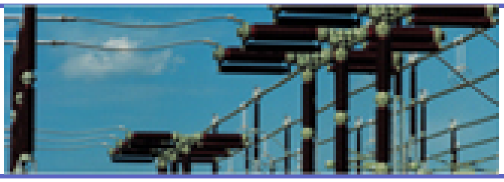
IEEE/PES TRANSFORMERS COMMITTEE

IEEE Transformers Committee Meeting

Montreal, QC

October 23, 2006

Core Overexcitation Requirements Task Force



Authorized by: **Performance Characteristics Subcommittee**

Chairman: Craig Stiegemeier

Secretary: Tim Raymond

Core Overexcitation Requirements Task Force

October 23, 2006 Agenda:

- Two attendance rosters being circulated
- Participant introductions
- Patent reminder
  - The Transformers Committee has posted the IEEE patent requirements on the Committee website and has notified all potential attendees through the Committee Association Management System
  - Members are asked to disclose (identify) any patents that may be related to the work of the TF
  - If anyone believes that any of the work of this Task Force may be patentable or may conflict with other patents, please see the Task Force Chairman or the Performance Characteristics Subcommittee Chairman immediately
  - The Minutes of this meeting will note that IEEE Patent disclosure requirements were addressed and that a request was made for disclosure of any patents that may be related to the work of the TF
- Approve Minutes of Costa Mesa Meeting
- Task Force Charter & Scope:
  - Charter – Performance Characteristics Subcommittee
  - Scope – The impact of excitation overvoltage on the transformer core
- Review Suggested Modifications to Standards based on discussion at the Costa Mesa meeting
- Discuss suggested text for Surface Temperature Limit
- Action item review

Current IEEE Std. C57.12.00-2000

4.1.6 Operation above rated voltage or below rated frequency

4.1.6.1 Capability

Transformers shall be capable of:

a) Operating continuously above rated voltage or below rated frequency, at maximum rated kVA for any tap, without exceeding the limits of observable temperature rise in accordance with 5.11.1 when all of the following conditions prevail:

1) Secondary voltage and volts per hertz do not exceed 105% of rated values.

2) Load power factor is 80% or higher.

3) Frequency is at least 95% of rated value.

b) Operating continuously above rated voltage or below rated frequency, on any tap at no load, without exceeding limits of observable temperature rise in accordance with 5.11.1, when neither the voltage nor volts per hertz exceed 110% of rated values.

In the case of multiwinding transformers or autotransformers, 4.1.6.1 applies only to the specific loading conditions used as the basis of design. These loading conditions involve simultaneous coordination of kVA input and output, load power factors, and winding voltage combinations [see item j) of 4.3.3]. Differences in loading and voltage regulation for various output windings may prevent simultaneous achievement of 105% voltage on all output terminals. In no case shall the kVA outputs specified for any loading condition require continuous loading of any input winding in excess of its rating.

4.1.6.2 Maximum continuous transformer operating voltage

The maximum continuous transformer operating voltage should not exceed the levels specified in ANSI C84.1-1995. System conditions may require voltage transformation ratios involving tap voltages higher than the maximum system voltage for regulation purposes. However, the appropriate maximum system voltage should be observed under operating conditions.

Comments on IEEE Std. C57.12.00-2000

4.1.6 Operation above rated voltage or below rated frequency

4.1.6.1 Capability

Transformers shall be capable of:

a) Operating continuously above rated voltage or below rated frequency, at maximum rated kVA for any tap, without exceeding the limits of observable temperature rise in accordance with 5.11.1 when all of the following conditions prevail:

1) Secondary voltage and volts per hertz do not exceed 105% of rated values.
2) Load power factor is 80% or higher.
3) Frequency is at least 95% of rated value.

This typically results in 10-15% over-excitation for a fully loaded generator step-up transformer

b) Operating continuously above rated voltage or below rated frequency, on any tap at no load, without exceeding limits of observable temperature rise in accordance with 5.11.1, when neither the voltage nor volts per hertz exceed 110% of rated values.

