Commencing Development of Just Approved New Guide on Moisture in Transformers and Reactors

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WG Moisture in Insulation Systems
F13 IEEE Transformers Committee Meeting
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Agenda

1. **Introduction of Attendees**
2. **Review of PAR**
   - Project Title and Timeline
   - Project Scope
   - Project Purpose
3. **Why New Guide?**
4. **Brief History of Establishment of WG**
5. **Call for Membership**
6. **Document Structure**
7. **Establishment of Task Forces**
8. **Next Meeting**
9. **Adjourn**

Agenda Item 1:
Introduction of Attendees

Agenda Item 2: Review of PAR

- **Project Title and Timeline**
- **Project Scope**
- **Project Purpose**

Project Title and Timeline: Extract from IEEE-SA Standards Board NesCom Recommendations

[SASB approval date: 23-Aug-2013]

[All votes unanimous unless noted otherwise]

- **PC57.162**
  Guide for the Interpretation of Moisture Related Parameters in Dry, Gas Insulated and Liquid Immersed Transformers and Reactors

- **Recommendation:**
  Approve new PAR until December 2017

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Scope of PC57.162

This reference document applies to dry, gas insulated and liquid immersed transformers and reactors and addresses:

- Moisture related phenomena and parameters in transformers and reactors
- The theory of moisture dynamics in solid-gas, solid-liquid and solid-liquid-gas insulating physical complexes
- Methods of assessment of moisture related parameters in solid-gas, solid-liquid and solid-liquid-gas insulating physical complexes
- The effects of moisture on operating transformers and reactors, and the risks associated with these effects
- The establishment of a baseline for each moisture related parameter
- The tracking and interpreting of changes against the baselines throughout the life of the transformer or reactor

Purpose of PC57.162

This document recommends methods for:

- the assessment of moisture and moisture related phenomena in dry, gas insulated and liquid immersed transformers and reactors
- the establishment of a baseline for each moisture related parameter
- the tracking and interpreting of the changes against the baselines throughout the life of the unit

Agenda Item 3: Why New Guide?

- **The current approach is that each existing IEEE standard or guide contains its own solution to the moisture related phenomena it is dealing with**
- **The current approach does not feature a holistic approach to the moisture related phenomena in transformers and reactors**
- **The current approach is lacking establishing baselines and tracking changes against them throughout the life of units**
- **It is anticipated that once developed, the new guide would serve as a single knowledge base and reference document for the IEEE (and IEC? Dual logo?) standards and guides dealing with moisture**
- **When needed, a certain standard or guide would refer to this document and/or develop its own higher level application based on this document**

Agenda Item 4:
Brief History of Establishment of WG

1. **<u>S11:</u> A proposal for new Task Force to develop a new document called "Moisture in Insulating Systems of Gas Insulated & Liquid Immersed Transformers & Reactors" has been presented by the Author to the Standards SC meeting**
   - Due to limited time it was agreed to continue the topic at the F11 meeting
2. **<u>F11:</u> An updated version of the proposed document has been again presented to the Standards SC meeting**
   - Further actions and efforts have been transferred to the oversight of the Insulation Life SC
3. **<u>S12:</u> The IL SC voted positively to establish a new TF with the title "Moisture in Insulation Systems"**
   - The aim of the TF was to prepare the Title, Scope & Purpose of the new document

Brief History of Establishment of WG (Cont'd)

4. **<u>F12:</u> 1st meeting of the TF Moisture in Insulation Systems**
   - Tabling and discussing drafts of the Title, Scope and Purpose
5. **<u>S13:</u> 2nd meeting of the TF Moisture in Insulation Systems**
   - Finalizing and voting for the Title, Scope ad Purpose
6. **<u>23 Aug 13</u>: PAR approved by SA Standards Board**
7. **<u>F13</u> (today): The 1st meeting of the newly established WG Moisture in Insulation Systems developing the new guide PC57.162**

