Transient Recovery Voltages (TRVs) for High Voltage Circuit Breakers - Harmonization of IEC and IEEE Standards

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RECOMMENDED CHANGES

TO TRV REQUIREMENTS

IN IEC and ANSI/IEEE
HIGH VOLTAGE CIRCUIT BREAKER STANDARDS

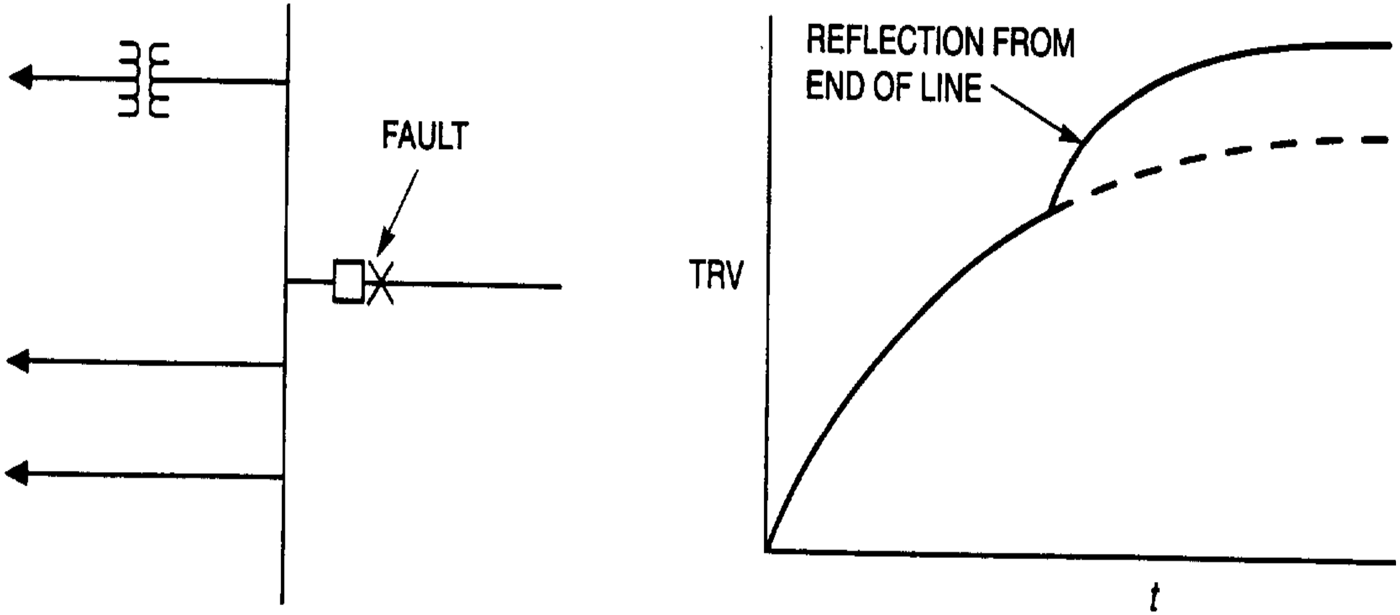
TO PROMOTE HARMONIZATION

The affected standards are

- **High Voltage Circuit Breaker Standards**

- **IEC 62271-100 (Formerly Publication 60056)**
- **IEEE C37.04, C37.06, C37.09, C37.010 and C37.011**

