Cascade Style
Dry Type Current Transformer for EHV Applications

Ruzhang Wang – Zhaohui Liu – Chunyao Cao

Huan Wang - Eric Euvrard – Robert Middleton

RHM International USA

RHM International

HV DryShield® dry type technology has delivered consistent benefits for the past 25 years in :

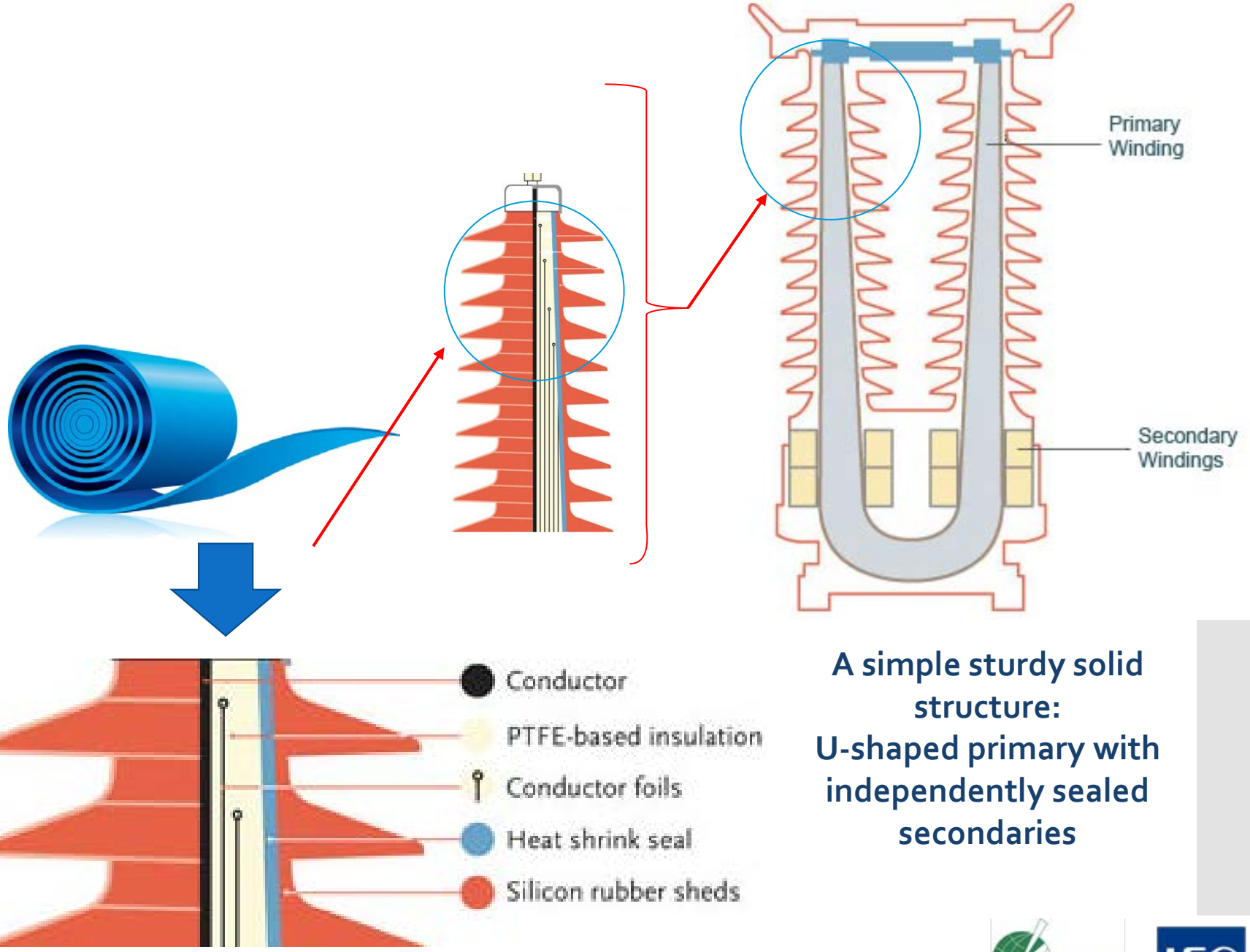
- safety,
- durability
-performance and
-maintenance

up to 500kV

Potential for explosion, toxic byproducts with oil & gas filled CTs

T&D substituted conventional CTs with HV DryShield type CTs

Wrapping PTFE tape around conductive foils and fitting silicone rubber sheds straight to the core makes the insulation solid, stress-free with large margins



