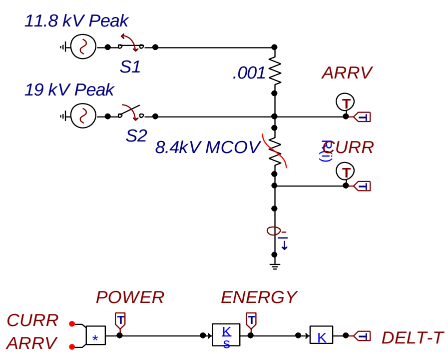
ArresterWorks

Modeling Temperature Rise in Arresters from Energy Absorption



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Topics

Introduction

There are many occasions, from the application of arresters to design tests of arresters, where prior modeling and prediction of the final temperature of an arrester after an energy absorption event would be useful. I have been doing these calculation by hand or with excel for years but recently from within ATP Draw using TACS modules, my favorite arrester and transient modeling tool. This Arresterfacts will cover all the calculation methods mentioned above. Enjoy.

Definition

Specific Heat: The heat required to raise the temperature of a unit mass of a given substance by 1 °C.

Background

Arrester designers very often need to know how hot an arrester will become when exposed to high energy inputs. This is because arresters have a negative temperature coefficient, meaning the hotter they get the more they conduct, which in turn makes them hotter. This negative effect of energy is what often determines the final mass and configuration of an arresters design.
If you are applying arresters in series capacitor banks, SVC's, HVDC Converter stations, and many other special applications, it is very useful to know the arresters temperature rise after an energy input. Knowing the temperature rise helps determine the optimum number of arresters to use in parallel in these special apps.

The following treatise of this subject is for all surge arrester stakeholders that need at one point or another to predict the temperature rise of an arrester.

Required Material Characteristics

To calculate the temperature rise of any object several of it's characteristics must first be known. These are as follows:

1. **Mass** of the object (grams)
   If the mass is unknown, it can be calculated with:
   a. **Density** of the material in gm/CC
   b. **Volume** of the material
2. **Specific Heat** of the object (Joules/gram/^{o}C)
3. **Energy Absorbed** by the object (joules)

MOV Arrester and Disk Characteristics

1. **Mass**: this is a variable and refers to the mass of the zinc oxide disks only. A rough estimate can be determined from catalog data by comparing the weights of different MCOV ratings.
2. **Specific Heat**: For MOV material, a value of .55 can be used. This means it takes .55 joules to raise the temperature of 1 gram 1 °C. This value is nearly universal for MOV material.
3. **Energy Absorbed:** This is generally an unknown and needs to be calculated based on the voltage, current and duration of the surge or event. Best units are Joules
4. **Density:** Another nearly universal value for MOV disk density is 5.35gms/CC
5. **Volume:** This value refers only to the volume of the disk stack as a total. This value is different for every supplier of arresters and will need to come from them.

Mass-Energy-Specific Heat Relationship

The temperature rise from absorption of energy in an MOV is

$$\Delta T = \frac{Energy\ Adsorbed}{Mass \times Sp\ Heat} \qquad \text{Eq 1}$$

Where:

ΔT	= °C
Energy Absorbed	= Joules
Mass	= Mass of MOV material in grams

Sp Heat = .55joules/gram/°C

If the energy is not known, it can be calculated as

$$Energy=\int_0^{T1} rms\ current \times rms\ voltage \quad \text{Eq 2}$$

Where

Energy	= Joules absorbed
rms current	= through the arrester
rms voltage	= voltage across the arrester
T1	= duration of the energy input in seconds

Rough Hand Calculation

If the energy adsorption event is a typical 8/20 current surge, the rms value of the current is approximately .61 x peak current. The rms voltage is .85 x peak voltage and the duration of the surge is approximately 40 E-6. A rough estimate of the energy absorbed is

$$Energy=(.61\times peak\ I)\times(.85\times peak\ V)\times 40E-6 \quad \text{Eq 3}$$

If the energy event is a square wave, use the peak values of the current and voltage and time in seconds and the resulting energy is in joules.