TRV for High-voltage Circuit Breakers



Exponential TRV characteristic

The system transient response to current interruption

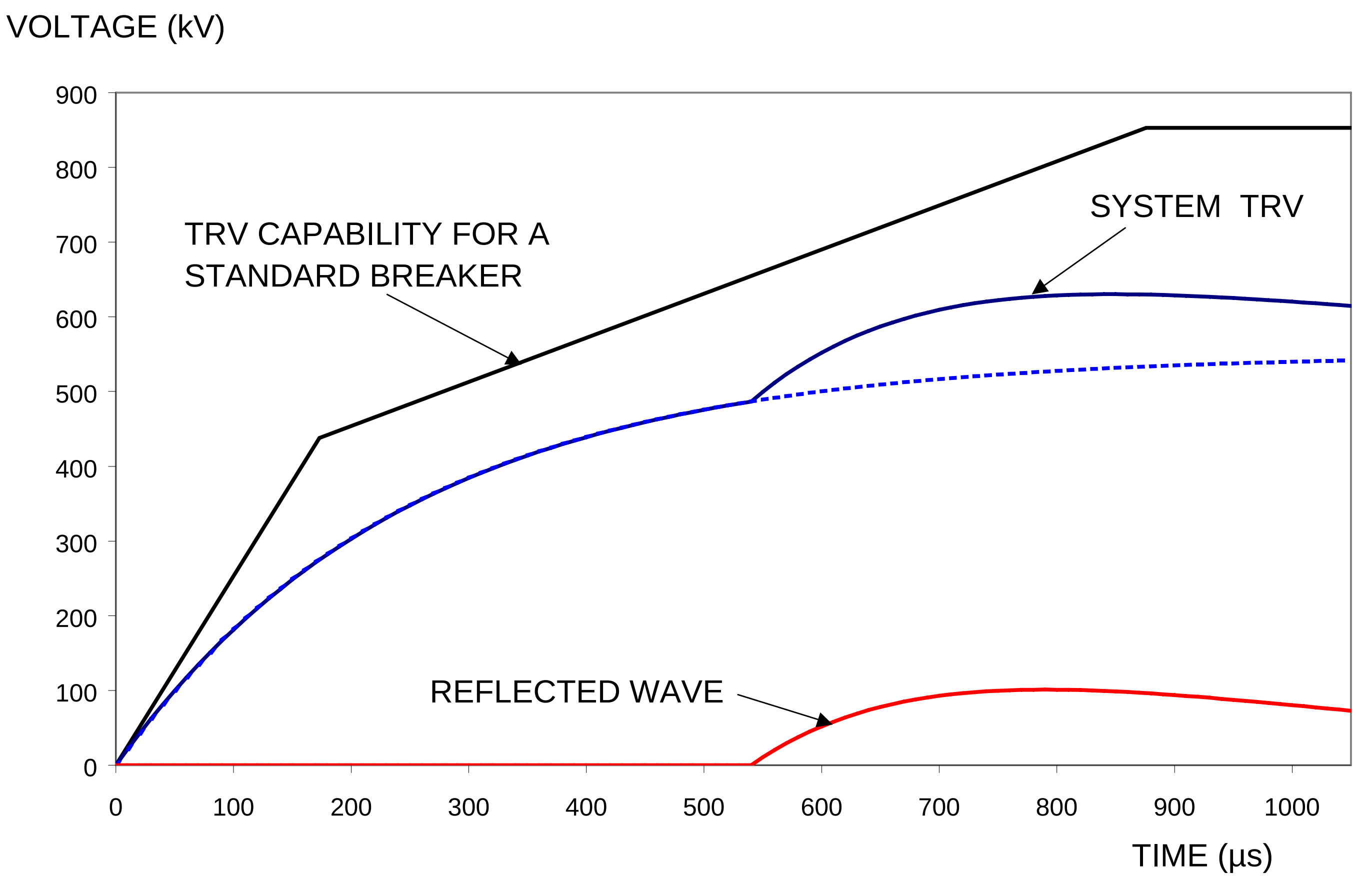
The exponential part is response to current ramp

