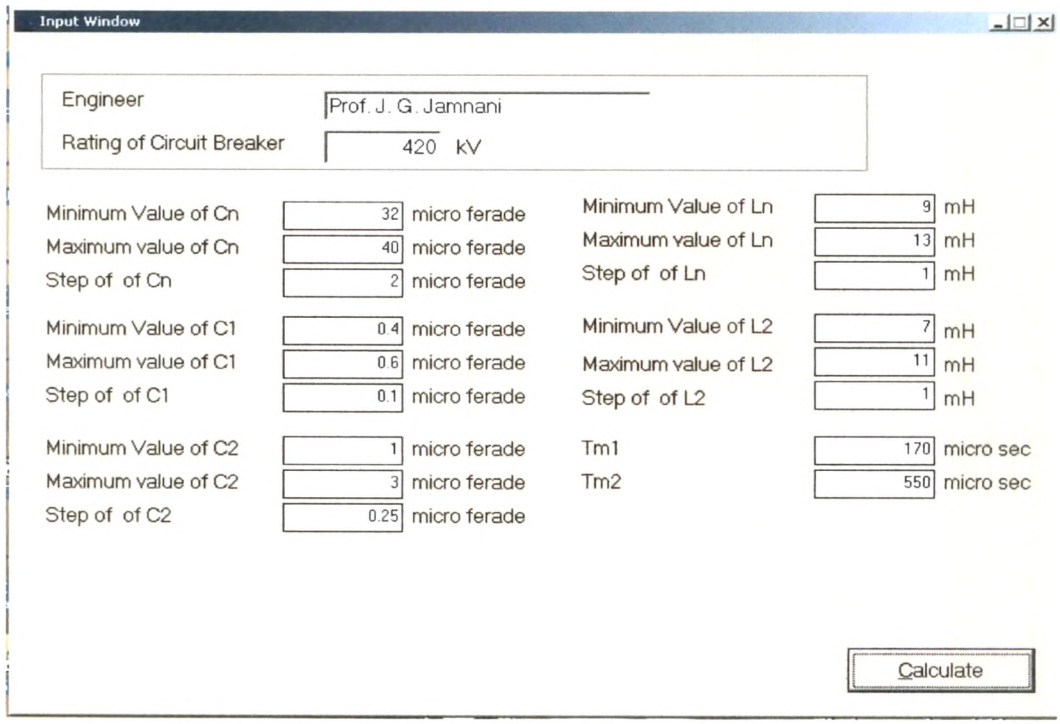

Optimization
Go Ba
Cn
Ln
L2
C2
C1
Tm1
Tm2
OPTIMIZED C1 3.2000E-05 1.4000E-02 0.9000E-02 3.0918E-06 5.2351E-07 1.6700E-04 8.0000E-04
OPTIMIZED C2 3.2000E-05 1.4000E-02 0.9000E-02 3.0918E-06 5.2351E-07 1.6700E-04 8.0000E-04
OPTIMIZED C1 3.2000E-05 1.5000E-02 0.9000E-02 2.9511E-06 5.0968E-07 1.6700E-04 8.0000E-04
OPTIMIZED C2 3.2000E-05 1.5000E-02 0.9000E-02 2.9511E-06 5.0968E-07 1.6700E-04 8.0000E-04
OPTIMIZED C1 3.2000E-05 1.6000E-02 0.9000E-02 2.8226E-06 4.9759E-07 1.6700E-04 8.0000E-04
OPTIMIZED C2 3.2000E-05 1.6000E-02 0.9000E-02 2.8226E-06 4.9759E-07 1.6700E-04 8.0000E-04
OPTIMIZED C1 3.2000E-05 1.7000E-02 0.9000E-02 2.7049E-06 4.8693E-07 1.6700E-04 8.0000E-04
OPTIMIZED C2 3.2000E-05 1.7000E-02 0.9000E-02 2.7049E-06 4.8693E-07 1.6700E-04 8.0000E-04
OPTIMIZED C1 3.2000E-05 1.8000E-02 0.9000E-02 2.5966E-06 4.7746E-07 1.6700E-04 8.0000E-04
OPTIMIZED C2 3.2000E-05 1.8000E-02 0.9000E-02 2.5966E-06 4.7746E-07 1.6700E-04 8.0000E-04

