Annex E Transformers and Reactors for HVDC Applications Subcommittee

October 23, 2023, 4.45 pm local time – Roanoke at the Westin at Crown Center, Kansas City, MO

Chair: **Ulf Radbrandt (ulf.radbrandt@ieee.org)**

Vice Chair: **Les Recksiedler (lrecksiedler@mhi.ca)**

Secretary: **Klaus Pointner (klaus.pointner@ieee.org)**

E.1 Introduction / Attendance / Approval of the Agenda / Essential Patent Issues

There was a total of 39 persons in the meeting, 13 members and 26 guests present. 8 new requests for membership were received.

Call for patents (essential patent claim) and IEEE copyright policy have been addressed.

Actual membership prior the Fall 2023 meeting is shown below:

First Name	Last Name	Email	Company
Camilo	Casallas	camilo.casallas@trench-group.com	Trench Limited
David	Caverly	david.caverly@trenchgroup.com	Trench Limited
Solomon	Chiang	schiang@thegundcompany.com	The Gund Company
Eric	Davis	esetdavis@aol.com	Consultant (on his own)
Evgenii	Ermakov	evgenii.ermakov@hitachienergy.com	Hitachi Energy
Alexander	Gaun	alexander.gaun@coilinnovation.com	Coil Innovation GMBH
Peter	Heinzig	peter.heinzig@weidmann-group.com	Weidmann Electrical Technology
Giovanni	Hernandez	dayan_hernandez@vatransformer.com	Virginia Transformer Corp.
Kurt	Kaineder	kurt.kaineder@trench-group.com	Trench Austria GmbH
Christoph	Ploetner	cp.xfmr@gmail.com	Siemens Energy
Klaus	Pointner	klaus.pointner@trench-group.com	Trench Austria GmbH
Ulf	Radbrandt	ulf.radbrandt@ieee.org	Hitachi Energy
Les	Recksiedler	lrecksiedler@mhi.ca	Manitoba Hydro International
Michael	Sharp	sharp.michael@siemens-energy.com	Trench Limited
Waldemar	Ziomek	wziomek@ptitransformers.com	PTI Transformers

13 members out of 15 members were present, thus quorum was met.

The agenda for this meeting, that was distributed via E-mail on October 5, 2023, was presented. No comments received. The agenda was unanimously approved.

The list of all attendees of the meeting is shown below:

First Name	Last Name	Email	Company	Request Member-ship
Kayland	Adams	kayland.adams@prolec.energy	Prolec GE	
Jennie	Aldenlid	jennie.aldenlid@hitachienergy.com	Hitachi Energy	
Hugo	Avila	hugo.p.avila@hitachienergy.com	Hitachi Energy	
Sean	Barker	sean.barker@hitachienergy.com	Hitachi Energy	x
Camilo	Casallas	camilo.casallas@trench-group.com	Trench Limited	
Juan	Castellanos	juangonzalo.castellanos@prolec.energy	Prolec GE	
David	Caverly	david.caverly@trenchgroup.com	Trench Limited	
Vivian	Chen	vivian.chen@hitachienergy.com	Hitachi Energy	
Solomon	Chiang	schiang@thegundcompany.com	The Gund Company	
Marcos	Czernorucki	marcos.czernorucki@hitachienergy.com	Hitachi Energy	x
Eric	Davis	esetdavis@aol.com	Consultant (on his own)	
Huan	Dinh	huan.m.dinh@hitachienergy.com	Hitachi Energy	
Evgenii	Ermakov	evgenii.ermakov@hitachienergy.com	Hitachi Energy	
Alexander	Gaun	alexander.gaun@coilinnovation.com	Coil Innovation GMBH	
Luis	Gonzales	lgonzales@conduct.com	Conduct Industries	x
Niklas	Gustavsson	niklas.gustavsson@hitachienergy.com	Hitachi Energy	
Peter	Heinzig	peter.heinzig@weidmann-group.com	Weidmann Electrical Technology	
Kevin	Juchem	kevin.juchem@hitachienergy.com	Hitachi Energy	
Kurt	Kaineder	kurt.kaineder@trench-group.com	Trench Austria GmbH	
Egon	Kirchenmayer	egon.kirchenmayer@siemens-energy.com	Siemens Energy	
Nitesh	Patel	nrpatel@hhiamerica.com	Hyundai Power	
Sylvain	Plante	plante.sylvain.3@hydro.qc.ca	Hydro-Quebec	x
Christoph	Ploetner	cp.xfmr@gmail.com	Siemens Energy	
Klaus	Pointner	klaus.pointner@trench-group.com	Trench Austria GmbH	
Bertrand	Poulin	bertrand.f.poulin@hitachienergy.com	Hitachi Energy	
Thomas	Prevost	tom.prevost@weidmann-group.com	Weidmann Electrical Technology	
Ulf	Radbrandt	ulf.radbrandt@ieee.org	Hitachi Energy	
Adnan	Rashid	adnan.rashid@canada.ca	Measurement Canada / ISED	x
Hossain	Saif	saif.hossain@trench-group.com	Trench Limited	x
Lina	Sandsten	lina.sandsten@hitachienergy.com	Hitachi Energy	x
Michael	Sharp	sharp.michael@siemens-energy.com	Trench Limited	
Hampton Allen	Steele	hasteele@tva.gov	TVA	
Dharam	Vir	dharam.vir@prolec.energy	Prolec GE	
Terry	Wong	terry.wong@trench-group.com	Trench Canada Limited	