Agenda Item 5: Call for Membership

- **End-users are encouraged to participate!**

Agenda Item 6: Document Structure

1. **Terminology and definitions**
2. **Measurement and evaluation of moisture-in-gas insulation parameters**
3. **Measurement and evaluation of moisture-in-liquid insulation parameters**
4. **Measurement and evaluation of moisture-in-solid insulation parameters**
5. **Evaluation of aging and end of life of solid insulation parameters**
6. **Factory/workshop application of knowledge on moisture; establishing baselines**
7. **Field application of knowledge on moisture***

   * Note: *This section lists the risks associated with moisture*

Publication Outlining the Document

- **V.G. Davydov, “Development of a New Reference Document on Moisture Related Phenomena in Transformers and Reactors”, *Proceedings of TechCon2012 Asia-Pacific,* Sydney, 17-18 April 2012**

Section 1: **Terminology and Definitions**

- **This section defines the terminology used in the document**

Section 2: **Measurement and Evaluation of Moisture-in-Gas Insulation Parameters**

- **This section describes general methods of moisture assessment in a gaseous medium**
- **Parameters of interest:**
  - Water vapor pressure
  - Saturation water vapor pressure
  - Total gas pressure
  - Absolute humidity
  - Relative humidity
  - Gas temperature
  - Dew point temperature
  - Other relevant parameters

Section 3: **Measurement and Evaluation of Moisture-in-Liquid Insulation Parameters**

- **Insulating Liquids to Consider:**
  - Mineral oils
  - Natural esters
  - Synthetic esters
  - Silicon insulating liquids
  - Insulating liquids for high temperature applications
  - Other
- **Parameters of Interest:**
  - Water content of insulating liquid, ppm
  - Water solubility limit of insulating liquid, ppm
  - Relative saturation of insulating liquid, %
  - Temperature of insulating liquid
  - Distributions of moisture and temperature in the insulating liquid medium of a loaded unit
  - Other relevant parameters

Section 4: **Measurement and Evaluation of Moisture-in-Solid Insulation Parameters**

- **It is proposed that this section consists of the following three <u>sub-sections</u>:**
  1. <u>Measurement</u> of moisture in solid insulation using balance
  2. <u>Evaluation</u> of moisture in solid insulation using dielectric response methods
  3. <u>Inferring</u> of moisture in solid insulation from measurements conducted in liquid or gaseous medium

Sub-Section 4.1: **Measurement of Moisture in Solid Insulation using Balance**

- **This sub-section describes methods of moisture measurement using samples of solid insulation**
- **Parameters of interest:**
  - Water content of surface of insulation of a unit
  - Distribution of moisture inside solid insulation
  - And derived from the above – the water content of the wettest inner layer

Sub-Section 4.2: **Evaluation of Moisture in Solid Insulation using Dielectric Response Methods**

- **Parameters of interest:**
  - Distribution of moisture in solid insulation of unit
  - Distribution of temperature in solid insulation of unit during the moisture assessment

Sub-Section 4.3: **Inferring of Moisture-in-Insulation Parameters from Moisture-in-Gas and Moisture-in-Liquid Data**

- **This sub-section describes methods of inferring moisture in solid insulation from that measured in the liquid or gaseous medium**
- **Parameters of interest:**
  - Parameters to be measured
  - Parameters to be inferred
  - Distributions of moisture and temperature

Notes regarding Inferring of Moisture Parameters in Solid Insulation

- **The existing inferring methods usually utilize:**
  - Measured parameters (e.g. RS, T, Load, other)
  - Equilibrium charts (vary for new and aged solids and liquids)
  - Intelligent algorithms (via utilizing moisture dynamics)
- **What parameter can we infer from daily moisture fluctuations?**
  - The water content of surface of solid insulation

Section 5: **Evaluation of Aging and End of Life Parameters for Solid Insulation**

