Purpose:	Commissioning	**Author:**	Charles de Verdun	**Contract : TO COMPLETE**
Breaker	GE AIB HV Circuit breakers	**Customer:**	CEMIG	**Concerned site (s) :**
Date:	06/11/2019			S/S BARBACENA & SIMILAR

CEMIG (Brazil)

Controlled Switching – Commissioning Procedure

Transformer Switching application – RPH2 & RPH3 + Breaker

Purpose of this document:

This document purpose is to detail LIVE TEST step-by-step procedure in case of RPH2/RPH3 commissioning on Power Transformer application.
LIVE TEST is STEP 4 of the complete RPH commissioning procedure. It is mandatory to consider any Controlled Switching Device fully commissioned.
The first 3 STEPS are detailed further in RPH2 or RPH3 service manuals.

Necessary items for RPH LIVE TESTS:

- First 3 steps of RPH commissioning successfully completed
- Availability of a 3-PH voltage transformer on any (HV, MV or LV) of the Power Transformer windings. For RPH3 it shall be connected to RPH3 load voltage input. For RPH2 it shall be available in the control room, close enough to RPH2 P&C cubicle.
- Availability of a 4-channel (or more) oscilloscope with voltage probes (recommended: Picoscope 4424 or equivalent)
- Scientific calculator or equivalent to make pre-arcing time calculation

Contents

1 RPH COMMISSIONING PROCEDURE REMINDER

Basically RPH commissioning task is splitted into FOUR CONSECUTIVE STEPS as detailed below, that might be scheduled continuously or not (depending on the contract and Substation owner constraints):

- **STEP1: "BREAKER TIMINGS measurement":** CB actual timings measurement (using a CB analyzer eg. Megger TM1800 or equivalent device). This requires an access to the HV parts of the breaker, which implies breaker isolation + earthing and implies the availability at site of either a manlift + driver or a ladder.

- **STEP2: "ERECTION":** RPH2(or RPH3) installation into P&C panel, step-by-step safe connection to pre-installed cables, correct assignment checking of RPH3 inputs/outputs and actual system HV phases (L1/L2/L3…). Apply phase rotation procedure, if necessary, for RPH2 (auxiliary contact + RPH output + breaker timings). Software configuration, bypass circuit integrity checking (when applicable), records consistency checking, alarms triggering conditions, etc. S/S level data collection + checking (CT & VT ratio, CT&VT correct coupling, source-side VT and load-side VT connections – when applicable, etc.). External sensor(s) erection & testing. Protection & Control related data collection: breaker failure protection timeout setting, auto-reclosing strategy and timings, BCU interlocking logics, connection philosophy for protection relays (1 contact per pole or 1 contact for 3 poles), insulation between DC source batteries…

- **STEP3: "DRY TESTS":** operate the CB via RPH3 while it is physically still isolated from the network (series disconnectors being OFF), using a fake reference voltage (or an actual one as issued from source-side VT secondary windings if available). Check the RPH records consistency, absence of alarms, acceptable matching between CB mechanical timings as expected and as measured. Test of the correct operation of the bypass circuit if any (both manual bypass and automatic bypass). Test of coils continuity monitoring feature (for RPH3). Reset and initialize the adaptive control algorithm where applicable and check that it gives no algorithmic divergence over ~10 consecutive switchings.

- **STEP4: "LIVE TESTS":** Detailed in the following document

2 RPH LIVE TEST COMMISSIONING PROCEDURE

2.1 *LIVE Test Setup*

Below we will describe the general setup to obtain sine wave recording during LIVE TESTS of significant signals (1-PH REF VOLTAGE & 3-PH LOAD VOLTAGE):