First Name	Last Name	Email	Company	Request Member-ship
Guang (Grace)	Yuan	guang.yuan@hitachienergy.com	Hitachi Energy	
Malia	Zaman	m.zaman@ieee.org	IEEE SA	
Bo	Zhang	bo.zhang@inl.gov	Idaho National Laboratory	x
Igor	Ziger	igor.ziger@koncar-mjt.hr	KONCAR - Instrument Transformers	
Waldemar	Ziomek	wziomek@ptitransformers.com	PTI Transformers	

Qualification for membership of the received requests will be checked and the applicants will be notified.

E.2 Approval of the minutes of the Spring 2023 meeting in Milwaukee

The minutes of the spring meeting as distributed by E-mail on March 27, 2023 have been presented. No comments were given. The minutes have been unanimously approved.

E.3 Results of the e-mail circulation regarding approval of the minutes of the October 17, 2022 meeting in Charlotte and the agenda of the March 20, 2023 meeting in Milwaukee

Since there were no quorum at the spring 2023 SC meeting in Milwaukee, the minutes of the October 17, 2022 meeting in Charlotte and the agenda of the March 20, 2023 meeting in Milwaukee were distributed via e-mail among the SC members for approval and both were approved.

E.4 Working Group Reports

The IEEE1277 has been published 2020 (10 years stability until Dec 31, 2030).

The dual logo standard IEC/IEEE 60076-57-129 was published 2017 and is good until Dec 31, 2027. The application for the PAR to start the revision process in on the way.

E.5 Status of the Entity WG for development of the Guide for vibration testing of oil immersed HVDC converter transformer. (Chairman: Dr. Jun Deng)

The SC HVDC will sponsor this Entity WG. Therefore, future work of this WG will be reported to this subcommittee. The actual status of the WG is outlined in the presentation submitted by the WG chair Jun Deng prior to the Fall meeting. Unfortunately, the WG chair could not come to this meeting but is encouraged to do so for the spring 2024 meeting in Vancouver.