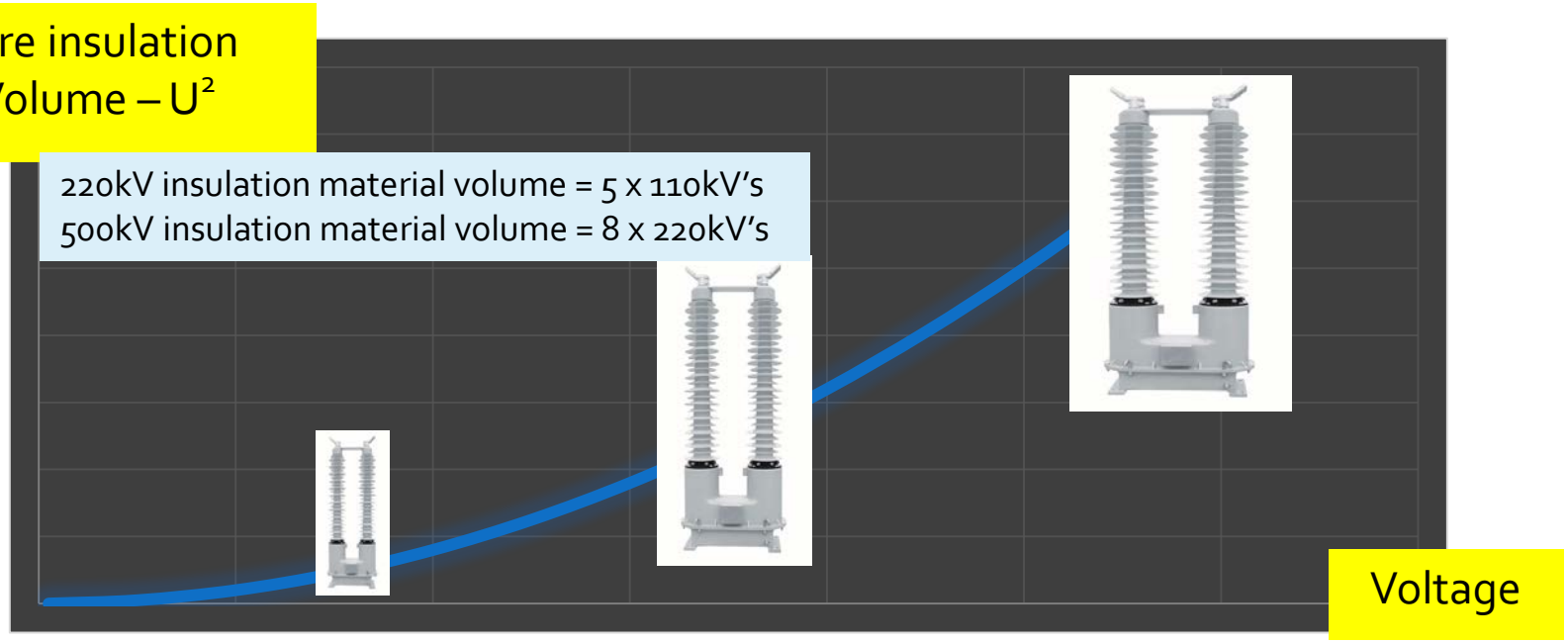
A simple sturdy solid structure:
U-shaped primary with independently sealed secondaries

Objective: how to design for EHV levels while retaining all dry type benefits and contained costs?

RHM International

The size of the condenser insulation grows with the square of rated voltage

How to ensure the same performance at EHV levels with the same safety, durability and cost effectiveness?



Consequences:

- Larger materials volumes are needed
- New equipment and investment are needed
- Repeatability and yield are affected
- Lead times are increased
- Relative costs are higher

A cascade structure is the series connection of several CTs of similar insulation level.