General Observations

- These limits generally work well for distribution transformers
- Are generators capable of producing the calculated Primary-side voltage at full load for large generator step up transformers?
- Many GSU transformers are overexcited, especially during periods of heavy load
- GSU transformers often have different voltage ratings than the generators to which they are connected
- Some utility planners specify “Super Safe” voltage variations
  - Range of voltage variation is, typically, smaller than specified
- Values of load P.F. are typically 0.9 - 0.95 Lagging
- For Autos, system voltages have a limited range of variation
- Often, with higher secondary voltages, the DETC position is not changed, causing higher core excitation

The design voltage sets the size of the core, which has a significant impact on the overall transformer size/cost

Initial suggested changes to IEEE Std. C57.12.00-2000

4.1.6 Operation above rated voltage or below rated frequency

4.1.6.1 Capability

Transformers shall be capable of:

a) Operating continuously above rated voltage or below rated frequency, at maximum rated kVA for any tap, without exceeding the limits of observable temperature rise in accordance with 5.11.1 when all of the following conditions prevail:

1) Secondary voltage and volts per hertz do not exceed 105% of rated values.

2) Load power factor is 80% or higher.

1a) For generator step-up transformers, the primary voltage is equal to the highest generator voltage at full load as specified by the user.

1b) For system tie transformers, the primary and secondary voltages are equal to the highest levels specified by the user.

3) 2) Frequency is at least 95% of rated value.

Red = remove / Blue = new text

IEEE/PES TRANSFORMERS COMMITTEE

Changes to IEEE C57.12.00-2000 after Memphis meeting

4.1.6 Operation above rated voltage or below rated frequency

4.1.6.1 Capability

Transformers shall be capable of:

a) Operating continuously above rated voltage or below rated frequency, at maximum rated kVA for any tap, without exceeding the limits of observable temperature rise in accordance with 5.11.1 when all of the following conditions prevail:

1) **For distribution transformers:**

   a) Secondary voltage and volts per hertz do not exceed 105% of rated values.

   b) Load power factor is 80% or higher.

2) **For generator step-up transformers, the primary voltage is equal to the highest generator voltage at full load as specified by the user.**

3) **For system tie transformers, the primary and secondary voltages are equal to the highest levels specified by the user.**

4) **Frequency is at least 95% of rated value.**

Red = existing text, modified format / Blue = new text

Core Hot Spot Temperature Limit

- **IEEE Standard does not presently have a core hot spot temperature limit**
  - **Standard states that a metallic part not in contact with current carrying conductor insulation, should not attain excessive temperatures under maximum loads**
- **Some recent customer specifications include a limit of 125 – 130ºC for core hot spot temperature under the condition of highest core over-excitation, full load, and the highest ambient temperature.**
- **There is a need for IEEE Transformers Committee to introduce a core hot spot temperature limit**
- **The hot spot is a function of the environment – clarification should be present that the 130ºC limit is based on mineral oil filled transformers**

IEEE Std C57.91-1995 (Loading Guide)

9.2 Limitations

9.2.1 Temperature and load limitations

Suggested limits of temperatures and loads for loading above nameplate rating are given in table 7. Suggested limits of temperature which give reasonable loss of life for the four types of loading are given in table 8.

Table 7—Suggested limits of temperature and load for loading above nameplate power transformers with 65°C rise

Top-oil temperature	110°C
Hottest-spot conductor temperature	180°C
Maximum loading	200%

Table 8—Suggested maximum temperature limits for the four types of loading

	Normal life expectancy loading	Planned loading beyond nameplate rating	Long-time emergency loading	Short-time emergency loading
Insulated conductor hottest-spot temperature, °C	120*	130	140	180†
Other metallic hot-spot temperature (in contact and not in contact with insulation), °C	140	150	160	200
Top-oil temperature,°C	105	110	110	110

*100°C on a continuous 24 h basis

†Gassing may produce a potential risk to the dielectric strength of the transformer. This risk should be considered when this guide is applied refer to annex A.

Modified changes to IEEE Std. C57.12.00

4.1.6 Operation above rated voltage or below rated frequency

4.1.6.1 Capability

Transformers shall be capable of:

a) Operating continuously above rated voltage or below rated frequency, at maximum rated kVA for any tap, without exceeding the limits of observable temperature rise in accordance with 5.11.1 when all of the following conditions prevail:

1) For distribution transformers:

1a) Secondary voltage and volts per hertz do not exceed 105% of rated values.

1b) Load power factor is 80% or higher.

2) For generator step-up transformers, the primary voltage is equal to the highest generator voltage at full load as specified by the user.