Status Report:

IEEE SA STANDARDS ASSOCIATION

WORKING GROUP STATUS OF IEEE PC57.132 "GUIDE FOR VIBRATION TESTING OF OIL-IMMERSED HIGH-VOLTAGE DIRECT CURRENT (HVDC) CONVERTER TRANSFORMER (±160 KV DC TO ±1100 KV DC)"

Jun Deng
Working Group Chair
October 23rd 2023

IEEE

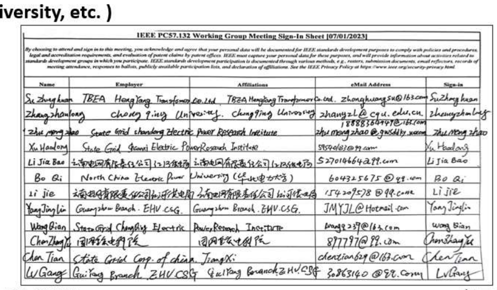
CURRENT STATUS OF WORKING GROUP

Date and Location of Last Working Group Meeting:
1ST, July 2023, Chongqing, China (kick-off meeting)

IEEE SA STANDARDS ASSOCIATION   IEEE 2

CURRENT STATUS OF WORKING GROUP

During the kick-off meeting, the Working Group is established. (48 experts participated, from Siemens, ABB, Chongqing University, etc.)



IEEE PC57.132 Working Group Meeting Sign-In Sheet [07/01/2023]

Name	Employer	Affiliations	eMail Address	Sign-in
Su Zhonghuan	TBEA HengYang Transformer Co.Ltd	TBEA HengYang Transformer Co.Ltd.	zhonghuangsu@163.com	Su Zhonghuan
Zhang zhanlong	chong qing University.	Chongqing University	zhangzl@cqu.edu.cn	zhangzhanlong
Zhu mengzhao	State Grid Shandong Electric Power Research Institute		18888364949@163.com zhumengzhao@gwsddky.com	Zhu Mengzhao
Xu Haolong	State Grid Shaanxi Electric Power Research Institute		[illegible]	Xu Haolong
Li Jia Bao	[illegible]	[illegible]	527014664@qq.com	Li Jia Bao
Bo Qi	North China Electric Power	University (华北电力大学)	604325675@qq.com	Bo Qi
Li jie	[illegible]	[illegible]	154209578@qq.com	Li Jie
Yang Jinglin	Guangzhou Branch. EHV.CSG.	Guangzhou Branch. EHV.CSG.	JMYJL@Hotmail.com	Yang Jinglin
Wang Bian	State Grid Chongqing Electric	Power Research Institute	wangq239@163.com	wang Bian
Chen Zhangyi	[illegible]	[illegible]	897797@qq.com	Chen Zhangyi
Chen Tian	State Grid Corp. of china. JiangXi		chentian629@163.com	Chen Tian
Lv Gang	GuiYang Branch. EHV.CSG	GuiYang Branch EHV.CSG	30863140@qq.com	Lv Gang

IEEE SA STANDARDS ASSOCIATION   IEEE 3

CURRENT STATUS OF WORKING GROUP

- **WG Chair Dr. Jun Deng introduce the Agenda, IEEE SA Procedure, IEEE Policies (include Call for Patents, copyright policy, entity participation) and Working Group Policies and Procedures.**
- **Agenda and WG P&P are approved by motion without opposition respectively.**
- **Candidates for Vice Chair and Secretary have been nominated by WG chair and approved by motion without opposition.**

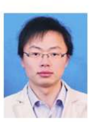
IEEE SA STANDARDS ASSOCIATION   IEEE 4

CURRENT STATUS OF WORKING GROUP

Working group officers

Working Group Chair
Name: Dr. Jun Deng
Company: China Southern Power Grid
Email: 13822116195@139.com

Working Group Vice Chair
Name: Prof. Bo Qi
Company: North China Electric Power University
Email: lqicb@ncepu.edu.cn

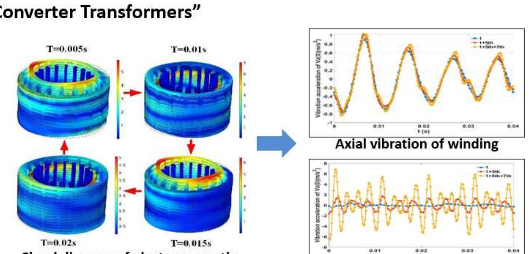


Working Group Secretary
Name: Dr. Tian Chen
Company: State Grid Corporation of China
Email: chentian629@163.com