The reflected part is the return of the modified exponential

Exponential-Cosine Wave

The reflected wave is very variable,

Distance to the shortest line and terminal impedances are variable

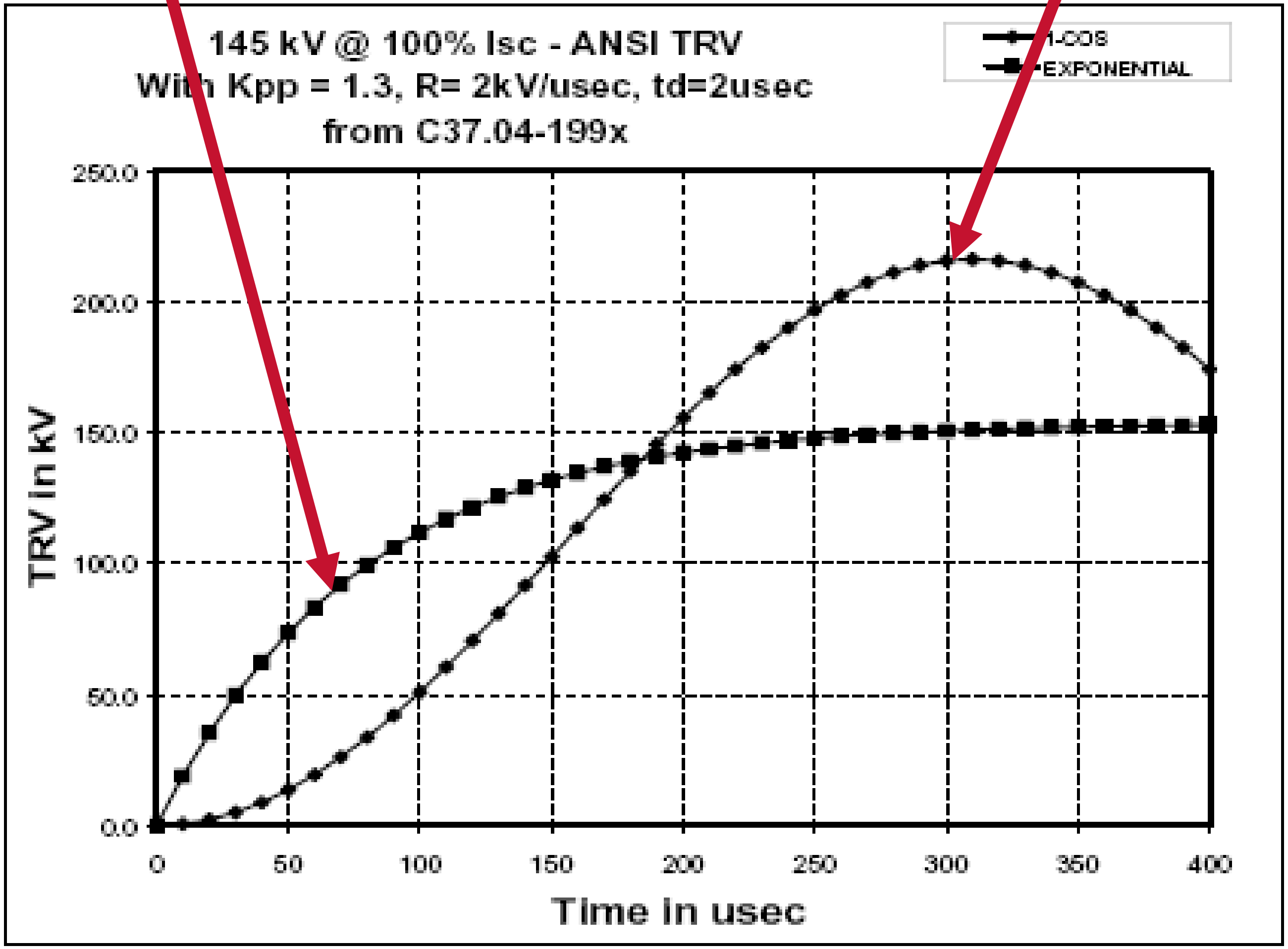


So the later part of the envelope is not really a 1-cosine

Exponential-Cosine Wave Chosen by IEEE in 1960's

The Exponential Initial Part

The 1-Cosine Later Part

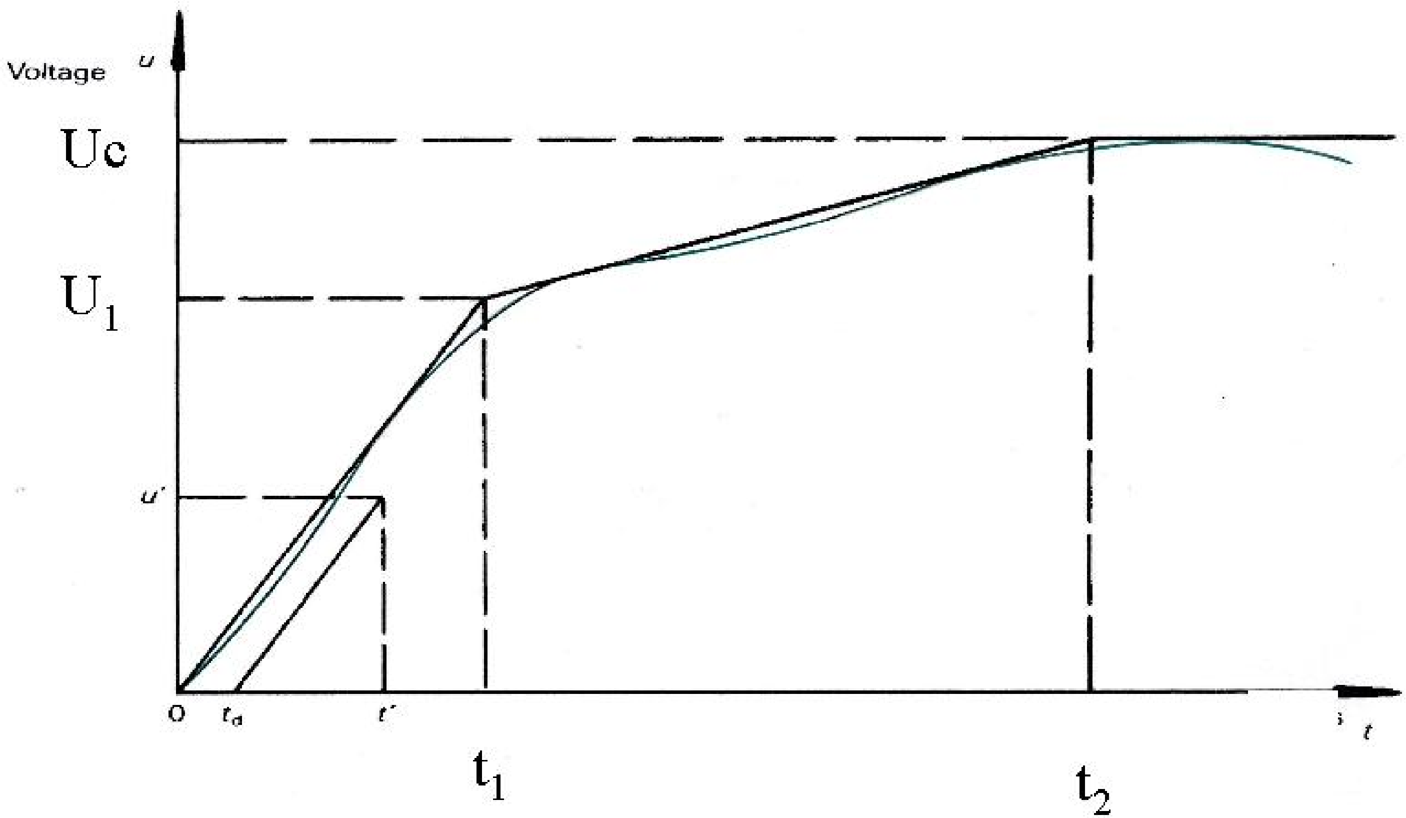


Exponential-Cosine Wave Chosen by IEEE in 1960's

- **The Exponential-Cosine Wave looks like a nicely defined mathematical function**
  - **BUT**
- **The Exponential-Cosine Wave is really just a simplified approximation of a typical real transient**

4-Parameter TRV Envelope

- A four-parameter envelope is a different approximation using straight lines to represent a wave form that exceeds most TRVs observed on real power systems



