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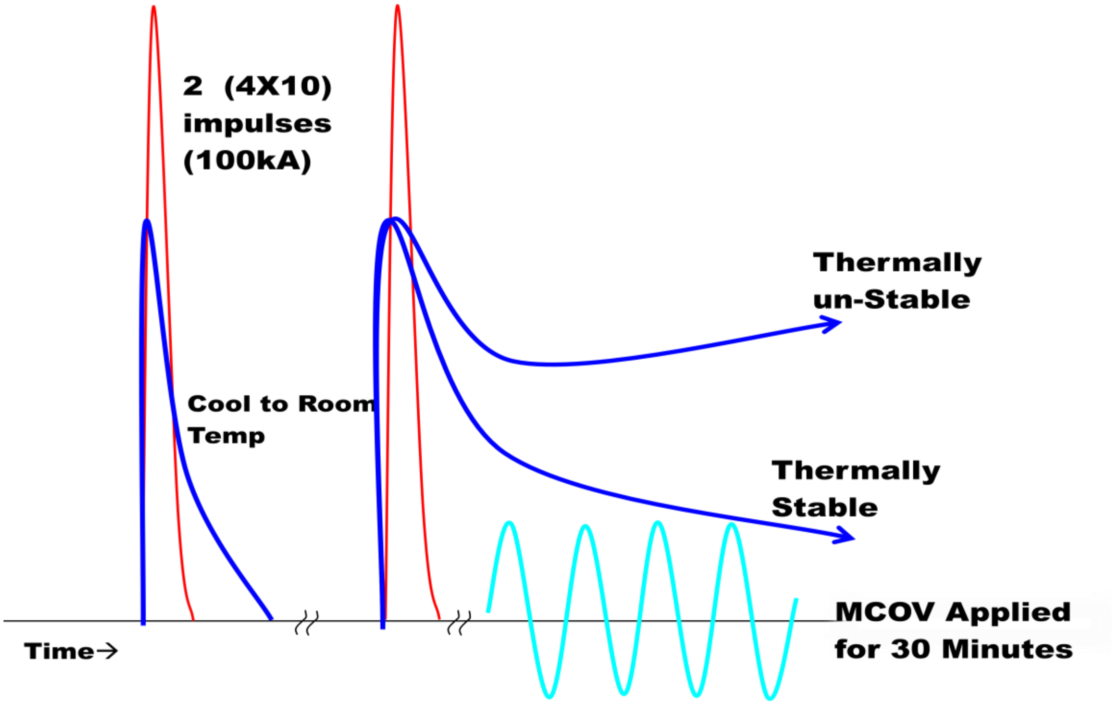
Understanding the Arrester Energy Handling Issue



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Introduction

Over the past two to three years, the arresters standards writers around the world have been actively trying to resolve the basic misunderstandings of surge arrester energy handling capacities. The most progressive resolution has come out of research at Darmstadt Technical University that is sponsored by CIGRE working group A3.17. At Darmstadt TU, Prof Volker Hinrichsen is leading a team that continues to produce results that are clarifying the issue. Members of A3.17 as well as members of IEC TC37 MT4 and IEEE SPD working group 3.3.11 are examining the research results and attempting to resolve the issue. Their plan is to publish guidance on the subject as well as a test standard that will resolve the issue once and for all. The following dissertation is my attempt to clarify and outline the issue after attending meetings from all the above mentioned expert groups.

The Issue

Engineers responsible for specifying arresters used on power systems often need to know how much energy an arrester can handle during normal operation. Unfortunately, no unified measurement of this characteristic has been set forth by the industry so it is not possible for users to compare arresters from various manufacturers.

The Many Dimensions of the Problem

<u>Surge Types</u>

The fundamental function of an arrester is to transfer accumulated charge on a power system to earth and at the same time limit the voltage stress on the protected insulation. During the process of the charge transfer, the arresters react to the charge and associated energy content based on the voltage and current waveshape and duration. Very fast charge transfers such as lightning affect the arrester differently than slow front, longer duration switching events.

<u>Energy Limits</u>

There are two types of energy overload limits and no accepted definition that differentiates them. The first limit is related to the temperature of the arrester where it cannot stably operate while energized. The second limit is related to the thermo-mechanical impulse withstand of the arrester. All electro-ceramic material has a limit where thermal mechanical failure or serious degradation may occur when exceeded.

<u>Voice of the Specifiers</u>

Those who specify arresters, typically specify energy handling capabilities in joules. Seldom is the duration of the surge specified making a realistic response to the specification impossible. See Table 1 for a summary of this issue.

<u>Measurement Methods</u>

Manufacturers have devised many ways to define and test energy handling capability. Some measure the energy in one pulse, some in three pulses; others do not define their method at all.

Unit of Measurement
There is little agreement in the industry as to whether charge (amp seconds), current (amps), or energy absorption (joules) should be the unit of measurement for durability. Each unit of measure has positive and negative attributes to consider.

