

Line Surge Arrester Benefit Calculator User's Manual

Introduction

The Line Surge Arrester Benefit calculator combines the power of Excel and OpenEtran to provide a tool that quickly and accurately offers the user an idea of the benefits of applying surge arresters on either transmission or distribution lines.

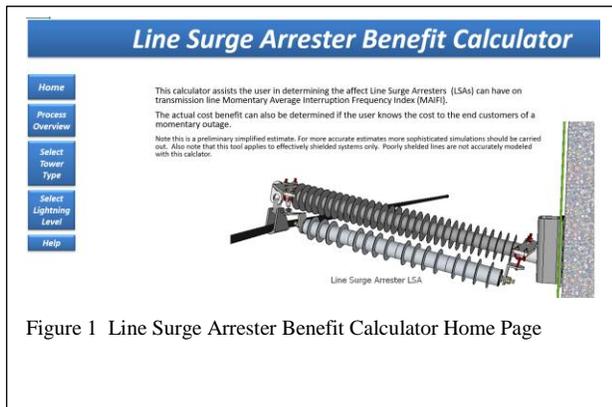


Figure 1 Line Surge Arrester Benefit Calculator Home Page

To use this tool, the user must have MS Excel installed on their computer, two files located in any folder. The executable program “OpenETran.exe” only needs to be located in the same folder as the Excel file “LSA Benefit Calculator Beta1.0.xlsm” The user never directly runs OpenEtran.exe, it is called from within the Excel program.

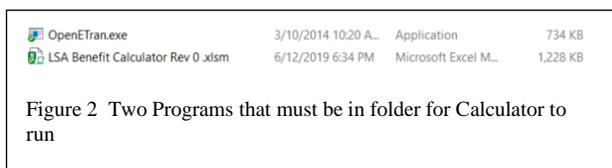


Figure 2 Two Programs that must be in folder for Calculator to run

To use the tool, open the LSA Calculator using Excel and set up the parameters of the system to be analyzed.

There are three basic parts to the calculator,

1. Input system electrical and physical parameters and run the program to determine the lightning current level (Critical Current) that will cause a backflash on the system. OpenEtran is the engine that determines this current level.

2. Based on the critical current of the system, the outage rate is calculated based on formula in IEEE 1410 and 1243.

The outage rate is shown for scenarios with and without arresters. This allows the user to see the benefit of line surge arresters on the system.

3. Based on the outage rate, cost of an outage, time value of investments, the financial benefits are calculated and displayed to the user.

OpenETran: An Open-Source Electromagnetic Transients Program

During the period from 1990 through 2002, EPRI funded the development of a Lightning Protection Design Workstation (LPDW), which was used by many utilities to assess the lightning performance of distribution lines. Since about 2002, this program has not been available. EPRI decided to release the simulation kernel of LPDW under the name OpenETran, with an open-source license (GPL v3), so it may be incorporated into IEEE Flash and other projects.

OpenETran can presently simulate multi-conductor power lines, insulators, surge arresters, non-linear grounds, and lightning strokes. It efficiently calculates energy and charge duty on surge arresters, and iterates to find the critical lightning current causing flashover on one or more phases. It is also suitable for use in substation insulation coordination. Capacitor switching, TRV, and other applications may be added.

EPRI originally had permission to use code from the Numerical Recipes book in LPDW. These routines have been removed in favor of the GNU Scientific Library (GSL), which also uses the GPL v3 license. As a result, the

OpenETran package can be freely used and modified, but not commercialized.

There are few error checks on the input data, and no checks on whether the data is reasonable. It may be possible to "crash" the console-mode version of this program with inappropriate input data. However, a spreadsheet interface has been provided for more convenient input, plotting, and critical current estimates.

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LSA Benefit Calculator Details

The basic assumptions methods used are as follows:

1. This calculator is a high level view of the system. The results will vary some from a detailed analysis, but not significantly.
2. All the towers footing resistance is constant along the line. Segments of the line can be analyzed separately if this is an issue)

3. All lines analyzed are effectively shielded. This means that lines with conductor significantly unshielded as in no shield or one shield on an H-Frame cannot be analyzed in this calculator. (This may be changed in the near future)
4. Tower type and impedance is not a significant factor in this analysis.
5. The ground resistance is given in as measured by 60 Hz and this value is used to determine the transient ground resistance taking soil ionization into account. E₀ 400000 and Rho of 250
6. The radius of the conductors are adjusted according to the system voltage.

System Voltages (kV)	Shield Diameter in Inches	Conductor Diameter in (in)
3-36	0.20	0.5
37-50	0.20	0.6
51-100	0.20	0.7
101-200	0.20	0.806
201-301	0.20	1.3
302-415	0.20	1.8
415-700	0.20	2.5

7. The max system voltage this calculator can work is 550kV p-p
8. The arrester 10kA discharge voltage is calculated based on the system voltage. The formula is 2 x Phase-Phase voltage. For example, a 115kV line will have an arrester with a 230kV 10kA discharge voltage.
9. The phase voltage is set at the opposite polarity to the surge with the peak voltage applied to the middle phase on vertical systems. This gives the average critical current instead of the max or min if the peak voltage is on the top or bottom phase. For horizontal construction, the peak negative AC voltage is applied to the center phase. For all configurations, the nonpeak phases are 33% and 66% of the peak.

10. The insulators are given by their CFO, not length. The model used for the insulators is the LPM model with Coefficients E_0 of $5.35e5$ th and K_L of $7.79e-7$.

The leader progression model is based on the based on the physics of flashover [11], whereas the destructive effect method is more of a curve-fitting approach. The leader progression model generally gives more accurate results.