1— Upper section's primary winding

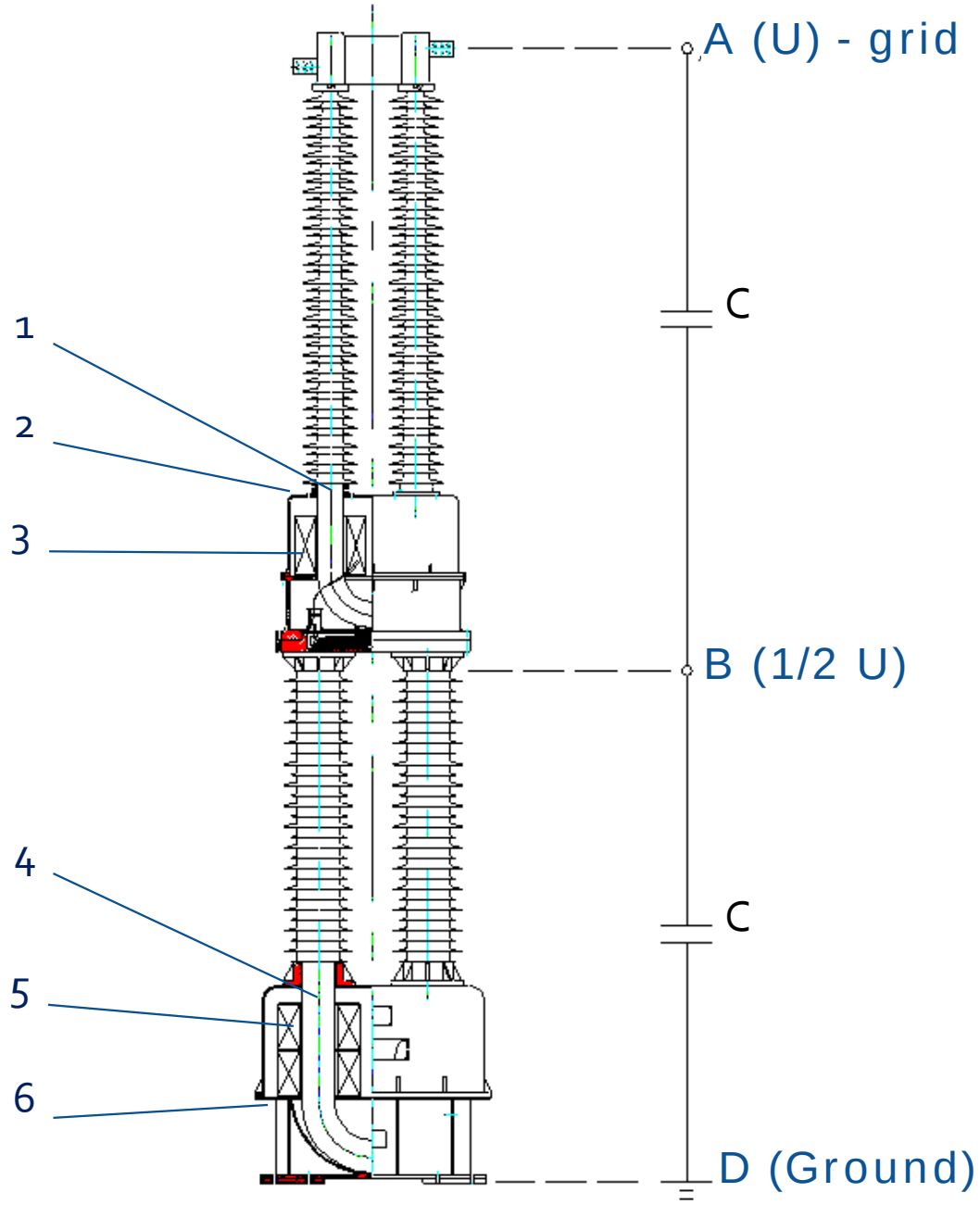
2— Top section's box;