IEEE SA STANDARDS ASSOCIATION   IEEE 5

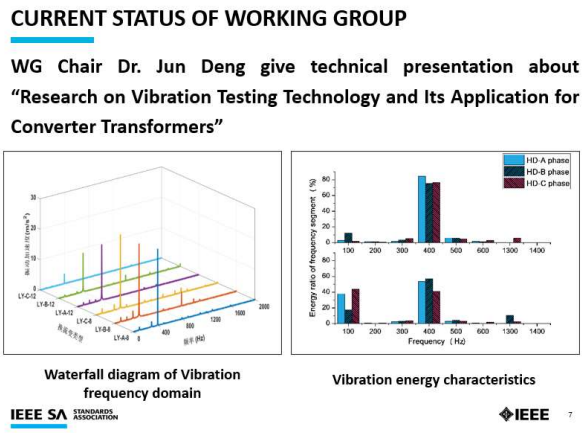
CURRENT STATUS OF WORKING GROUP

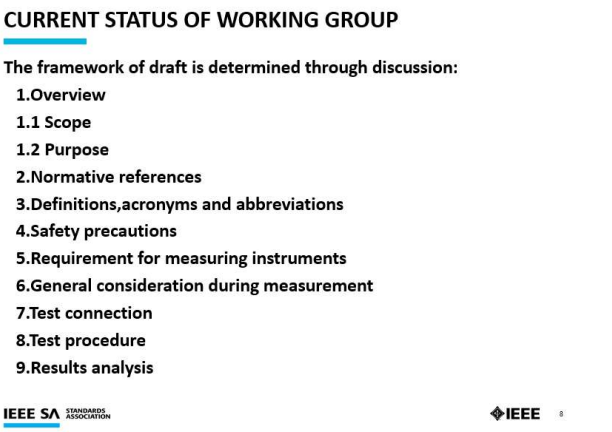
WG Chair Dr. Jun Deng give technical presentation about "Research on Vibration Testing Technology and Its Application for Converter Transformers"

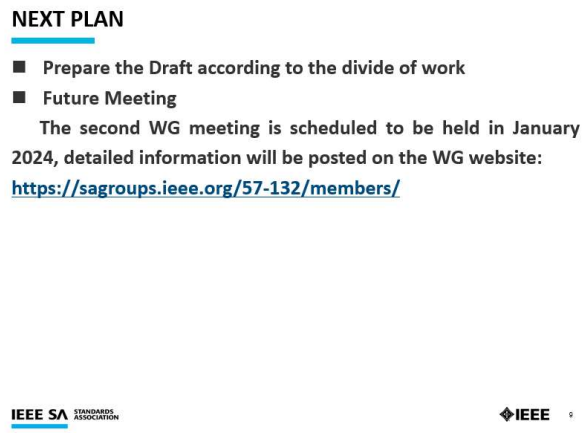


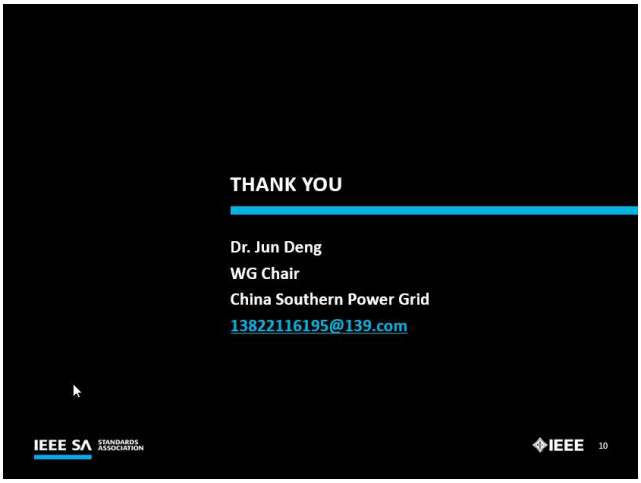
Cloud diagram of electromagnetic field distribution in windings
Axial vibration of winding
Radial vibration of winding

IEEE SA STANDARDS ASSOCIATION   IEEE 6









The SC shall stay involved in this WG. Participation in person would be possible in an expert function. However, the ballot will be organized according to the rules for such entity PAR's (one entity – one vote), but this SC has to agree that a draft proposed by the WG for balloting is in the required shape to start the ballot process.