The Importance of Harmonization of TRV Standards

- **Both methods of describing TRV and of specifying ratings have served the industry very well.**
- **TRV failures in service are very rare**
- **A harmonized TRV will allow one set of tests to be performed under conditions that will satisfy both standards.**

Similarities between the standards

- **RRRV at 100% of rated Isc**
  - both use 2 kV/usec as the RRRV
  - both use a time delay of 2 usec

- **Peak TRV**
  - first pole to clear factor of 1.3 for effectively grounded systems at 245 kV and above
  - maximum TRV peaks are nearly the same
  - time to reach TRV peaks are nearly the same

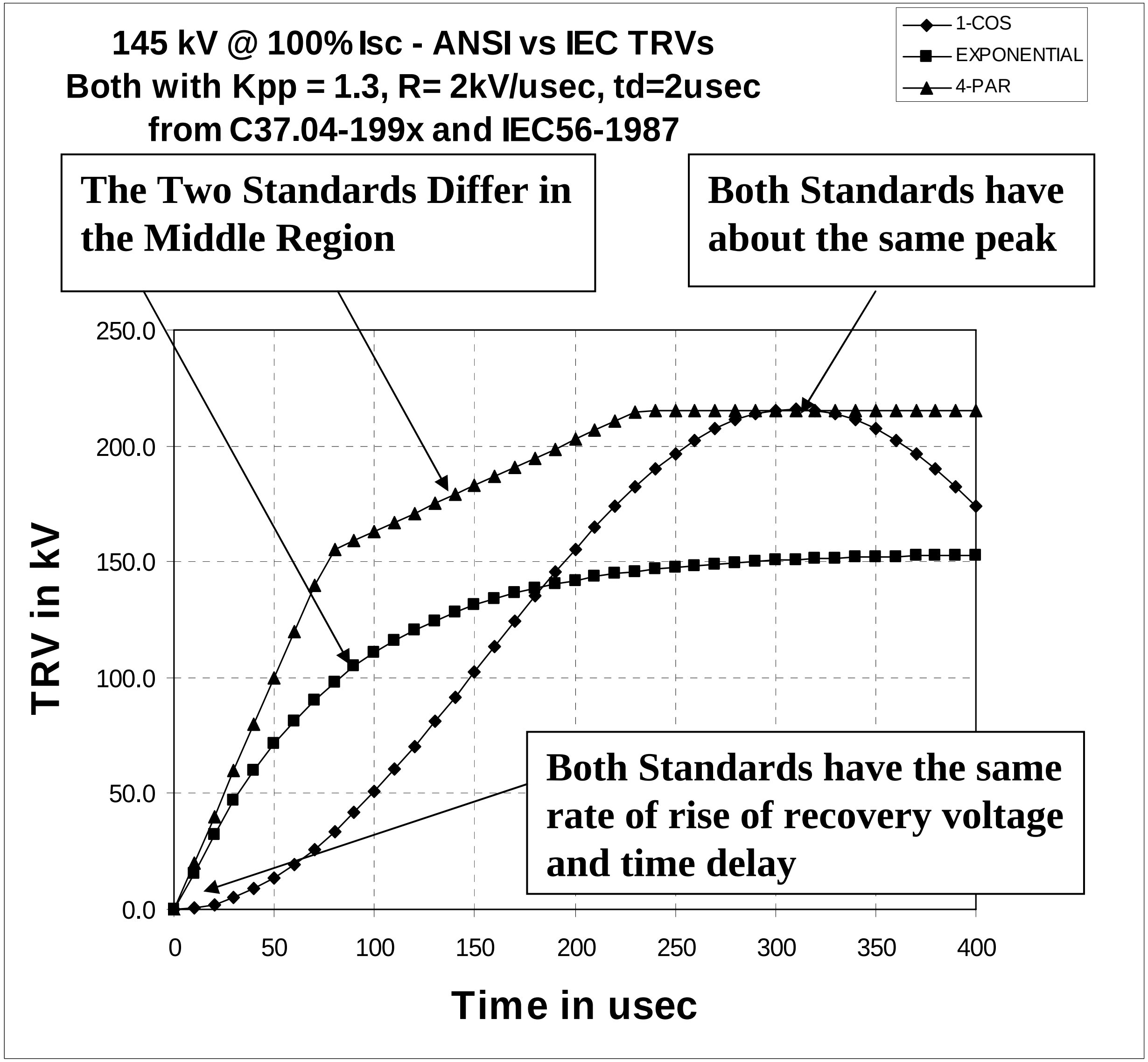
Similarities between the standards

- **Short Line Fault**
  - **surge impedance = 450 ohms**
  - **time delays:**
    - **0.2 microseconds at rated voltages less than 245 kV**
    - **0.5 microseconds at rated voltages of 245 kV and above**
  - **amplitude factor of 1.6**
- **Initial TRV**
  - **same requirements**

Differences between the standards

- **Wave Shape**
  - **ANSI/IEEE = exponential / 1-cosine wave (Ex-Cos)**
  - **IEC = 4-parameter straight line description**
- **Ex-Cos and the 4-parameter TRVs**
  - **similar in the beginning and similar at the peak**
  - **diverge in the middle**
- **TRV Peaks at < 245 kV first pole to clear factor**