3— Top section's secondary winding

4— Bottom section's primary winding

5— Bottom section's secondary windings

6— Bottom section's box

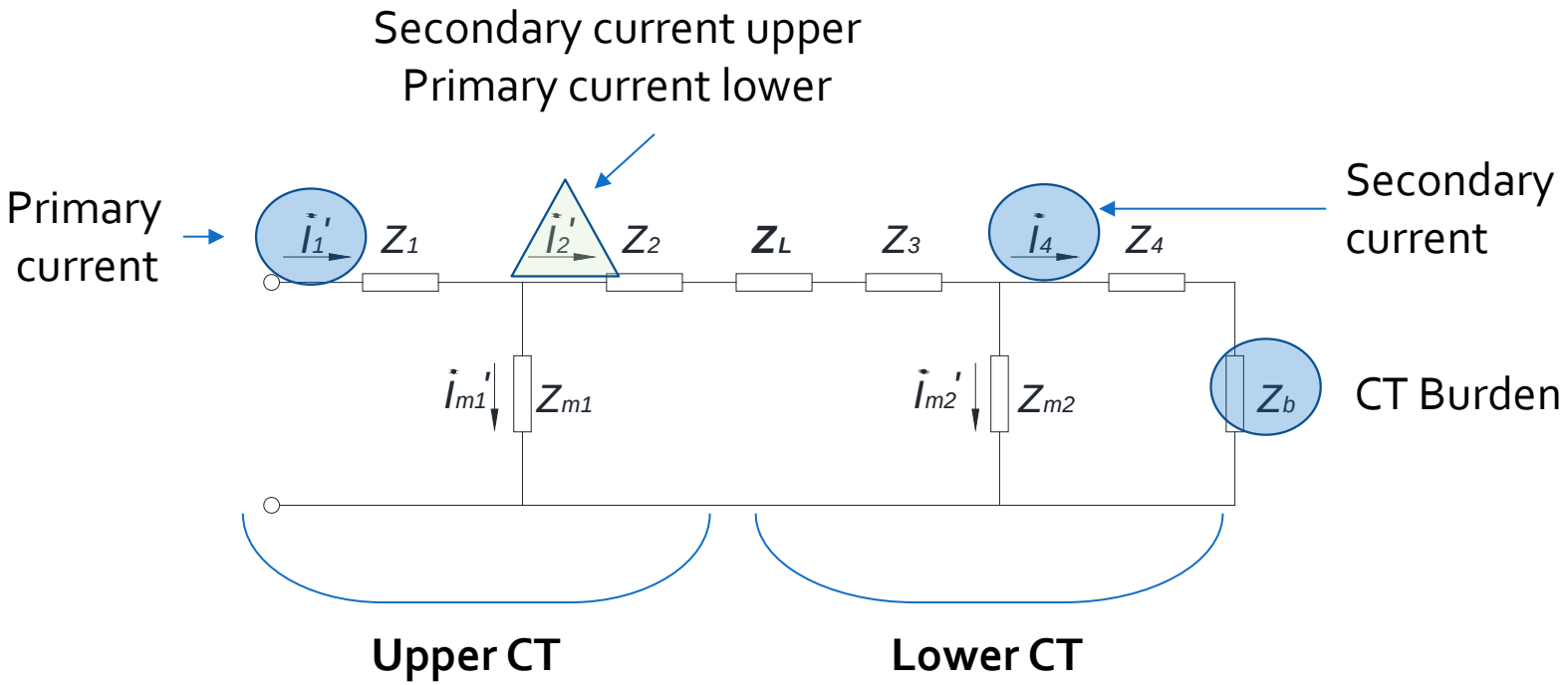


Overall Lower Risks, lower Cost and Easier Installation vs single core designs

Advantages of the Cascade design:

- Primary insulations handle half of total voltage: high insulation margins with lower risks
- Lighter insulation: uses less materials
- Easier manufacturing: consistency
- Shorter lead times
- 2 part shipping: easier assembly on site
- Lower costs of production and better value for users

The design aims at reducing the weight of the upper and lower CT iron cores while still meeting the accuracy requirements



Key design parameters:

Larger amp. turns: smaller core
Higher burden: bigger core

Larger K: smaller secondary core
i_2' small: upper core small
i_2' large: lower core small