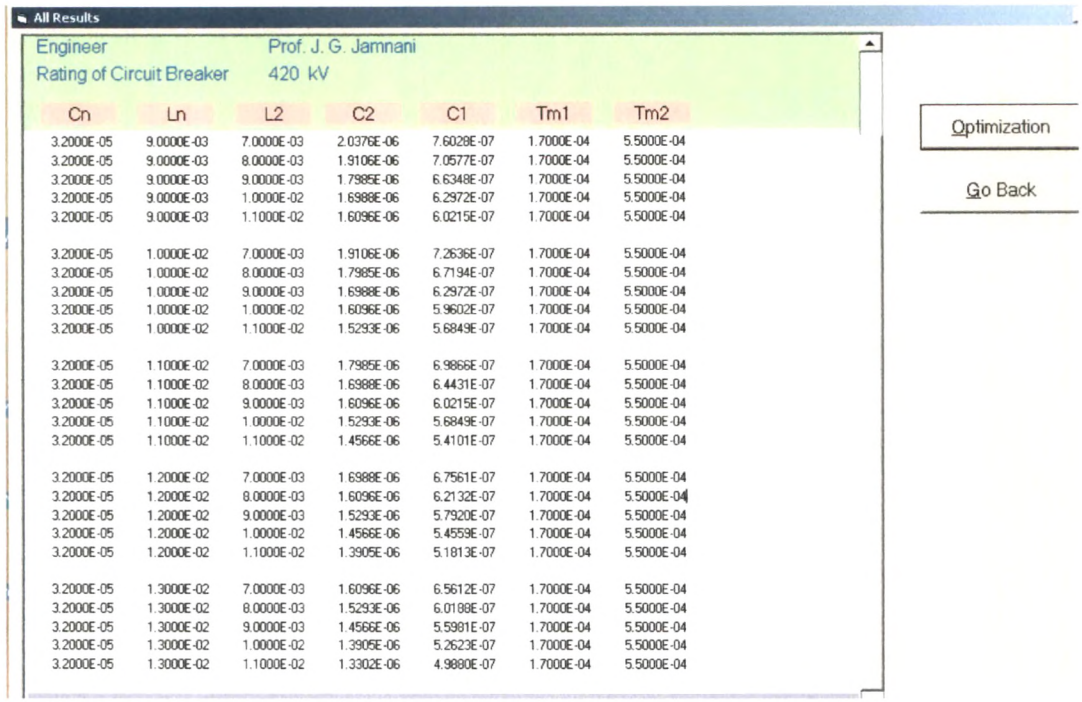
The suitable and optimized circuit components obtained are as follows:

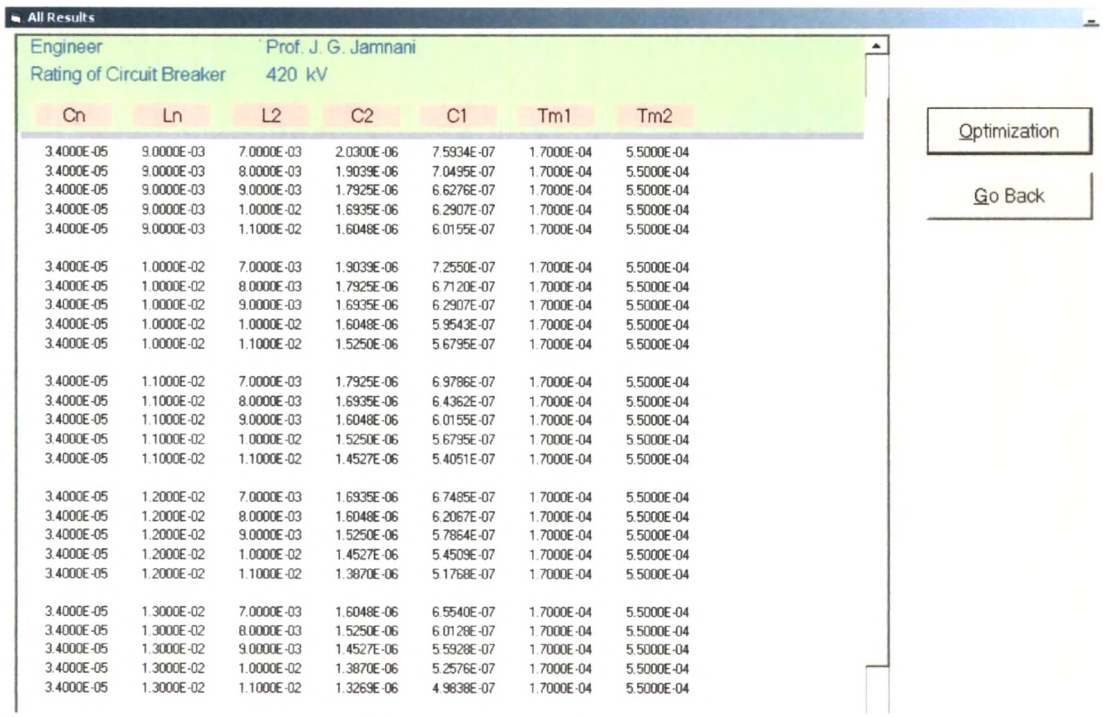
Rating of CB	Circuit components		Terminal Fault Test Duty
420kV			As per case-II
	Capacitor Banks		
	Main Capacitor Bank:	C_n	32 μF
	TRV Capacitor Banks:	C_1	0.5 μF
		C_2	2.6 μF
	Reactors :	L_n	18 mH
		L_2	9 mH