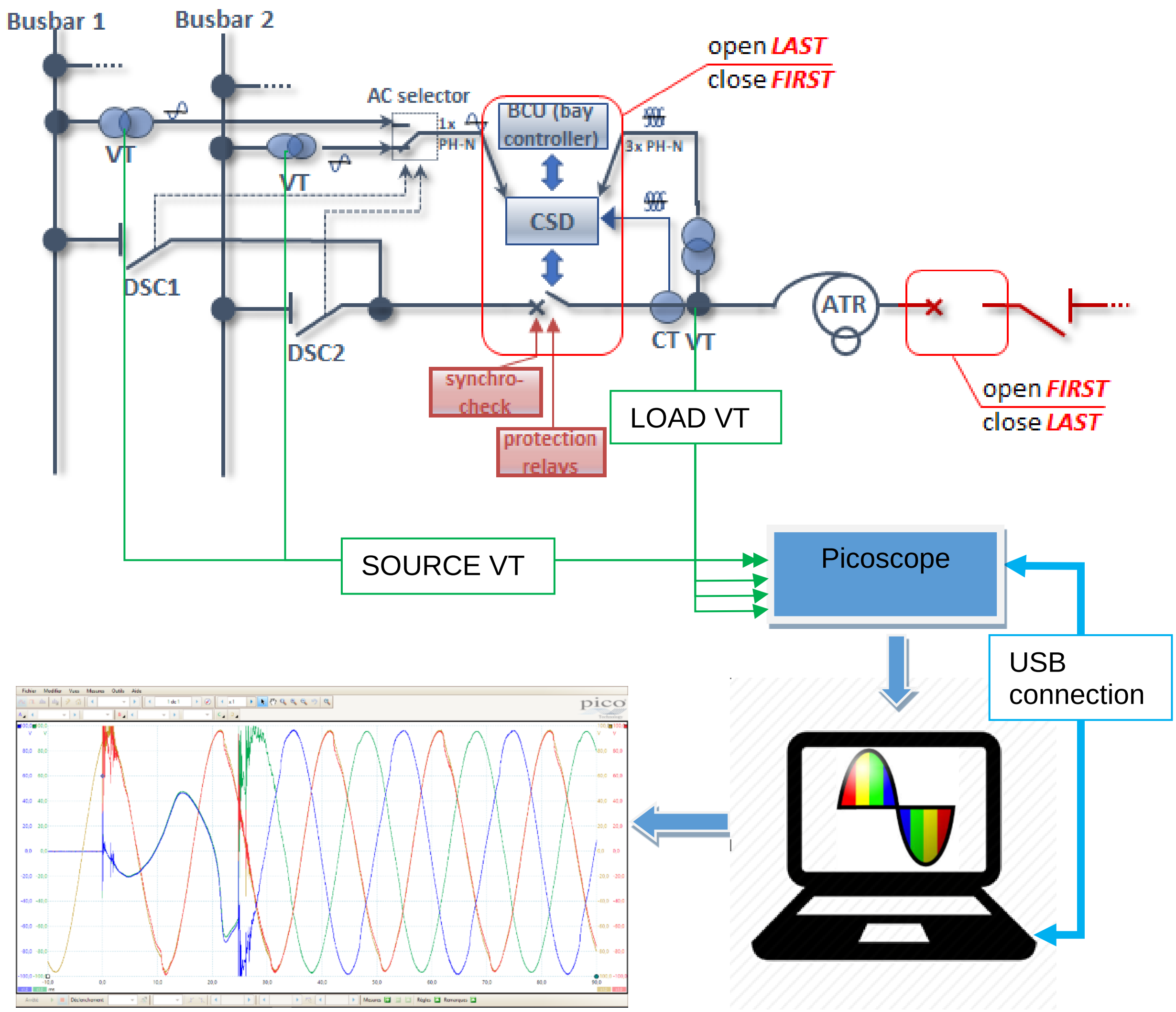


Figure 1 - Setup for LIVE TEST sine wave recording

Recommended Picoscope options (applicable for other oscilloscopes):

- Trigger at 30% of rated peak voltage for first phase to close (load VT secondary voltage rated peak = 115V => **around 40V**)
- Record window of 100ms to capture the whole closing (20% before trigger, 80% after)