E.6 Dual logo standard IEC/IEEE 60076-57-129 (WG Chair: Waldemar Ziomek)

As outlined in the minutes of the Spring meeting, Waldemar Ziomek was proposed as the WG chair for this revision work. This was confirmed by an e-mail survey amongst the members.
Waldemar is currently working on the draft for the PAR including a proposal for the scope and title, with the target to have the PAR ready for the January RevCom meeting.

At the meeting, the WG chair did call for WG members and the following attendees have shown interest.

WG Chair: Waldemar Ziomek
WG Vice Chair: Eric Davis
Volunteer Members (so far): Eric Davis, Chis Ploetner, Peter Heinzig, Ulf Radbrandt, Sean Barker, ….

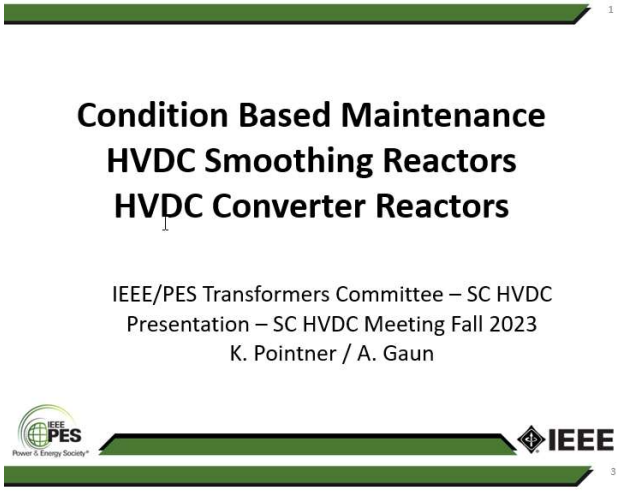
Chris Ploetner (Chair of the TC 14 of IEC and SC HVDC member) mentioned that Marcos Czernorucki is nominated as the IEC counterpart and will be announced within short when confirmed.

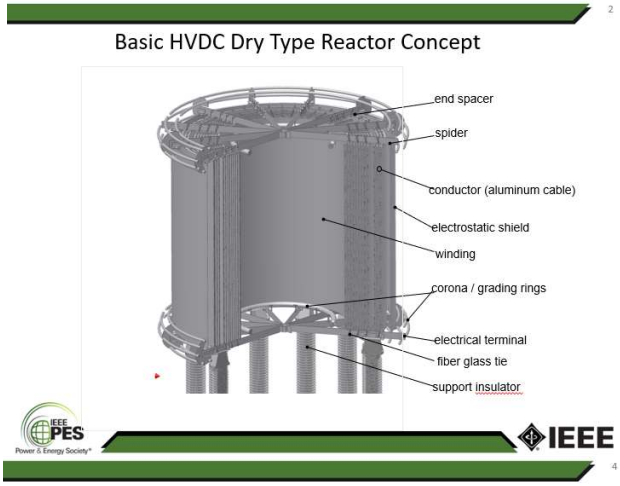
According to Malia Zaman, it is IEC who holds the original word file of the current standard. Chris Ploetner confirmed that he will try to obtain this file and to send it to the WG chair.