Using Excel to Predict Energy and Delta T

If the voltage, current and time are available in an excel document, the energy and delta T can be very accurately be calculated. A sample of this method can be downloaded from ArresterWorks.com. This method uses the commonly accepted trapezoidal rule to solve the integral.

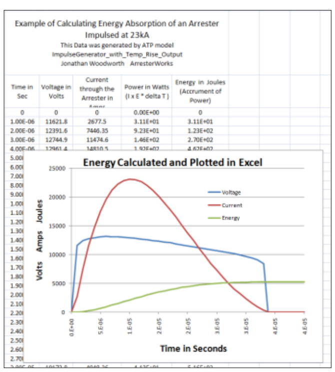

Figure 1 Excel Energy Calculator

Once the energy is determined for the event, then Equation 1 can be used to ascertain the temperature rise.

If the mass (grams) is not known, it is the product of the volume and density.

Using ATP and ATP Draw

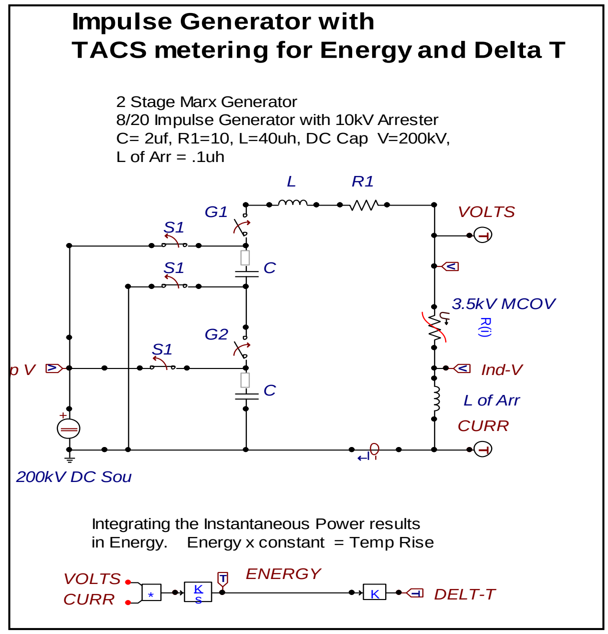

Figure 2 ATP Model of an Impulse Generator with TACS metering of Arrester

Any model can be used to generate a voltage and current through an arrester. Once a model is chosen the current and voltage signals can be used along with , TACS circuit couplers, probes, transfer functions, and Fortran statements to solve, equations 1 and 2 directly within ATP. For example if a simple Marx generator is used to generate a surge through an arrester it might look similar to Figure 2.

In Figure 3, the output of the above model is plotted in XYPlot. In this case variables VOLTS, CURR, and ENERGY are referenced to the left Y axis and DELT-T is referenced to the right Y axis. What this plot is telling us is that for a 23kA 8/20 current impulse, the 3.5kV MCOV arrester

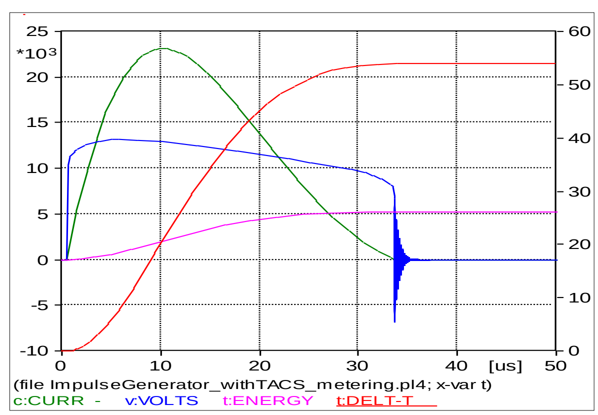

Figure 3 Plot of Temperature Rise from an Impulse Arrester Current, Voltage and Absorbed Energy on the left Y axis and Delta T in °C on the right Y axis

absorbs about 5000 joules and its temperature raises is 53 °C In this example the mass of the MOV material is 177 grams.

The TACS K/S integral function is used to derive the energy from the voltage and current probes which is then multiplied with a math function K to derive temperature.