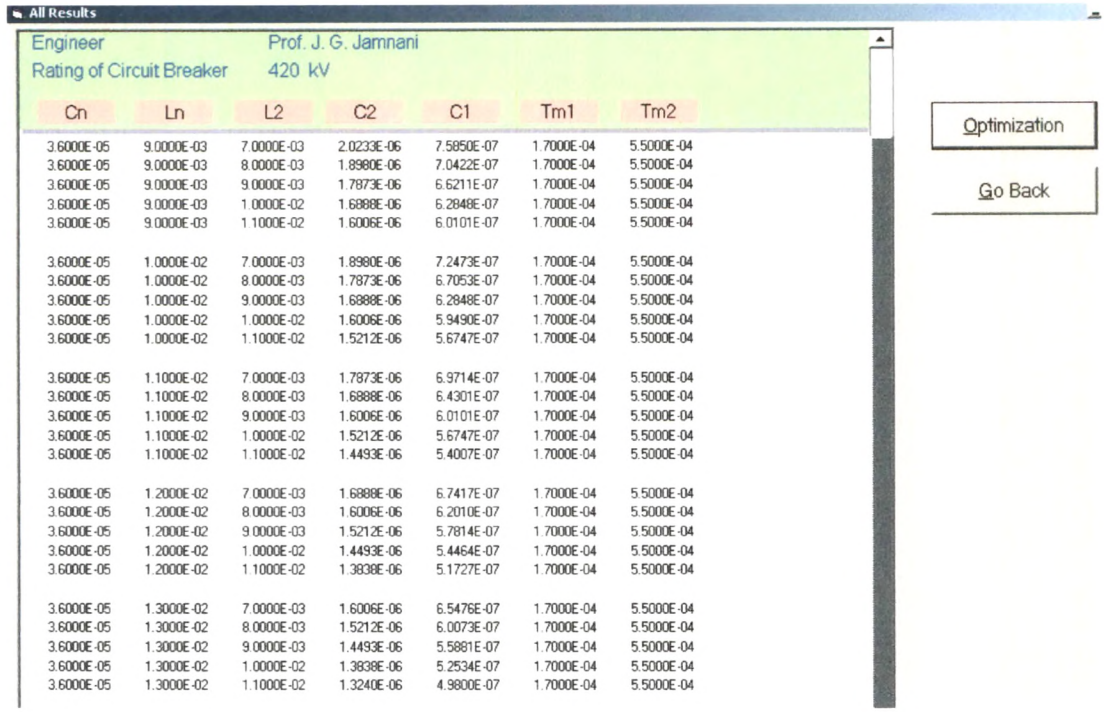
(C) Finding all possible and optimized circuit components for desired frequencies fn_1 and fn_2 (tm_1 and tm_2)

