| | | | | |
|---|---|---|---|---|
| **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*

## *Shunt Reactor 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 Shunt reactor 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 current transformer in the bay. For RPH3 it shall be connected to RPH3 CT 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 & current 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 for OPEN & CLOSE operations*

It is complicated with reference voltage & CT signals to determine the actual opening or closing time. Therefore, we use as a reference point **the OPEN/CLOSE order from RPH to coils** (on reference phase).
Below we will describe the general setup to obtain sine wave recording during LIVE TESTS of significant signals (1-PH VDC ORDER OUTPUT & 3-PH CURRENT) when only a 4-channel oscilloscope is available:

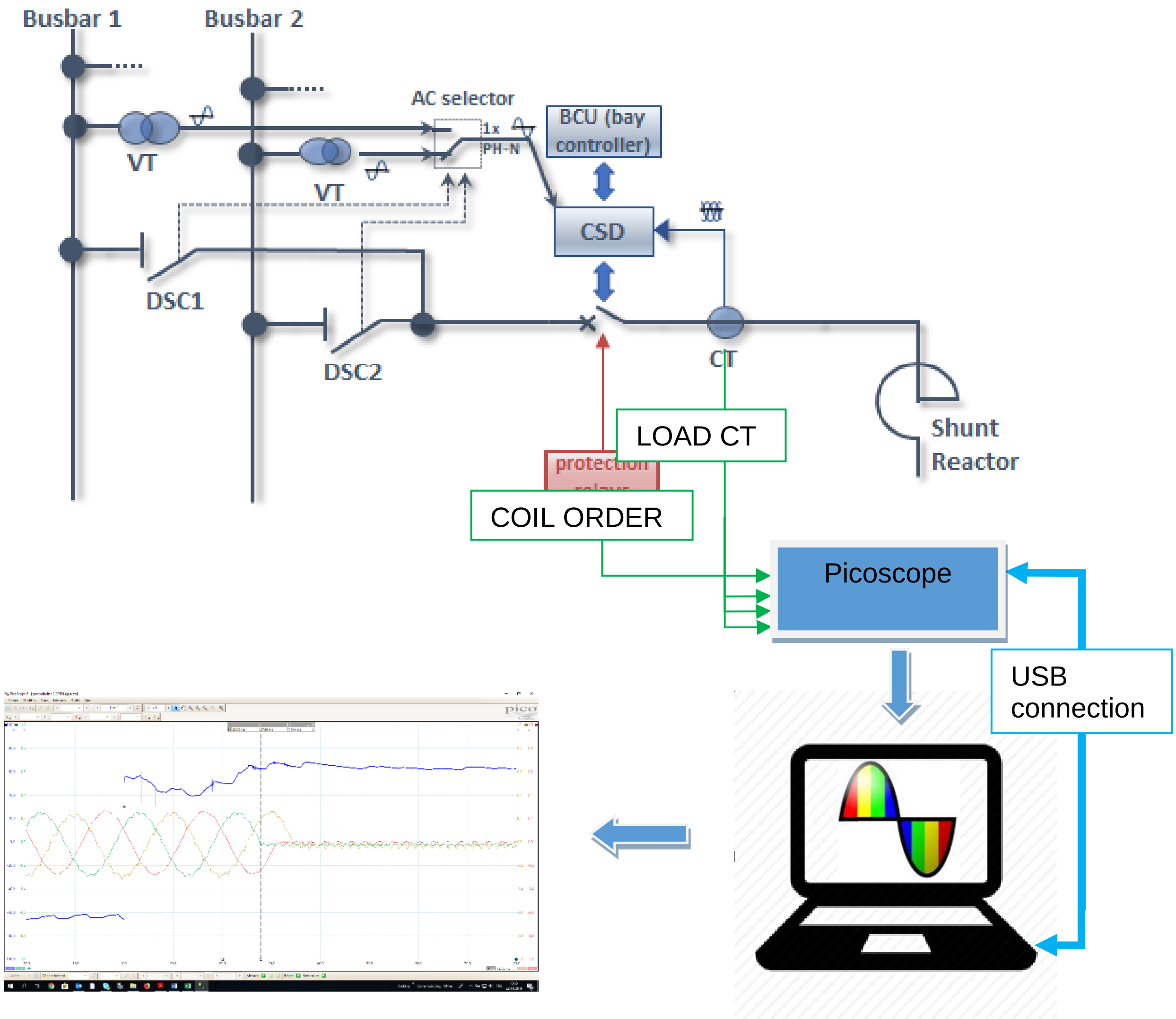



**Figure 1 - Setup for LIVE TEST sine wave recording**

**Connection:**

- Connect one voltage probe to RPH2/RPH3 reference phase output OPEN order (resp. CLOSE order for CLOSE operations)
- Connect 3 current probes (ex: picoscope TA018) to the 3 CT phases

**Recommended Picoscope options (applicable for other oscilloscopes):**

- Trigger at 60% of rated peak voltage for reference phase (for OPEN/CLOSE order to coils DC rated value to ground ~= 65V => **around 40V**)
- Record window of 100ms to capture the whole opening (20% before trigger, 80% after) & 150ms to capture whole closing.