3) For system tie transformers, the primary and secondary voltages are equal to the highest levels specified by the user.

4) Frequency is at least 95% of rated value.

b) Operating continuously above rated voltage or below rated frequency, on any tap at no load, without exceeding limits of observable temperature rise in accordance with 5.11.1, when neither the voltage nor volts per hertz exceed 110% of rated values.

In the case of multiwinding transformers or autotransformers, 4.1.6.1 applies only to the specific loading conditions used as the basis of design. These loading conditions involve simultaneous coordination of kVA input and output, load power factors, and winding voltage combinations [see item j) of 4.3.3]. Differences in loading and voltage regulation for various output windings may prevent simultaneous achievement of 105% voltage on all output terminals. In no case shall the kVA outputs specified for any loading condition require continuous loading of any input winding in excess of its rating.

4.1.6.2 Maximum continuous transformer operating voltage (unchanged)

4.1.6.3 Core hotspot temperature limit

To avoid the generation of gasses in the core, the core hot spot temperature should be limited to 130ºC for the condition of highest core over-excitation, full load, and the highest ambient temperature <u>for transformers filled with mineral oil.</u> It should be noted that the calculation for the hotspot is unique and different from the core surface temperature. <u>The location of the core hotspot is typically in the center, or between cooling ducts, of the upper part of the core. Gas generation in this area is caused by overheating of a thin film of mineral oil.</u>

Red = existing text, modified format / Blue = new text

Suggested addition to IEEE Std. C57.12.00

4.1.6 Operation above rated voltage or below rated frequency

4.1.6.3 Core hotspot temperature limit

To avoid the generation of gasses in the core, the core hot spot temperature should be limited to 130°C for the condition of highest core over-excitation, full load, and the highest ambient temperature <u>for transformers filled with mineral oil</u>**. It should be noted that the calculation for the hotspot is unique and different from the calculation core surface temperature.** <u>The location of the core hotspot is typically in the center, or between cooling ducts, of the upper part of the core. Gas generation in this area is caused by overheating of a thin film of mineral oil.</u>

The absolute value (temperature) of the core hotspot is the parameter which influences gassing.

The note concerning mineral oil was added as a result of the discussion during the Memphis meeting.

Suggested Additions – Induction Limits

- **Set induction limits for the core**
  - **The induction at the maximum defined voltage on the system shall be 1.93 Tesla for step lap cores and 1.90 Tesla for non step-lap cores**
  - **Another suggestion was 1.95 Tesla for HI-B material and 1.93 Tesla for RGO material.**

- **This is a design parameter that is best left to the manufacturer to decide upon depending on the customer requirements, core design and the core material**

It was agreed at the Costa Mesa meeting that explicit induction limits should not be part of the standard

These recommendations are for continuous overexcitation limits and Short Term Limits should be considered by a future PCS Task Force

Suggested Additions – Hot Spot Calculation

- It was suggested that a hot spot temperature calculation should be included in the standard
- Following is a general guideline for core hot spot temperature calculations:
  - Maximum Core Hot Spot Temperature =

    Maximum Ambient temperature + Temperature Rise of oil around the region of the core Hot spot at full Load + Core Temperature Rise at maximum core excitation at full Load
    - For three phase, three limb, Core Form Transformers, the suggested method of calculation of Temperature Rise of oil around the region of the core Hot spot is as follows:
      - Temperature Rise of ambient oil =

        7/8 * TOP OIL RISE + 1/8 * BOTTOM OIL RISE
    - For cores where the core hot spot is located at the top of a wound limb, the temperature rise of the ambient oil will need to be equal to that used in the calculation of the winding hot spot temperature
    - For Shell Form transformers, the temperature rise of the ambient oil will need to be calculated for the oil at the inside of the phases at the top of the core

Suggested Additions – Core Surface Temperature Limit

- **Add a limit on the maximum allowed core surface temperature**
- **Suggestions for Surface Temperature Rise of Cores**
  - **The surface temperature rise of the core will not exceed 125ºC at rated load and at the rated MVA of the transformer and with 105 % voltage on the loaded windings at the defined load power factor. The hot spot temperature shall not exceed 130ºC.**
  - **The material used to maintain cooling ducts in the core should be capable of operating continuously at 125ºC.**
- **Temperature limits of the core should be part of the Loading Guide, C57.91**
- **This is outside the scope of this task force**

Ramsis Girgis volunteered to make a first pass at the wording for a surface temperature limit

Suggested Text: Surface Temperature Limitation

- **The core surface hot spot temperature rise over adjacent oil in a certain region of the core is the sum of the following two components of temperature rises:**
  1. **Core temperature rise due to core losses caused by the main flux in the transformer core**
  2. **Core temperature rise due to eddy losses generated by leakage flux impinging into the surface of the core from the windings at this region**

The TF needs to determine if this text is sufficient and/or necessary.