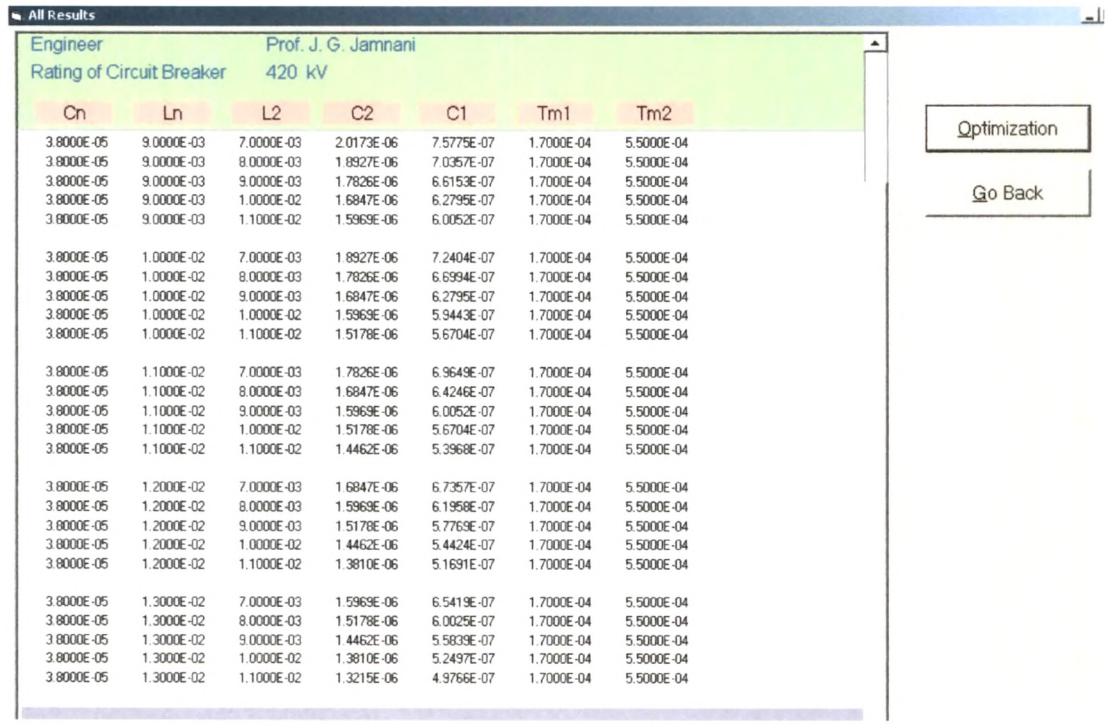
- Rating of circuit-breaker: 420kV
- Type of test duty: Short line fault
- TRV envelope: 4-parameters TRV envelope defined by IEC standards shown in Fig.3.9, case-I