2.2 Acceptance criteria

For transformer & Capacitor Bank Inrush current performance criteria we need to calculate what **is the rated peak value** of switching application. This can be done thanks to the formula below :

$$1\ P.U. = \frac{\sqrt{2} * Power\ of\ LOAD\ (in\ kVA)}{\sqrt{3} * Voltage\ level\ (in\ kV)}$$

For instance, in case of a 3 x 60 MVAR 345 kV Power transformer we have:

$$1\ P.U. = \frac{\sqrt{2} * 180\ 000}{\sqrt{3} * 345} = 426\ A$$

In case of Power Transformer 1st energization, we expect first closing to be around 1 P.U.
And the objective is to have final closings consistently and significatively below 1 P.U.

2.3 *LIVE TEST Procedure*

After Setup is complete and we know our acceptance criteria in terms of inrush currents we can start energizing/ de-energizing power transformer and apply our strategy to reach acceptable and repeatable performances:

I. First Close with RPH

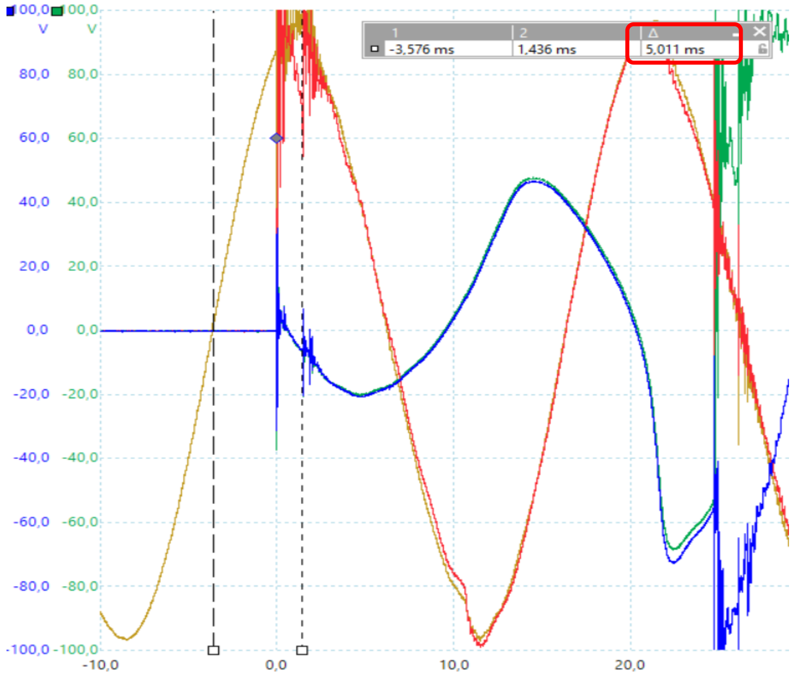
Make sure oscilloscope properly recorded the closing & register inrush current level on each phase.