A decision on how to proceed with the information must be made.

Suggested addition to IEEE Std. C57.12.00

4.1.6 Operation above rated voltage or below rated frequency

4.1.6.3 Core hotspot temperature limit

To avoid the generation of gasses in the core, the core hot spot temperature should be limited to 130°C for the condition of highest core over-excitation, full load, and the highest ambient temperature for transformers filled with mineral oil. It should be noted that the calculation for the hotspot is unique and different from the core surface temperature. The location of the core hotspot is typically in the center, or between cooling ducts, of the upper part of the core. Gas generation in this area is caused by overheating of a thin film of mineral oil.

Table 8—Suggested maximum temperature limits for the four types of loading

	Normal life expectancy loading	Planned loading beyond nameplate rating	Long-time emergency loading	Short-time emergency loading
Insulated conductor hottest-spot temperature, °C	120*	130	140	180†
Other metallic hot-spot temperature (in contact and not in contact with insulation), °C	140	150	160	200
Top-oil temperature,°C	105	110	110	110

*100°C on a continuous 24 h basis

†Gassing may produce a potential risk to the dielectric strength of the transformer. This risk should be considered when this guide is applied refer to annex A.

The TF decided that this information should be placed in the hands of the Insulation Life SC responsible for C57.91 for action

Suggested changes:

- Include statement that nameplate must adequately identify the actual capacity to which the transformer was originally designed
  - Standards may specify an overvoltage.
  - If the transformer is capable of a greater or lesser overvoltage than that expected from the general clause of 4.1.6.1 due to the actual capacity of the generator to which it was originally connected, this must be clearly shown on the nameplate.
- Develop a duration of the overvoltage, since the impact of time will influence the development of gas

The TF agreed at Costa Mesa that the core hot spot definition should be referred to PCS WG revising C57.12.00

DGA Guide – C57.104

- Guide does not presently address the mechanism of H_2/CH_4 gas generation due to core overheating in transformers filled with mineral oil
- Recommended Addition to C57.104 during a future revision
  - Add wording about the mechanism where H_2 and CH_4 is produced at low ppm per day with a 6-8 ratio
    - Is caused by moderate core overheating
    - Not harmful to the unit

The TF agreed at the Costa Mesa meeting that this should be referred to Insulating Fluids Subcommittee responsible for revising C57.104 for appropriate action

Summary of Action Items

The TF will meet at the Spring 2007 Meeting to review responses received from the following actions:

- **Performance Characteristics SC (Ramsis Girgis, Chair)**

  WG revising C57.12.00 (Steve Snyder, Chair)

  - **Recommend that the wording for 4.1.6.1 be modified and an addition (4.1.6.3) be included that should aid in the clarification of overvoltage capability and hotspot limits.**
  - **The inclusion of a specific temperature should note that the limit applies only to mineral oil insulated transformers.**
  - **Capacity limits or capabilities should be included on the nameplate that make the transformer design unique.**
- **Insulation Life SC (Don Platts, Chair)**

  WG revising C57.91 (Tim Raymond, chair)

  - **Suggest inclusion of core hotspot temperature limit in C57.91**
  - **Provide the suggested addition of 4.1.6.3 for consideration**
- **Insulating Fluids SC (Rick Ladroga, Chair)**

  WG revising C57.104 Gas Guide (Rick Ladroga, Chair)

  - **Suggest that text should be included to note that moderate core overheating doesn't place the transformer at risk**
  - **A guideline that low levels of gas generation with a H_2/CH_4 ratio in the range of 6-8 should be considered for incorporation into a future revision of C57.104**

Thanks for attending!

Have you seen & initialed one of the attendance rosters?

Does anyone have information on any patents that may be related to the work of this TF?