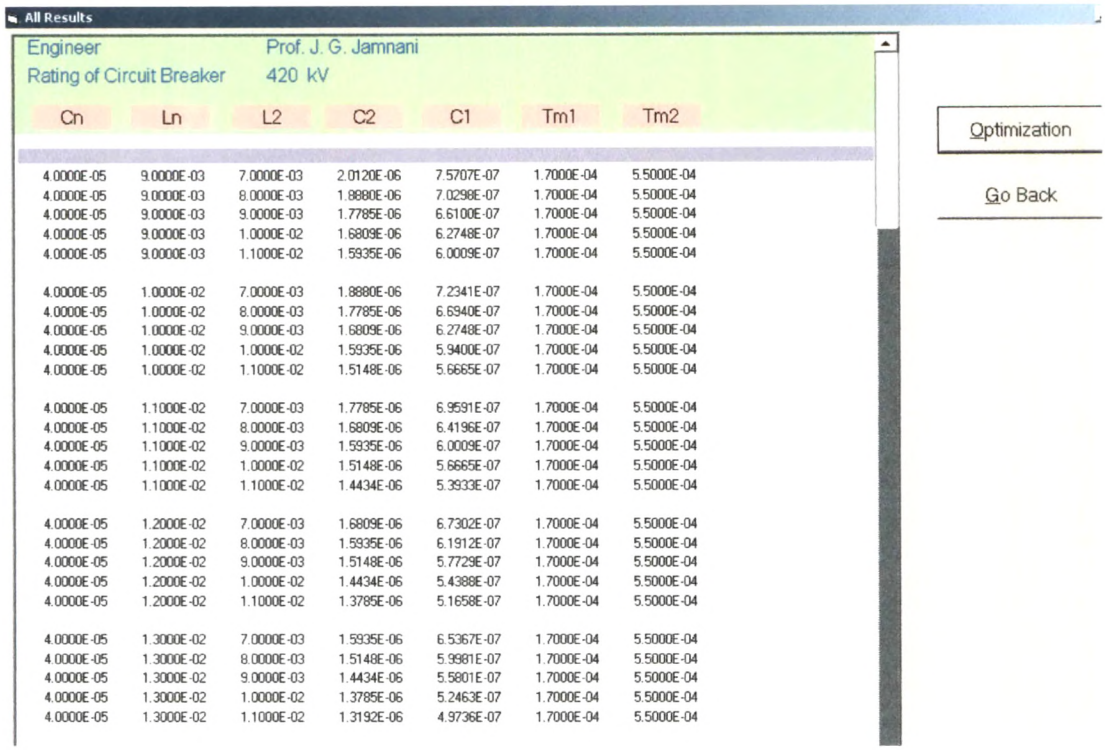


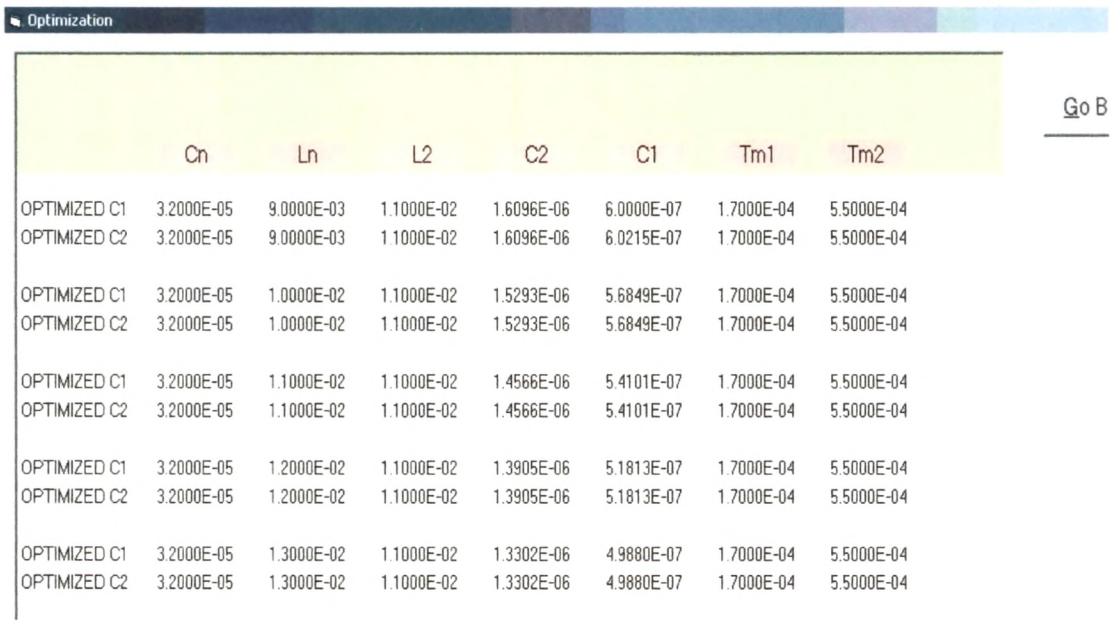

All Results
Engineer
Prof. J. G. Jamnani
Rating of Circuit Breaker
420 kV
Cn Ln L2 C2 C1 Tm1 Tm2
3.2000E-05 9.0000E-03 7.0000E-03 2.0376E-06 7.6028E-07 1.7000E-04 5.5000E-04
3.2000E-05 9.0000E-03 8.0000E-03 1.9106E-06 7.0577E-07 1.7000E-04 5.5000E-04
3.2000E-05 9.0000E-03 9.0000E-03 1.7985E-06 6.6348E-07 1.7000E-04 5.5000E-04
3.2000E-05 9.0000E-03 1.0000E-02 1.6988E-06 6.2972E-07 1.7000E-04 5.5000E-04
3.2000E-05 9.0000E-03 1.1000E-02 1.6096E-06 6.0215E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.0000E-02 7.0000E-03 1.9106E-06 7.2636E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.0000E-02 8.0000E-03 1.7985E-06 6.7194E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.0000E-02 9.0000E-03 1.6988E-06 6.2972E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.0000E-02 1.0000E-02 1.6096E-06 5.9602E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.0000E-02 1.1000E-02 1.5293E-06 5.6849E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.1000E-02 7.0000E-03 1.7985E-06 6.9866E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.1000E-02 8.0000E-03 1.6988E-06 6.4431E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.1000E-02 9.0000E-03 1.6096E-06 6.0215E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.1000E-02 1.0000E-02 1.5293E-06 5.6849E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.1000E-02 1.1000E-02 1.4566E-06 5.4101E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.2000E-02 7.0000E-03 1.6988E-06 6.7561E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.2000E-02 8.0000E-03 1.6096E-06 6.2132E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.2000E-02 9.0000E-03 1.5293E-06 5.7920E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.2000E-02 1.0000E-02 1.4566E-06 5.4559E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.2000E-02 1.1000E-02 1.3905E-06 5.1813E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.3000E-02 7.0000E-03 1.6096E-06 6.5612E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.3000E-02 8.0000E-03 1.5293E-06 6.0188E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.3000E-02 9.0000E-03 1.4566E-06 5.5981E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.3000E-02 1.0000E-02 1.3905E-06 5.2623E-07 1.7000E-04 5.5000E-04
3.2000E-05 1.3000E-02 1.1000E-02 1.3302E-06 4.9880E-07 1.7000E-04 5.5000E-04
Optimization
Go Back