## 2.2 Acceptance criteria

### 2.2.1 For OPEN operations

General acceptance criteria for Opening operations on shunt reactor application is the absence of reignition on one or multiple phases (i.e: current breaks when it is supposed to).
To determine this, we need a reference (open order to coils) and we need to compare expected opening time vs opening time as measured through oscilloscope recording.

### 2.2.2 For CLOSE operations

For Shunt reactor 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 shunt reactor we have:

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

The objective for shunt reactor closing is to minimize DC transients that can introduce perturbations to the surrounding equipments. We want inrush values to be as close as possible to rated peak values of current.

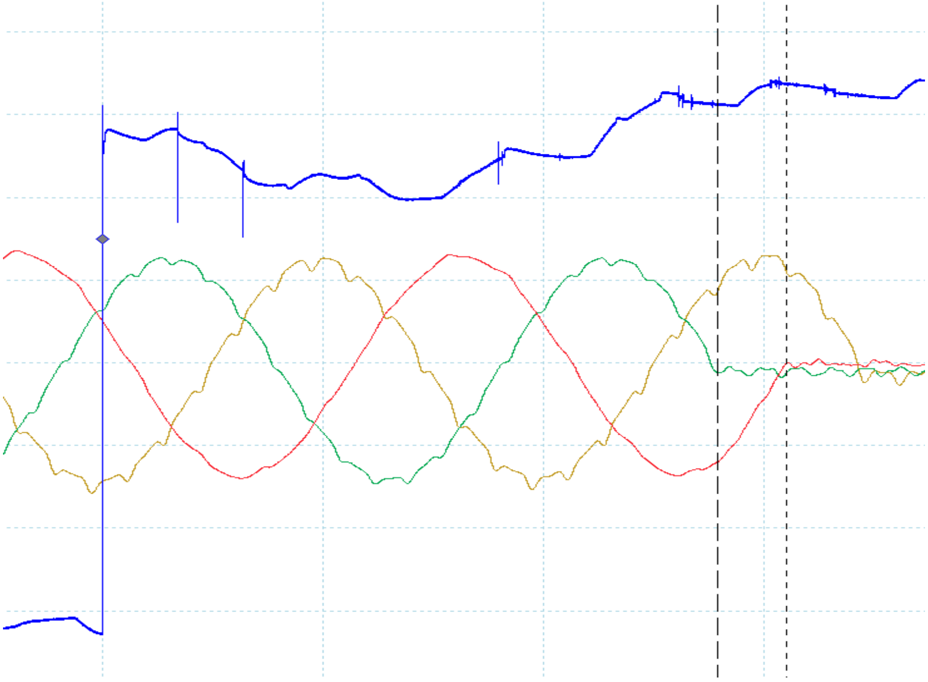
## 2.3 LIVE TEST Procedure

After Setup is complete and we know our acceptance criteria we can start energizing/ de-energizing shunt reactor and apply our strategy to reach acceptable and repeatable performances.

### 2.3.1 OPEN

#### I. First OPEN with RPH

Make sure oscilloscope properly recorded the OPENING, check that phases OPEN in the expected order depending on the application (grounded or ungrounded shunt reactor, 3 legs or 5 legs).
For instance, on a 60 Hz grid, on a grounded 5-leg shunt reactor check that each phase OPEN in the proper order with a 2.86ms (60°) timeshift between each phase.



If one of the phases does not OPEN when expected, check for

- Swap in OPEN circuit wiring
- Swap in CT connection.
- Ref voltage is not coming from the phase we expect (120° timeshift – dangerous)

If one of the phases is opening 8.6 ms after the target ([forecasted OPEN time + arcing time]), it means there is a **reignition.** All configuration & cabling **must be reviewed** (including CT/VT injection).

If it OPEN in the correct order at [Measured OPEN time]=[forecasted OPEN time + arcing time] after the OPEN order to coils, then it is a correct OPEN (no reignition).