The same method to determine temperature rise in an arrester can be used with energy input from a power frequency source. Fig 4 is a typical Temporary Overvoltage (TOV) which is used to test the TOV withstand capability of arresters. The

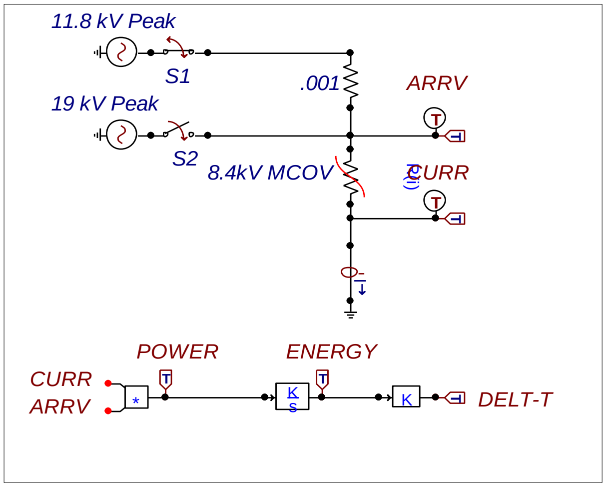

Figure 4: 60 Hz Overvoltage Stress of an arrester that generates a temperature rise.

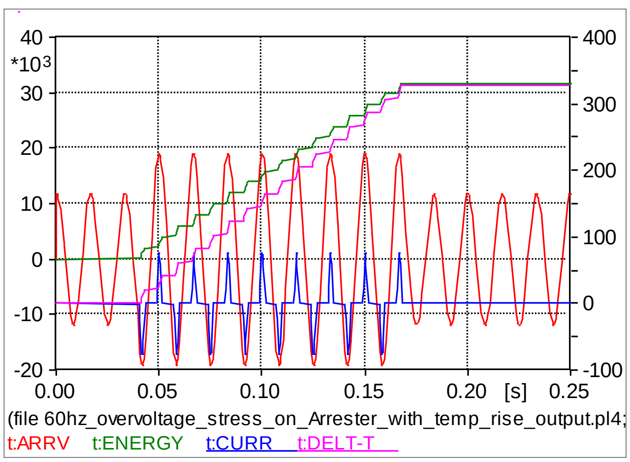

Figure 5: 60 Hz Overvoltage Stress of an arrester that generates a temperature rise. ARRV and ENERGY referenced to Left Y axis.

arrester is first energized at normal voltage levels, and then stressed for 8 cycles at a voltage 1.6 PU. This increase in voltage results in significant current flow through the arrester.

Using the same TACS probes as in the Impulse Model, the temperature rise can be directly calculated within ATP and Plotted using XYPlot as shown in Figure 5.

In Fig 5, the voltage (red) and the energy (green) are referenced to the left Y axis. This then indicates that for the overvoltage duration, the energy absorbed by the arrester is approximately 30kJ. This is typical for an arrester during an excessive overvoltage.

The current and temperature rise are shown on the right Y axis. From this plot, it can be seen that the temperature rise from 80 amps of conduction for 8 cycles is about 330 °C which would be expected for an 8.4kV MCOV arrester. In this case the arrester will most likely fail since this is a temperature significantly above typical maximum operating temperatures of arresters.

Summary

As it is shown in this ArresterFacts, the temperature rise of an arrester can be very accurately and simply modeled using ATP and TACS tools.

Further Study

To assist the users of ArresterFacts, the following resources are downloadable from ArresterWorks.com that are related to this ArresterFacts

1. ArresterFacts 030 Modeling Temperature Rise in Arresters from Energy Adsorption
2. ArresterFacts 028 Understanding Temporary Overvoltage Behavior of Arresters
3. ImpulseGenerator_with_Temp_Rise_output.acp
4. 60hz_overvoltage_stress_on_Arrester_with_temp _rise_output.acp
5. Arrester_Temperature_Rise_Calculator
6. Calculating_Energy_Using_Excel_and_Trapezoid al_Rule

About ArresterFacts