All Results
Engineer
Prof. J. G. Jamnani
Rating of Circuit Breaker
420 kV
Cn Ln L2 C2 C1 Tm1 Tm2
3.4000E-05 9.0000E-03 7.0000E-03 2.0300E-06 7.5934E-07 1.7000E-04 5.5000E-04
3.4000E-05 9.0000E-03 8.0000E-03 1.9039E-06 7.0495E-07 1.7000E-04 5.5000E-04
3.4000E-05 9.0000E-03 9.0000E-03 1.7925E-06 6.6276E-07 1.7000E-04 5.5000E-04
3.4000E-05 9.0000E-03 1.0000E-02 1.6935E-06 6.2907E-07 1.7000E-04 5.5000E-04
3.4000E-05 9.0000E-03 1.1000E-02 1.6048E-06 6.0155E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.0000E-02 7.0000E-03 1.9039E-06 7.2550E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.0000E-02 8.0000E-03 1.7925E-06 6.7120E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.0000E-02 9.0000E-03 1.6935E-06 6.2907E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.0000E-02 1.0000E-02 1.6048E-06 5.9543E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.0000E-02 1.1000E-02 1.5250E-06 5.6795E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.1000E-02 7.0000E-03 1.7925E-06 6.9786E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.1000E-02 8.0000E-03 1.6935E-06 6.4362E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.1000E-02 9.0000E-03 1.6048E-06 6.0155E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.1000E-02 1.0000E-02 1.5250E-06 5.6795E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.1000E-02 1.1000E-02 1.4527E-06 5.4051E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.2000E-02 7.0000E-03 1.6935E-06 6.7485E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.2000E-02 8.0000E-03 1.6048E-06 6.2067E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.2000E-02 9.0000E-03 1.5250E-06 5.7864E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.2000E-02 1.0000E-02 1.4527E-06 5.4509E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.2000E-02 1.1000E-02 1.3870E-06 5.1768E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.3000E-02 7.0000E-03 1.6048E-06 6.5540E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.3000E-02 8.0000E-03 1.5250E-06 6.0128E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.3000E-02 9.0000E-03 1.4527E-06 5.5928E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.3000E-02 1.0000E-02 1.3870E-06 5.2576E-07 1.7000E-04 5.5000E-04
3.4000E-05 1.3000E-02 1.1000E-02 1.3269E-06 4.9838E-07 1.7000E-04 5.5000E-04
Optimization
Go Back


All Results
Engineer
Prof. J. G. Jamnani
Rating of Circuit Breaker
420 kV
Cn Ln L2 C2 C1 Tm1 Tm2
3.6000E-05 9.0000E-03 7.0000E-03 2.0233E-06 7.5850E-07 1.7000E-04 5.5000E-04
3.6000E-05 9.0000E-03 8.0000E-03 1.8980E-06 7.0422E-07 1.7000E-04 5.5000E-04
3.6000E-05 9.0000E-03 9.0000E-03 1.7873E-06 6.6211E-07 1.7000E-04 5.5000E-04
3.6000E-05 9.0000E-03 1.0000E-02 1.6888E-06 6.2848E-07 1.7000E-04 5.5000E-04
3.6000E-05 9.0000E-03 1.1000E-02 1.6006E-06 6.0101E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.0000E-02 7.0000E-03 1.8980E-06 7.2473E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.0000E-02 8.0000E-03 1.7873E-06 6.7053E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.0000E-02 9.0000E-03 1.6888E-06 6.2848E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.0000E-02 1.0000E-02 1.6006E-06 5.9490E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.0000E-02 1.1000E-02 1.5212E-06 5.6747E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.1000E-02 7.0000E-03 1.7873E-06 6.9714E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.1000E-02 8.0000E-03 1.6888E-06 6.4301E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.1000E-02 9.0000E-03 1.6006E-06 6.0101E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.1000E-02 1.0000E-02 1.5212E-06 5.6747E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.1000E-02 1.1000E-02 1.4493E-06 5.4007E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.2000E-02 7.0000E-03 1.6888E-06 6.7417E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.2000E-02 8.0000E-03 1.6006E-06 6.2010E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.2000E-02 9.0000E-03 1.5212E-06 5.7814E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.2000E-02 1.0000E-02 1.4493E-06 5.4464E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.2000E-02 1.1000E-02 1.3838E-06 5.1727E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.3000E-02 7.0000E-03 1.6006E-06 6.5476E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.3000E-02 8.0000E-03 1.5212E-06 6.0073E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.3000E-02 9.0000E-03 1.4493E-06 5.5881E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.3000E-02 1.0000E-02 1.3838E-06 5.2534E-07 1.7000E-04 5.5000E-04
3.6000E-05 1.3000E-02 1.1000E-02 1.3240E-06 4.9800E-07 1.7000E-04 5.5000E-04
Optimization
Go Back