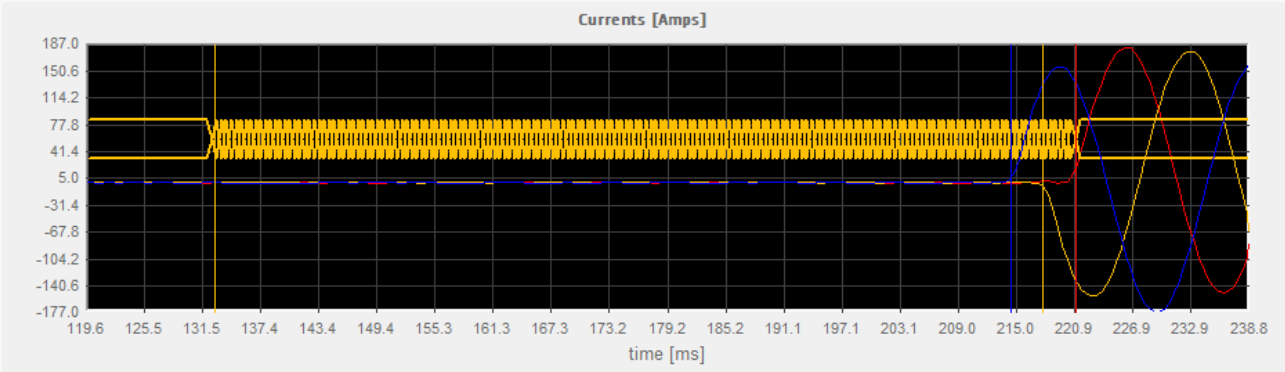
#### II. Other OPEN operations

Several OPEN operations (at least 5) must be made in order to validate the correctness & stability of the system & its configuration.

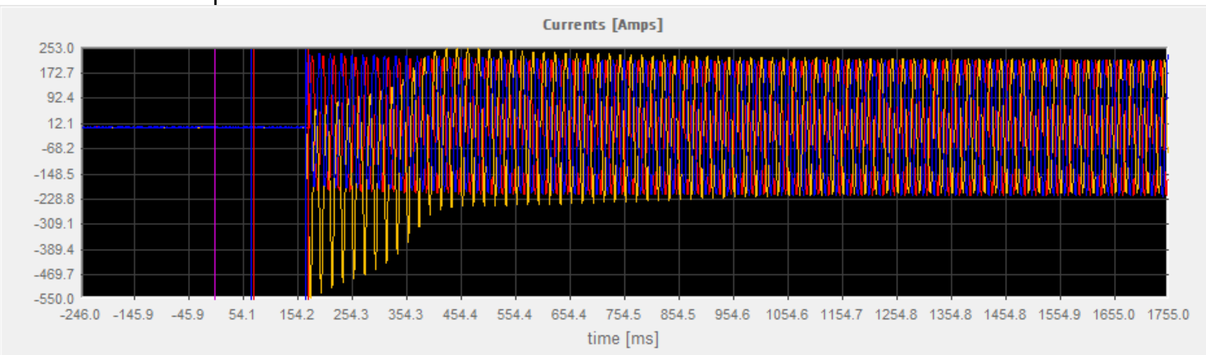
## 2.3.2 CLOSE

### I. First CLOSE with RPH

Shunt reactor CLOSING LIVE tests are quite simple. We expect current to start flowing at[forecasted CLOSE time - prearcing time] ms after CLOSE order to coils.
Below, reference phase is L2 (yellow), and [forecasted CLOSE time - prearcing time] is close to the moment current actually start flowing. For other phases, we have a 120° timeshift. This is a GOOD CLOSE with limited DC transient.




Below is an example of bad CLOSE on shunt reactor:




In this kind of situation, yellow phase did not close on the target. Current appeared earlier or later than expected:
This can be due to:

- Mechanical error
- Wrong closing times
- Drop of voltage in DC supply when order is sent
- Wrong targets

To have a better closing, it is necessary to:

- Check configuration, cabling & if signals are the ones expected (CT, VT)
- If signals are correct, adjust pre-arcing time so that breaker closes when expected.

| Situation | Adjustment of pre-arcing time |
|---|---|
| Circuit breaker closes after it is expected (too slow) | Reduce pre-arcing time ⇔ Send the close order earlier |
| Circuit breaker closes before it is expected (too slow) | Increase pre-arcing time ⇔ Send the close order later |

### How to calculate ΔT

To determine the amount of correction needed, it is necessary to **compare** the moment current was expected to flow VS the moment current started flowing. We will call this error **ΔT.**

We have:

- moment current was expected to flow ⇔ CLOSE order output + Forecast – Prearcing time
- moment current started flowing ⇔ CLOSE order output + current not zero on oscilloscope recording

**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= 1ms**, scatter= 0.5ms and initial pre-arcing time is 2.5ms (for instance) then:

$$t_{prearc\ L2} = 2.5 - (\mathbf{\Delta T} - \mathbf{scatter}) = 2\text{ms}$$

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.

### II. Close again the breaker

After pre-arcing time modification (if necessary), check the level of inrush currents on each phase, register it & compare it to the ones of previous closing. Values should be lower.

### III. 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 DC inrush currents are not satisfactory (over 1.5 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 4-5 OPENINGS & CLOSING are satisfying and below acceptance criteria calculated previously, we can consider RPH to be fully commissioned.