II. Calculate ΔT

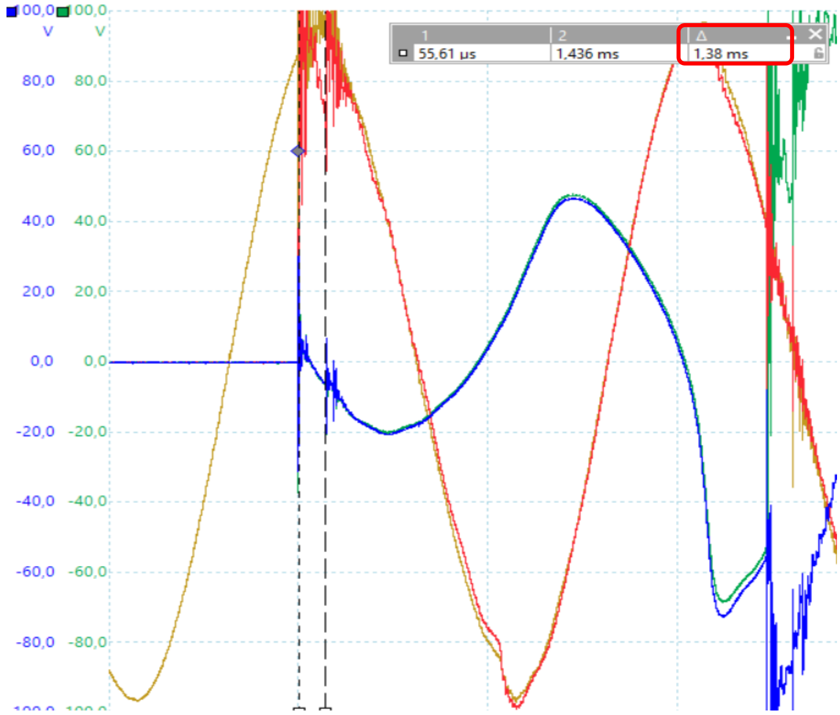
If Inrush current upon closing is over 0.3 P.U. Calculate ΔT, otherwise do not change anything and do another closing.

How to calculate ΔT

- First, mark the maximum of ref voltage in the oscilloscope recording (5ms after zero for 50Hz network, 4.17ms after zero for 60Hz network) with a cursor.



- Secondly, mark the moment voltage appeared on first phase to close (L2 for instance, in red on the image above)



- **Here ΔT= 1,38ms**
  It means that circuit-breaker actually closes before expected moment on the ref voltage sine-wave. Circuit-breaker is faster to close than expected.

To correct this mistake, we will change pre-arcing time instead of changing rated closing times (that correspond to real measurements through CB timing device).

III. Change pre-arcing times from **ΔT** value

How to change pre-arcing times when we have ΔT

Part of the error can be due to **incorrect rated closing times**, part can be due to **mechanical scatter** of the breaker. It is not recommended to modify pre-arcing times with ΔT value directly. If scatter of breaker is +- 0.5ms, we need to substract that from ΔT value to have the correct modified pre-arcing time.

On the previous example, if **ΔT= 1,38ms**, scatter= 0.5ms and initial pre-arcing time is 2.53ms (for instance) then:

$$t_{prearc\ L2} = 2.53 - (\mathbf{\Delta T} - \mathbf{scatter}) = 1.65\text{ms}$$

In the same way, if breaker **is slower than expected** (L2 closes after reference voltage peak), we need to **add** ΔT value to pre-arcing times.

<u>Note:</u> In case there is magnetic (shared magnetic core) or electric (delta connection) coupling between phases, we need to account for it when changing remaining phases pre-arcing time.
Indeed, for the remaining phases we will close at a maximum of phase-phase voltage therefore the circuit-breaker will see a different voltage and pre-arcing time is different.

$$t_{prearc\ L1,L3} = \frac{\sqrt{3}}{2} * t_{prearc\ L2} = 1.43\text{ms}$$

Once the new values of pre-arcing times have been calculated for each phase, report them inside RPH.

IV. Close again the breaker

Check the level of inrush currents on each phase, register it & compare it to the ones of previous closing. Values should be lower.

V. Check oscilloscope recording

Calculate **ΔT** as per above procedure and **verify that its value is within scatter range** (<0.5ms for our previous example).

If **ΔT** >0.5ms, repeat previous steps & calculate new pre-arcing times.
If **ΔT** <0.5ms but inrush currents are not satisfactory (over 1 P.U.) it can be due to error on opening, check opening archives. It can also be due to closing scattering being too high.

3 CONCLUSION

When 2-3 closing are satisfying and below acceptance criteria calculated previously, we can consider RPH to be fully commissioned.
LIVE TESTS on Power Transformer applications are a compromise between severity of acceptance criteria and number of authorized switching (which is not a lot, most of the times). It is up to the client to decide what to prioritize between low inrushes and small number of CLOSE operations.