  - **ANSI Kpp = 1.3 (changed to 1.3 in 1999 – formerly 1.5)**
  - **IEC Kpp = both 1.3 and 1.5 listed**

145 kV at 100% Isc - ANSI vs IEC TRVs A Comparison Example



Changes to ANSI/IEEE

- Adopt the 4-Parameter TRV as the Rated TRV description at 100% and 60% Isc, replacing Ex-Cos

- Adopt the 2-Parameter TRV as the Rated TRV description at 30% and 10% Isc, replacing 1-Cosine

- Adopt the Same RRRVs, time delays and delay line descriptions as IEC at 100% and 60% Isc

- Adopt the Peak Voltage values of Uc (E2) and times to peak of t2 presently in IEC standards at 100% and 60% of Rated Isc

Changes to IEC

- **Solidly Earthed as basis of rating from 100 and above**
  - **Kpp = 1.3 is preferred**
  - **Koop = 2 for out-of-phase switching voltage factor**
- **Non-effectively earthed applications from 100 and above**
  - **Kpp = 1.5 is retained**
  - **Koop = 2.5 for out-of-phase switching voltage factor**
- **Adopt 2-Parameter TRV at 30% Isc**

Changes to Both ANSI/IEEE & IEC

- **Adopt new harmonized values for U1 and T1 as a compromise between ANSI and IEC to harmonize the 2 standards around the middle of the TRV wave front where the major differences presently exist:**
  - **Present IEC, U1= 1.0 per unit with (T2 / T1) = 3**
  - **Present ANSI, U1= 0.5 per unit with (T2 / T1) = 5.5 approximately**
  - **Harmonized, U1 = 0.75 per unit with (T2 / T1) = 4**