All Results
Engineer
Prof. J. G. Jamnani
Rating of Circuit Breaker
420 kV
Cn Ln L2 C2 C1 Tm1 Tm2
3.8000E-05 9.0000E-03 7.0000E-03 2.0173E-06 7.5775E-07 1.7000E-04 5.5000E-04
3.8000E-05 9.0000E-03 8.0000E-03 1.8927E-06 7.0357E-07 1.7000E-04 5.5000E-04
3.8000E-05 9.0000E-03 9.0000E-03 1.7826E-06 6.6153E-07 1.7000E-04 5.5000E-04
3.8000E-05 9.0000E-03 1.0000E-02 1.6847E-06 6.2795E-07 1.7000E-04 5.5000E-04
3.8000E-05 9.0000E-03 1.1000E-02 1.5969E-06 6.0052E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.0000E-02 7.0000E-03 1.8927E-06 7.2404E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.0000E-02 8.0000E-03 1.7826E-06 6.6994E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.0000E-02 9.0000E-03 1.6847E-06 6.2795E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.0000E-02 1.0000E-02 1.5969E-06 5.9443E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.0000E-02 1.1000E-02 1.5178E-06 5.6704E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.1000E-02 7.0000E-03 1.7826E-06 6.9649E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.1000E-02 8.0000E-03 1.6847E-06 6.4246E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.1000E-02 9.0000E-03 1.5969E-06 6.0052E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.1000E-02 1.0000E-02 1.5178E-06 5.6704E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.1000E-02 1.1000E-02 1.4462E-06 5.3968E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.2000E-02 7.0000E-03 1.6847E-06 6.7357E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.2000E-02 8.0000E-03 1.5969E-06 6.1958E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.2000E-02 9.0000E-03 1.5178E-06 5.7769E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.2000E-02 1.0000E-02 1.4462E-06 5.4424E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.2000E-02 1.1000E-02 1.3810E-06 5.1691E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.3000E-02 7.0000E-03 1.5969E-06 6.5419E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.3000E-02 8.0000E-03 1.5178E-06 6.0025E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.3000E-02 9.0000E-03 1.4462E-06 5.5839E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.3000E-02 1.0000E-02 1.3810E-06 5.2497E-07 1.7000E-04 5.5000E-04
3.8000E-05 1.3000E-02 1.1000E-02 1.3215E-06 4.9766E-07 1.7000E-04 5.5000E-04
Optimization
Go Back


All Results
Engineer
Prof. J. G. Jamnani
Rating of Circuit Breaker
420 kV
Cn Ln L2 C2 C1 Tm1 Tm2
4.0000E-05 9.0000E-03 7.0000E-03 2.0120E-06 7.5707E-07 1.7000E-04 5.5000E-04
4.0000E-05 9.0000E-03 8.0000E-03 1.8880E-06 7.0298E-07 1.7000E-04 5.5000E-04
4.0000E-05 9.0000E-03 9.0000E-03 1.7785E-06 6.6100E-07 1.7000E-04 5.5000E-04
4.0000E-05 9.0000E-03 1.0000E-02 1.6809E-06 6.2748E-07 1.7000E-04 5.5000E-04
4.0000E-05 9.0000E-03 1.1000E-02 1.5935E-06 6.0009E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.0000E-02 7.0000E-03 1.8880E-06 7.2341E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.0000E-02 8.0000E-03 1.7785E-06 6.6940E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.0000E-02 9.0000E-03 1.6809E-06 6.2748E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.0000E-02 1.0000E-02 1.5935E-06 5.9400E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.0000E-02 1.1000E-02 1.5148E-06 5.6665E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.1000E-02 7.0000E-03 1.7785E-06 6.9591E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.1000E-02 8.0000E-03 1.6809E-06 6.4196E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.1000E-02 9.0000E-03 1.5935E-06 6.0009E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.1000E-02 1.0000E-02 1.5148E-06 5.6665E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.1000E-02 1.1000E-02 1.4434E-06 5.3933E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.2000E-02 7.0000E-03 1.6809E-06 6.7302E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.2000E-02 8.0000E-03 1.5935E-06 6.1912E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.2000E-02 9.0000E-03 1.5148E-06 5.7729E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.2000E-02 1.0000E-02 1.4434E-06 5.4388E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.2000E-02 1.1000E-02 1.3785E-06 5.1658E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.3000E-02 7.0000E-03 1.5935E-06 6.5367E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.3000E-02 8.0000E-03 1.5148E-06 5.9981E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.3000E-02 9.0000E-03 1.4434E-06 5.5801E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.3000E-02 1.0000E-02 1.3785E-06 5.2463E-07 1.7000E-04 5.5000E-04
4.0000E-05 1.3000E-02 1.1000E-02 1.3192E-06 4.9736E-07 1.7000E-04 5.5000E-04
Optimization
Go Back