Standards
Neither the IEC nor IEEE standards effectively address the subject of energy handling capability. High current tests, transmission line discharge tests, operating duty test, and the latest lightning discharge test all attempt to address the energy handling measurement , but fall short.

Conflicting Characteristics
If energy absorption is measured in joules, an arrester with a higher discharge voltage will have a higher energy rating, and this is in contradiction to seeking the better arrester. For a gapped MOV arrester that has significantly better (lower) discharge voltage, a joule energy rating is altogether inadequate.

Recent Progress

CIGRE working group A3.17 met two times in 2008 and reviewed recent progress on work being done at Darmstadt Technical University to resolve the issue. It appears that the Klaus Ringler Energy Handling Equation as published in a 1997 IEEE Transaction was reconfirmed however, with new surprising findings using the 200 µs lightning discharge impulse. Also for the first time publicly, impulse degradation was quantified using a change V_{ref} before and after energy input. From the discussion, clear definitions of the two well-known energy-handling characteristics began to emerge. Both of these definitions were described in a CIGRE paper presented in Brazil in September 2007. The two types of energy ratings discussed were Thermal Energy Absorption Limit and Single Impulse Energy Absorption Limit.

The Thermal Energy Absorption Limit is defined as the maximum level of energy injected into an arrester at which it can still cool back to its normal operating temperature while energized. This limit can be reached over the entire disk, or locally along preferential current paths inherent in MOV material. This characteristic is due to the negative thermal coefficient of ZnO

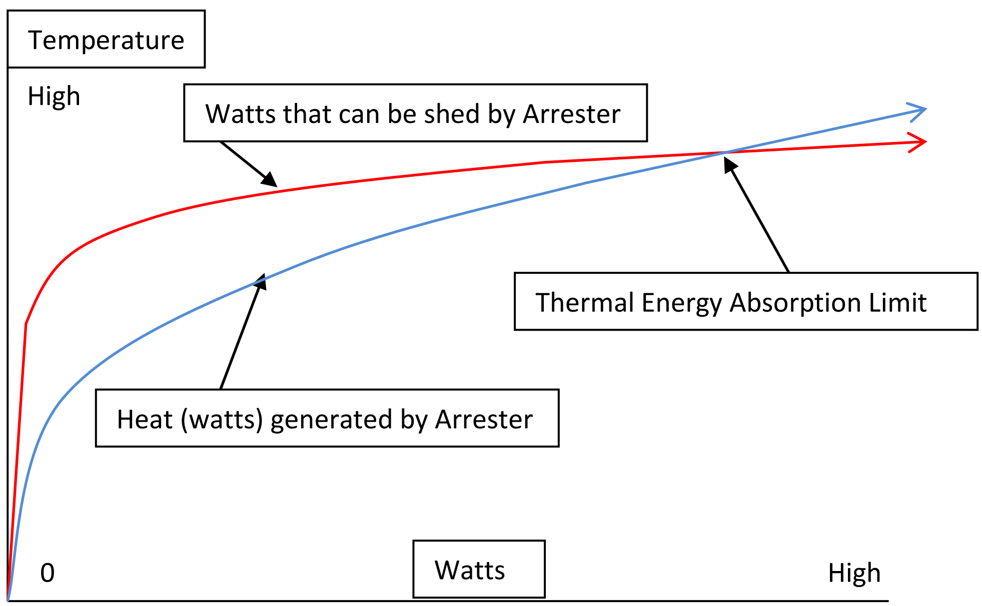

Figure 1: Arrester Thermal Stability Curve
When the ability of the arrester to dissipate or shed heat is exceeded by the heat being generated internally by the arrester, thermal stability is exceeded.

material in general. In other words, as the temperature of MOV material increases, so does its leakage current, this in turn generates more heat. At some point the ability of the material to create heat exceeds its ability to shed it off through conduction and radiation. Figure 1 shows this graphically.

The Single Impulse Energy Absorption Limit is the energy in joules (current density, or amp seconds) and duration of energy injection, required to damage an arrester permanently. The damage can be at a macroscopic level or a microscopic level. In either case it is measurable using Vref and/or physical fracture.

The Solution

These two characteristics discussed above need clear definitions and both need to be used to describe arrester energy handling capability, not just one or the other. Once the two-part definition is accepted, then the tests to measure these characteristics need to be developed. Along with the test to measure these characteristics, the unit of measure needs to be agreed upon. The industry needs to eradicate the joule rating from the solution of this energy handling issue.

Specifiers and Manufacturers Responsibility

To resolve the energy handling issue, specifiers will need to adopt new specification methods that provide more information about the energy handling needs and in particular it will need a new section that describes the energy injection duration. Manufacturers also need to adopt new specification procedures and not continue to respond to the joule-rating question when it is not correct. See Table 1 for more on this.

Looking Ahead

We will have two new definitions of energy handling, new test procedures (or modified old procedures) that relate to both types of energy ratings, and new specification procedures.