- **This section describes approaches for evaluation of parameters of end of life of solid insulation affected by moisture**
- **For the standard test procedures, the raw data is to be obtained from:**
  - Existing test models (e.g. Dual Temperature model, Lockie model, other)
  - Modified existing test models that would have new feature of:
    - **Moisture level control**
    - **On-line monitoring of data**
  - New test models featuring:
    - **Condition control – temperature, moisture, oxygen and chemicals**
    - **Monitoring of data – continuous on-line and periodic off-line monitoring**
- **For the field applications, the raw data is to be obtained from on-line assessments in the field**

Materials and Parameters of Interest

- **It is proposed that consideration is given to the following types of solid insulating materials:**
  - Cellulose materials:
    - **Kraft paper**
    - **Thermally upgraded paper**
    - **Pressboard**
    - **Compressed wood**
    - **Other (e.g. cotton)**
  - Polymer materials:
    - **Aramid fiber materials**
    - **Other**
- **Aging and end of life parameters of interest:**
  - Degree of polymerization (DP) – for cellulose materials
  - 50% tensile strength – for both cellulose and polymer materials
  - Life expectancy
  - Loss of insulation life

Notes regarding Aging of Solid Insulation

- **It is proposed that aging of solid insulation is considered under the combined effect of the following parameters:**
  1. Temperature only – assuming that insulation is dry – for the reference purpose
  2. Temperature and moisture – for units that are properly preserved against the ingress of atmospheric air
  3. Temperature, moisture and oxygen – for units that feature some exposure to atmospheric air
  4. Temperature, moisture and aggressive chemicals – for old or contaminated units

Section 6: **Factory/Workshop Application of Knowledge on Moisture; Establishing Baselines**

- **This section describes a factory/workshop approach to the establishment of a baseline for each important moisture related parameter**

Establishing Baselines for New and Repaired Units

It is proposed establishing the factory/workshop baselines for the following parameters:

1. Water content of solid insulation, characterized by the two values:
   a. **Water content of insulation surface**
   b. **Maximum water content of inner layers of insulation**
2. Water Solubility Limit parameter – for insulation liquid immersed units
3. Aging parameters of solid insulation:
   a. **DP and 50% tensile strength for cellulose materials**
   b. **50% tensile strength for polymer materials**

Section 7: **Field Application of Knowledge on Moisture**

- **This section describes:**
  - The risks associated with moisture in operating transformers and reactors
  - Approaches to mitigate the risks
  - Tracking and interpreting changes against the baselines throughout the life of the transformer or reactor

Moisture Risks for Liquid Immersed Units

1. **Bubble emission and water drops release from winding insulation:**
   a. During a short term emergency loading above the nameplate rating
   b. During a cold start following a long-term (years) storage
2. **Formation of oversaturated (foggy) insulating liquid:**
   a. During a sudden drop of load after a period of high load
   b. During a rapid cooling of the insulating liquid in the cooler (e.g. due to a sudden heavy rain on a hot summer day)
   c. During load removal in sub-zero winter weather
3. **Formation of water drops at the main tank's inlet of the conservator during a cooling period**
4. **Risk of loss of life of solid insulation**
5. **Risk of loss of life of insulating liquid**

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Moisture Risks for Gas-Insulated Units

- **Risk of loss of life of solid insulation due to moisture**
- **For dry-type units, the risk of dielectric breakdown due to the high moisture content when the unit was de-energized for a prolonged period and then must be re-energized**
  - This is more of an installation / maintenance issue rather than loading

Tracking and Interpreting Changes against the Baselines throughout the Life of the Transformer or Reactor

- **Parameters to be evaluated in the field:**
  1. Two values of the water content of solid insulation:
     a. **Water content of insulation surface**
     b. **Maximum water content of inner layers of insulation**
  2. Water Solubility Limit parameter – for insulation liquid immersed units
  3. Aging parameters of solid insulation:
     a. **DP and 50% tensile strength for cellulose materials**
     b. **50% tensile strength for polymer materials**