Changes to Both ANSI/IEEE & IEC

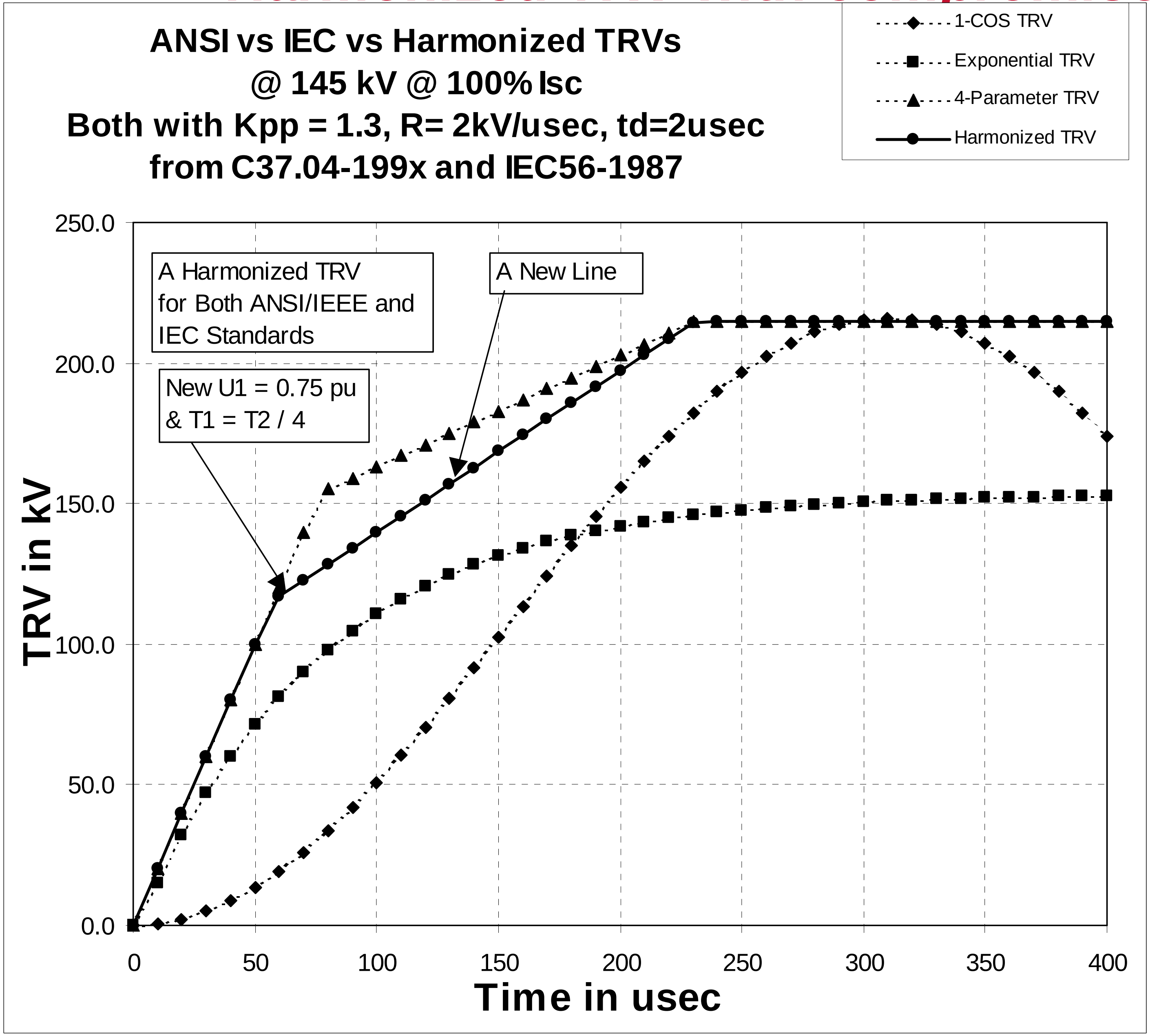
- **New Compromise Peak TRV Values,**
  - **Uc (E2) and t3 (T2) at 30% & 10% of Rated Isc**

- **Use new harmonized TRV values for the source side TRV under short line fault conditions**

- **Use new harmonized TRV values for the source side TRV under out-of-phase switching condition**

- **Develop new common 2-Parameter TRV values for special purpose fast rate of rise TRV conditions such as transformer fed faults based on the new trial use standard ANSI C37.06.1-1997**

Harmonized TRV with compromise U1 &T1



Importance of TRV

- **The TRV is a decisive parameter that limits the interrupting capability of a circuit breaker.**
- When developing interrupting chambers, manufacturers must check and prove the withstand of TRVs specified in the standards for different test duties.
- Users must specify TRVs in accordance with their applications.
- The breaking capability was found to be strongly dependent on TRV already in the 1950’s.

Harmonizing TRV requirements will benefit Manufacturers and Users alike

Harmonization was accomplished by compromise changes to both IEC and IEEE standards

Thank you for your attention
Questions ?