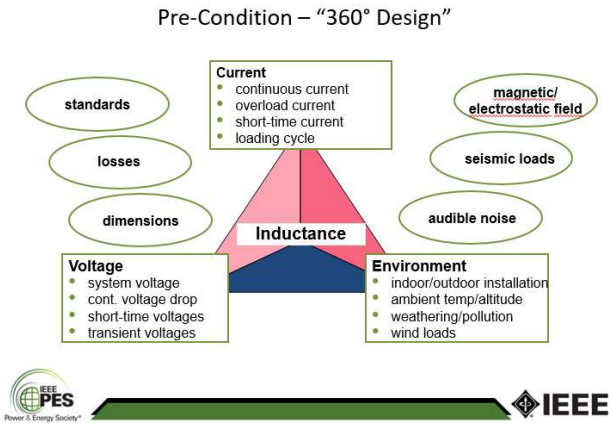
It is planned to hold the WG meetings during the SC HVDC meeting (as done for the IEEE 1277), these meetings will mainly be to report status from the joint WG (IEC and IEEE). The SC chair suggested working meetings for the joint WG in conjunction to the Transformers Committee meetings and intermediate working meetings, e.g. in Europe.

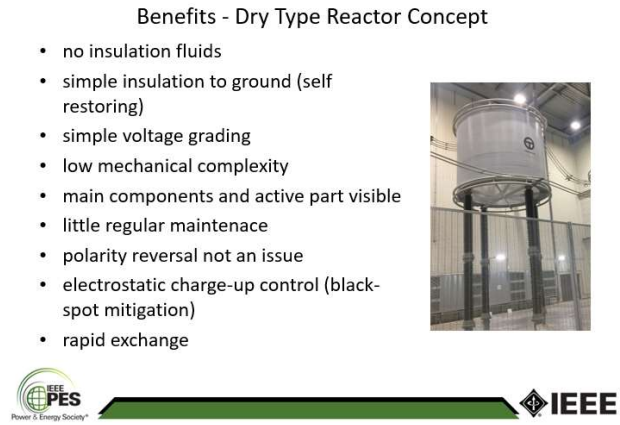
E.7 Presentation "Condition Based Maintenance of HVDC Smoothing and HVDC Converter Reactors"

Presentation on air-core dry-type HVDC converter reactors and air-core dry-type HVDC smoothing reactors prepared by Alexander Gaun and Klaus Pointner. Duration approx. 30 minutes

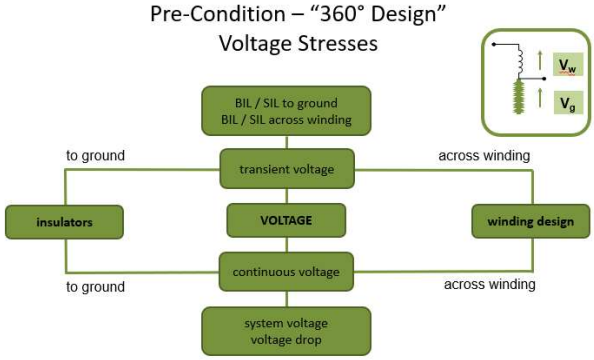




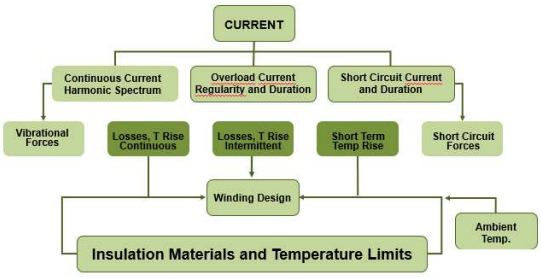




Pre-Condition – "360° Design" Voltage Stresses



Pre-Condition – "360° Design" Current Stresses



Maintenance Basic Guideline

Type / Pollution *)	a	b	c	d	e
	Very light	Light	Medium	Heavy	Very Heavy
Filter Reactor	2	2	1,5	1	1
HVDC Smoothing Reactor	2	2	1,5	1	1
Converter Reactor	2	2	1,5	1	1
HVDC Filter Reactor	2,5	2,5	2	1,5	1,5