Agenda Item 7: Establishment of Task Forces

- **TF1: Terminology and definitions**
- **TF2: Measurement and evaluation of moisture-in-gas insulation parameters**
- **TF3: Measurement and evaluation of moisture-in-liquid insulation parameters**
- **TF4: Measurement of moisture in solid insulation using balance**
- **TF5: Evaluation of moisture in solid insulation using dielectric response methods**
- **TF6: Inferring of moisture in solid insulation from measurements conducted in liquid or gaseous medium**
- **TF7: Evaluation of aging and end of life of solid insulation parameters**
- **TF8: Factory/workshop application of knowledge on moisture; establishing baselines**
- **TF9: Field application of knowledge on moisture**

  * Note: *This section lists the risks associated with moisture*

Two Major Types of Moisture Dynamics

- **Two major types of moisture dynamics in the insulation system of a transformer or reactor are to be considered:**
  1. Moisture exchange between the surface of solid insulation and the surrounding liquid or gaseous medium
  2. Moisture diffusion within the solid insulation
- **The solution to the issue of moisture in transformers and reactors lays in proper addressing these two types of moisture dynamics**

Resolving the Issue of ‘Moisture Exchange vs. Moisture Diffusion’

- **The solution would lay in measuring or evaluating the two parameters:**
  1. Water content of surface of solid insulation
  2. Maximum water content of inner layers of solid insulation

E.g.: WC of Inner Layers vs. WC of Surface *

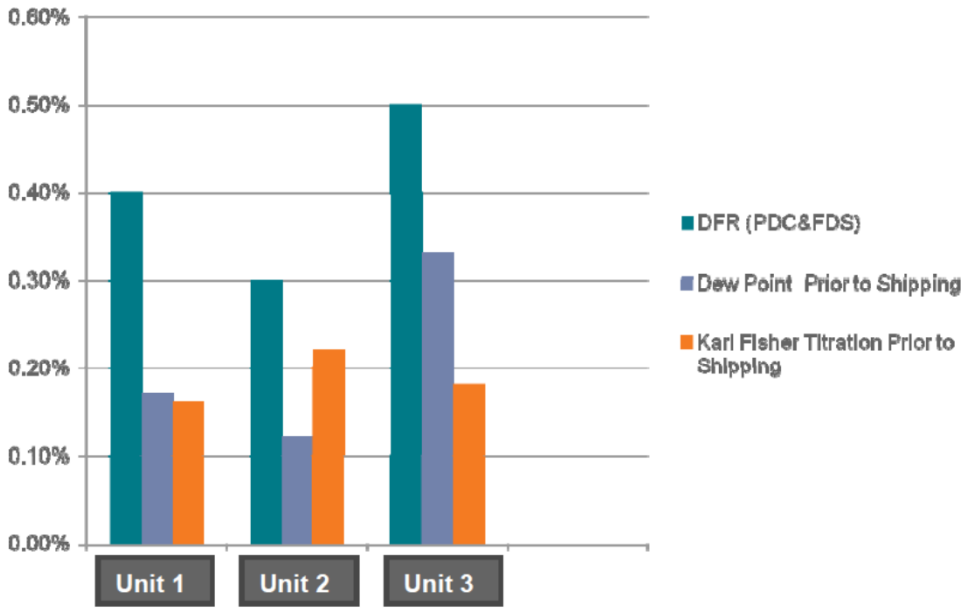
*Ref: Jin Sim, "Moisture in Solid Insulation of Power Transformers", 2012 Weidmann Conference, Las Vegas

How to estimate water content in transformers?

SPX

Dielectric Frequency Response

This "combined" method was tried at a factory on three different transformers with all design information available to build very accurate X-Y model and then compared to other techniques



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Agenda Item 8: Next Meeting

Adjourn