We will learn that a distribution arrester (Class 1 10kA arrester in the IEC world) needs to handle both types of energy input when it functions to clamp lightning surges. Not only must it not exceed its Single Impulse Energy Absorption Limit, but it must also not exceed its Thermal Energy Absorption Limit. The high current short duration test of the IEEE standard first stresses the Impulse Energy Absorption Limit of the arrester, then the Thermal Energy Absorption Limit. See Figure 2

We will learn that the energy handling

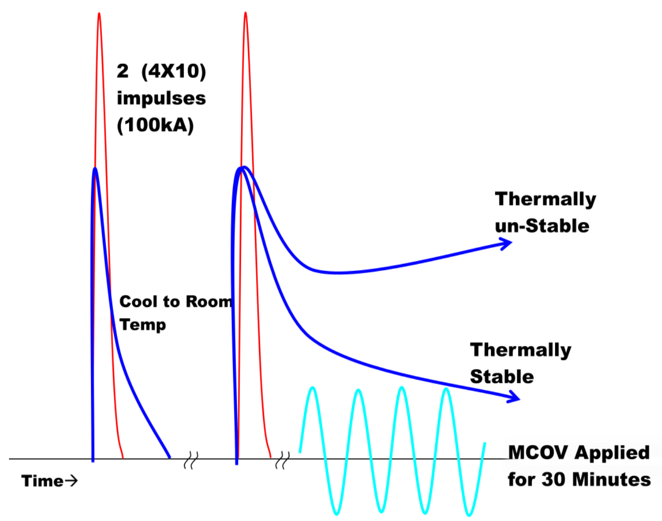

Figure 2: IEEE HCSD Test
The two High Current Impulses test the Impulse Energy Absorption Limit and the AC applied after the second impulse tests the thermal energy absorption limit.

capability of a transmission line arrester may need to be different than that of a station or distribution arrester. Currently in the IEC, there is a different test for each, and perhaps it should be that way in the IEEE standards too.

We will also learn that the proper way to quantify these two new limits of arrester energy handling limits, are with means that do not discriminate between equally good arrester designs as the joule rating does.

Table 1 Arrester Energy Handling Requirement Overview

Application	Typical Arrester for this application	Energy Handling Req.	Test to Verify	Issues	Comments
Distribution System Equipment	IEC - Class 1 (2.5, 5, 10kA) IEEE- Dist Class (Light, Normal, Heavy Duty)	Lightning (No Switching)	IEC- Operating Duty Test IEEE - High Current Short Duration Test	There is no defined energy capability measurement.	Cap banks and Reactors should be checked more closely
Distribution and Transmission Lines <230kV	IEC Class 1,2,3 IEEE - Dist, Inter and Station	Lightning	IEC- Operating Duty Test IEEE - High Current Short Duration Test and TLD Test	Since the switching surge energy level is so low, lightning duty is all that may be necessary.	Cap banks and Reactors should be checked more closely
	Externally Gapped Line Arrester (EGLA)	Lightning	IEC – Lightning Durability Test for systems >52kV IEEE - No Test	Test Standard IEC 60099-8 is forthcoming for this arrester	
Transmission Line >230kV	IEC- Class 2,3,4 IEEE- Station	Lightning and Switching	IEC- Operating Duty Test IEEE - High Current Short Duration Test and TLD Test	No defined energy capability measurement.	
	Externally Gapped Line Arrester (EGLA)	Lightning	IEC – Lightning Durability Test for systems >52kV IEEE - No Test	Test Standard IEC 60099-8 is forthcoming for this arrester	Cap banks and Reactors should be checked more closely
Distribution Feeders from Substations	IEC - Class 1 (2.5, 5, 10kA) IEEE- Dist Class (Light, Normal, Heavy Duty)	Lightning (No Switching)	IEC- Operating Duty Test IEEE - High Current Short Duration Test	There is no defined energy capability measurement.	Cap banks and Reactors should be checked more closely
Substation <230kV	IEC- Class 2,3,4	Lightning (No Switching)	IEC- Operating Duty Test IEEE - High Current Short Duration Test and TLD Test	No defined energy capability measurement.	
Substations >230kV	IEC – Class 3,4,5	Lightning and Switching	IEC- Operating Duty Test IEEE - High Current Short Duration Test and TLD Test	No defined energy capability measurement.	
Riser Pole or Terminal Poles <230kV	IEC- Class 1,2,3,4 IEEE- Dist, Inter, Station	Lightning (No Switching)	IEC- Operating Duty Test IEEE - High Current Short Duration Test and TLD Test	No defined energy capability measurement.	
FACTS Equipment	IEC- Class 2-5 IEEE – Station Plus Special Parallel column High Energy Devices	Lightning, Switching and Fault Current	IEC- Operating Duty Test plus 60143-2 IEEE - High Current Short Duration Test and TLD Test Plus IEEE 824	No Issues	

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- **VI Characteristics**
- **The Externally Gapped Arrester (EGLA)**
- **The Disconnector**
- **Understanding Mechanical Tests of Arresters**
- **What is a Lightning Arrester?**
- **The Switching Surge and Arresters**
- **The Lightning Surge and Arresters**

ArresterFacts Usage

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