*) classification as per IEC60815-1
Note: If an insulator cleaning program is in place, this shall be considered for the reactors as well

Surface condition which requires re-painting

Maintenance Basic Guideline

Maintenance items	
General visual inspection of the equipment for equipment integrity.	✓
Check if the arms of the top/bottom spiders have become loose from the winding.	✓
Check if the spider struts (if any) have become loose and re-tighten the bolts where necessary.	✓
Check the top and bottom of the winding for any abnormalities such as carbonization, arc marks etc. If such marks are found, notify Trench before re-energization.	✓
Check the top of the winding and the cooling ducts for foreign particles, in particular for bird's nests and remove them.	✓
Check the inside and outside surface of the reactor winding for possible tracking marks. If such marks are found, notify the manufacturer before re-energization.	✓
Check the tightening torque of the bolts of the support structure randomly. If any bolts are found to be loose, re-tighten all bolts.	✓
Check the condition of the ground wires (tightness of bolting, corrosion, etc.).	✓
Check the surface of the reactors and insulators for contamination. Clean reactors and insulators, if necessary.	✓
Check the status of the protective paint of the reactor. Local imperfections or minor paint peeling should be touched-up	✓

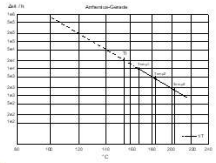
Aging Modes and Mitigation Strategies

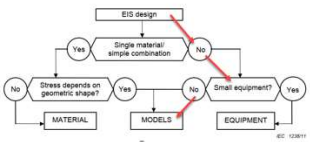
Thermal Aging

- Halfing Interval Cycle: ~10K for typical dry-type insulation systems
- Material/system tests as per e.g. IEC 60505

Counter measure

- Calculation of life-time based on load profile and temperatures
- Safety margin
- Load cycling
- Fiber optic temperature measurement – surface mounted probes





Aging Modes and Mitigation Strategies

Hydrolysis

- Moisture ingress
- Deterioration of materials due to chemical breakdown of polymers caused by water (steam)

Counter measure

- Selection of material
- Accelerated endurance testing of materials (polymers)
- Exclusion of vulnerable materials or limitation of their temperature range

13

Aging Modes and Mitigation Strategies

UV degradation

- Degradation of epoxy resin
- Degradation of surface paint

Counter measure

- Selection of material – protect epoxy from UV exposure
- Accelerated endurance testing top coat (weather-o-meter)
- Upgade of surface protection by RTV coating
- Regular visual checks and touch up or complete re-painting

Example: UV Testing

- acc. DIN EN ISO 4892-2
- total radiation intensity: 250-765W/m2
- wavelength: 300-800nm

14

Aging Modes and Mitigation Strategies

Tracking and Erosion

- Surface tracking
- Carbonisation of of tracking path
- Trigger of flash over

Counter measure

- Material qualification
- Pollution control
- Cleaning intervals
- Upgraded surface treatment (RTV coating – hydrophobic surface)
- Insulator selection acc. IEC60815

Example: Tracking and Erosion test - Inclined plane testing (IEC60587)

15

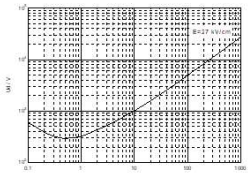
Aging Modes and Mitigation Strategies

Dielectric aging

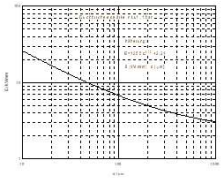
- partial discharge
- erosion of soild insulation material

Counter measure

- **Exclude PD by design at operating conditions**
- Low turn-turn voltage stress
- Paschen's Law



Paschen curve for air



normalized Paschen curve for air

16

Summary

- Reliability starts with the specification, particularly for air-core dry-type reactors, which are fully exposed to the environment
- Careful material selection and material testing required to avoid day zero vulnerabilities
- RAM statistics shall be available – ask for background information
- Typically a visual inspection and some simple checks are sufficient
- Be aware of operational limits and contingencies