Only the leader propagation time is modeled; the corona inception time and streamer propagation time are ignored. The program keeps track of the remaining unbridged gap length in both positive and negative directions. The leader propagation velocity is:

$$dx/dt = Ke(t) \left[\frac{e(t)}{x} - E_0 \right]$$

where K = propagation constant
 E_0 = breakdown gradient
 x = unbridged gap length
 $e(t)$ = voltage across gap

The unbridged gap length, x , starts at a value given by CFO / E_0 . Two instances of this equation are integrated at each time step, one for positive $e(t)$ and one for negative $e(t)$. Only one leader can grow at each time step, and only if $e(t)$ exceeds E_0 .

Running the LSA Benefit Calculator

To run the program, open the Excel prog LSA Benefit Calculator .xslm. You may need to allow the program to open and use Macros that embedded in the routine.

1. Typically the first input should be the Ground Flash Density of the lightning in the location of study. This is selected on the Select Lightning Level page.

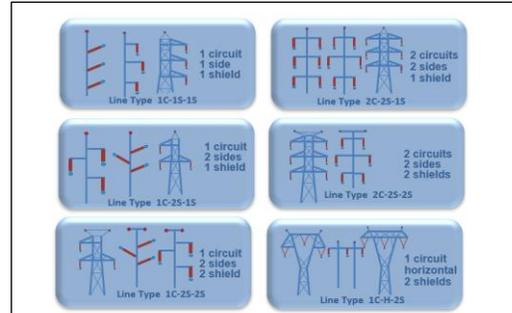


Figure 3 The Line Configuration Options

2. Select the basic configuration of the line to be studied. The program has all shielded lines grouped into 6 categories.

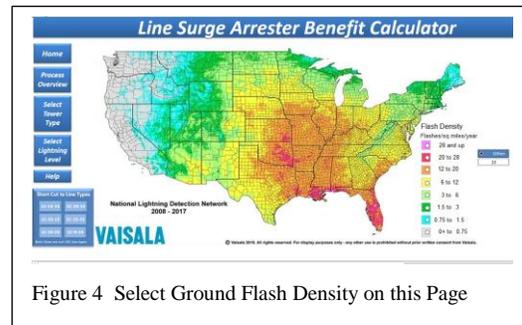


Figure 4 Select Ground Flash Density on this Page

In this example the single circuit two sided on shield tower is chosen.

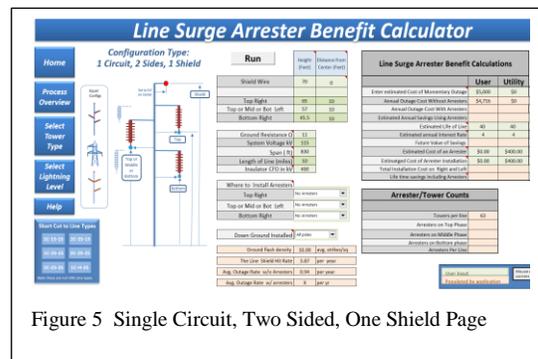


Figure 5 Single Circuit, Two Sided, One Shield Page

On this page you will run the rest of the study. Input the electrical and physical parameters and press the run button. This will calculate the outage rate of the line without arresters and if you had chosen arresters, it will also show the outage rate with the selected arresters.

Run

	Height (Feet)	Distance from Center (Feet)
Shield Wire	70	0
Top Right	65	10
Top or Mid or Bot Left	57	10
Bottom Right	45.5	10

Ground Resistance Ω	11
System Voltage kV	115
Span (ft)	830
Length of Line (miles)	10
Insulator CFO in kV	400

Where to Install Arresters

Top Right	Every Tower
Top or Mid or Bot Left	No Arresters
Bottom Right	Every Tower

Down Ground Installed

Ground flash density	10.00	avg. strikes/sq
The Line Shield Hit Rate	11.06	per year
Avg. Outage Rate w/o Arresters	2.69	per year
Avg. Outage Rate w/ arresters	1.75	per yr

Figure 6 Calculator section that takes input and shows the outage rate.

This part of the calculator also shows the expected hit rate on the shield based on the tower dimensions and the ground flash density.

You can experiment with different arrester locations and press the run button for each case.

Once you have completed the outage rate calculations you can move on to the Financial Benefits. On the right side of the same page.

Line Surge Arrester Benefit Calculations			
	User	Utility	
Enter estimated Cost of Momentary Outage	\$5,000	\$0	USD/Outage
Annual Outage Cost Without Arresters	\$13,473	\$0	USD/Year
Annual Outage Cost With Arresters	\$8,737	\$0	USD/Year
Estimated Annual Savings Using Arresters	\$4,736	\$0	USD/Year
Estimated Life of Line	40	40	Years
Estimated annual Interest Rate	4	4	%
Future Value of Savings	\$450,011	\$0	USD
Estimated Cost of an Arrester	\$0.00	\$400.00	USD
Estimated Cost of Arrester Installation	\$0.00	\$400.00	USD
Total Installation Cost on Right and Left	\$0	\$100,800	USD/One time
Life time savings including Arresters	\$450,011	-\$100,800	USD/life of line

Figure 7 This section shows the financial benefits of arresters.

Again you can run as many scenarios as you wish but you must press the run button between each scenario to get the proper results.

To save your work, you can just hit save on the Excel program header. If you wish to give the scenario a name, you can save the entire program with that name for example

LSA BC Hudson Line North and it will save the calculator under that name.

Other Files

Note that when the calculator runs, it creates three new files in the location where the prog is executed. Test.dat, Test.out, and Test.cvs. These files do not need to be saved, they are working files that will be created again if deleted.

Enjoy.....