Full ratio is the product of the 2 CT units' ratios

If the current ratio of upper CT is K1, and the current ratio of lower CT is K2, the current ratio K of the entire cascade CT is:

$$K = K_1 \times K_2$$

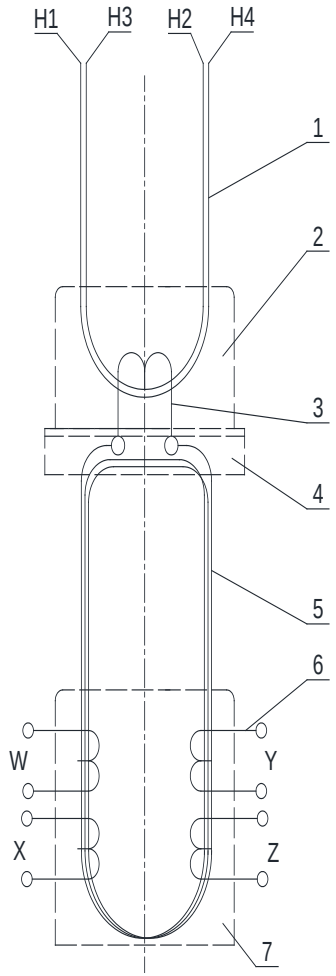
Ex: Upper CT ratio is 2000/20A, and the current ratio of the lower CT is 20/5A, then the current ratio of the entire cascade CT is 2000/5A

Application: A 600kV Cascade CT

RHM International

Application for a 600kV Max operation. Two IEC 220kV insulation enough: low risk level

- Maximum Continuous Op. Voltage: 600kV
- BIL: 600/860/1300/1800kV
- Short-time Thermal Current: 63kA,1s
- Dynamic Current:150kA
- Number of Secondary Windings: 4
- Ratio: 2000x4000 to 200x400-5-5-5-5A
- Accuracy Class and Burden: 2.5L800 and 0.3B1.8 at 0.9 P.F.



Accuracy must be considered as a composite of the 2 sections,
All tests were passed.

- Every stage of a cascade CT is an independent CT
- and the sum of these composite (vectorial) errors is the composite error for the entire cascade CT
- The total error is therefore smaller than the sum of the absolute values of the composite errors of each CT stage.

$$\dot{\varepsilon}_{\max} \leq \left|\dot{\varepsilon}_1\right| + \left|\dot{\varepsilon}_2\right|$$

All taps shows an error less than 2.5%

HV-DryShield dry type insulation fits particularly well cascade designs.

It is a solid path to EHV and UHV applications with safer, clean and reliable operations

In Summary:

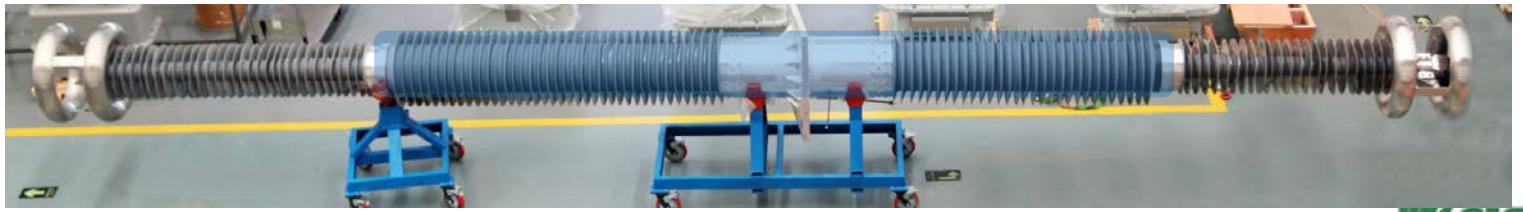
1. Dry CTs have been meeting expectations for the past 20 years
2. Reaching EHV and UHV applications is needed with the same safe consistent performance
3. The cascade design is meeting process, safety, and cost expectations: lighter, handling half of maximum voltage and shorter lead times
4. This is a safe, clean and cost effective way to develop performant EHV equipment without any oil or gas or paper based insulations

And Cascade designs are implemented in other ways

Cascade designs applied to bushings:

Cascade 400kV DC & 550kV AC HV DryShield® Wall Bushing

Half the weight of existing wall bushings



And Cascade 362kV paperless RIF® Transformer Bushings

Path to EHV dry type water proof with heat dissipation enhance benefit

RIF®