Vision

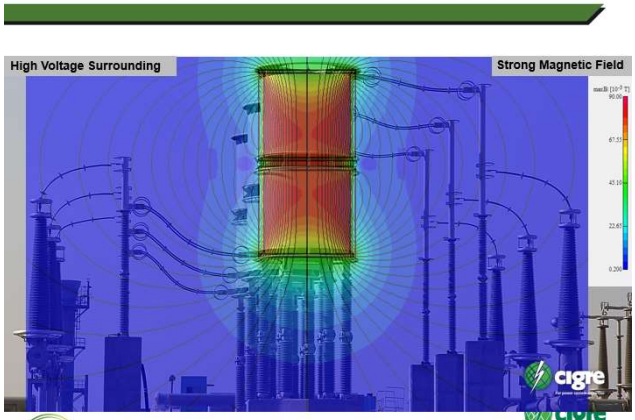
Online Monitoring Essential Quantities of Air Core Reactors

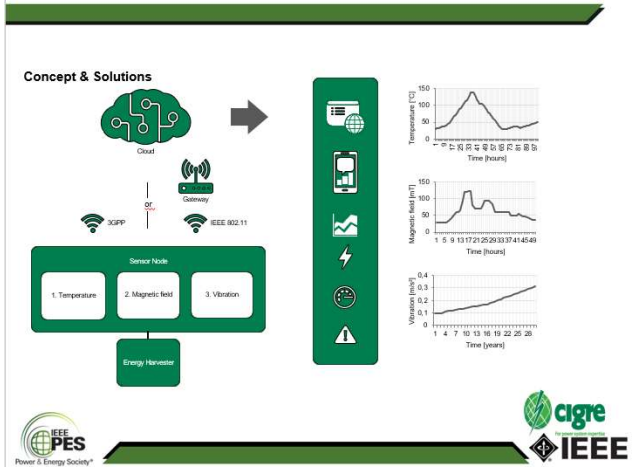
Source: CIGRE Paris Session 2020 – SC A3 – PS2
NGN showcase presentation

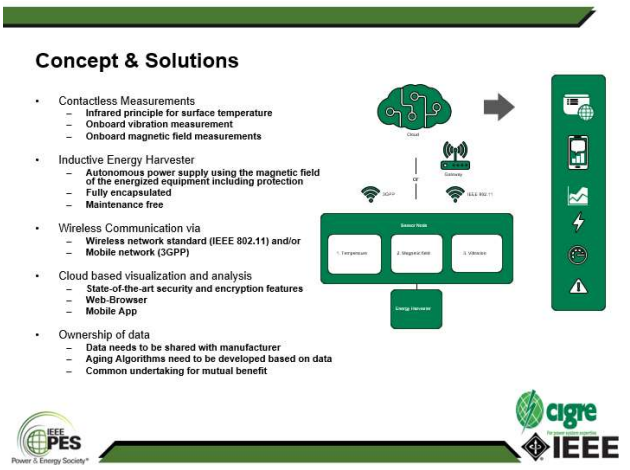
Vision

Monitoring Essential Quantities of Air Core Reactors

- Quantities
  - **Temperature of Winding**
  - **Magnetic Field**
  - **Vibration**
- Monitoring these Quantities to
  - **Extend Lifetime of Air Core Reactor**
  - **Condition based maintenance**
  - **Enable Overload Capabilities with feedback of thermal aging**
  - **Affordable Monitoring**







E.8 Old Business

There was no old business

E.9 New Business

Discussion about time slot of the meeting due to some conflict of participants with other WG activities. The SC HVDC meeting is the only sub-committee meeting not taking place on Wednesday.

The chair noted, that on Wednesday only the late afternoon time slot in parallel to the SC standards is available. Furthermore, the current time slot is used for WG activities if needed.

It was decided, to keep the time slot as it is for the time being.

E.10 Adjournment

The meeting was adjourned at 5:56pm.