Optimization
Cn Ln L2 C2 C1 Tm1 Tm2
OPTIMIZED C1 3.2000E-05 9.0000E-03 1.1000E-02 1.6096E-06 6.0000E-07 1.7000E-04 5.5000E-04
OPTIMIZED C2 3.2000E-05 9.0000E-03 1.1000E-02 1.6096E-06 6.0215E-07 1.7000E-04 5.5000E-04
OPTIMIZED C1 3.2000E-05 1.0000E-02 1.1000E-02 1.5293E-06 5.6849E-07 1.7000E-04 5.5000E-04
OPTIMIZED C2 3.2000E-05 1.0000E-02 1.1000E-02 1.5293E-06 5.6849E-07 1.7000E-04 5.5000E-04
OPTIMIZED C1 3.2000E-05 1.1000E-02 1.1000E-02 1.4566E-06 5.4101E-07 1.7000E-04 5.5000E-04
OPTIMIZED C2 3.2000E-05 1.1000E-02 1.1000E-02 1.4566E-06 5.4101E-07 1.7000E-04 5.5000E-04
OPTIMIZED C1 3.2000E-05 1.2000E-02 1.1000E-02 1.3905E-06 5.1813E-07 1.7000E-04 5.5000E-04
OPTIMIZED C2 3.2000E-05 1.2000E-02 1.1000E-02 1.3905E-06 5.1813E-07 1.7000E-04 5.5000E-04
OPTIMIZED C1 3.2000E-05 1.3000E-02 1.1000E-02 1.3302E-06 4.9880E-07 1.7000E-04 5.5000E-04
OPTIMIZED C2 3.2000E-05 1.3000E-02 1.1000E-02 1.3302E-06 4.9880E-07 1.7000E-04 5.5000E-04
Go B

The suitable and optimized circuit components obtained are as follows:

Rating of CB	Circuit components	Short line fault Test Duty
420kV		As per case-I
	Capacitor Banks	
	Main Capacitor Bank: C_n	32 μF
	TRV Capacitor Banks: C_1	0.5 μF
	C_2	1.5 μF
	Reactors : L_n	13 mH
	L_2	11 mH

5.5 Conclusion

The parameters of TRV defined by IEC standards are quite impossible to analytically link with the values of the components of the test circuit. So computer aided design of synthetic testing circuits (TRV shaping circuits) is first necessary in order to determine the parameters of the TRV corresponding to a given test circuit.

Also, as per IEC 62271-100, the rated characteristics of a circuit breaker include rated transient recovery voltage for terminal fault as well as short line fault condition.

The circuit-breaker should be capable of performing following switching duties:

(i) Interruption of terminal faults

(ii) Interruption of short line faults

The analysis and mathematical modeling of 4-Parameters TRV parallel current injection method synthetic test circuit is done.

In order to find circuit components and to optimize the values of capacitance of capacitor banks for the desired frequencies of a particular rating of circuit-breakers, the program/software has been developed by using MATLAB. The program is also developed with the help of VISUAL Basic 6 software to find all possible combinations of the circuit components for the desired frequencies of a particular rating of circuit-breakers. This software is user friendly and the speed is very fast.

The developed program/softwares are tested for finding all possible and optimized circuit components to test 420kV rating circuit-breakers for terminal as well as short-line fault test duty condition according to IEC standards. It is seen that the circuit components obtained for testing 420kV rating circuit-breakers by using both the softwares, developed in MATLAB as well as Visual Basic 6 are the same.