Advanced Tap Changer Control of Parallel Transformers based on IEC61850 GOOSE Service

Author: Jose Miguel Yarza
Co-author: Roberto Cimadevilla (presenter)
Overview

- Interest of the application
- Aim of Automatic Voltage Regulator (AVR)
- AVR working with Parallel Transformers
- IEC 61850 based solution
- RTDS tests
Field of Application

Transmission and Distribution substations with 2 or more power transformers coupled on LV busbars

Roberto Cimadevilla

2013 CIGRE CANADA CONFERENCE
Growing interest

Looking to the future, we can foresee:

- More demanding requirements to control Q
- Higher integration of Distributed Generation (DG)
- AVR (automatic voltage regulator) + OLTC (on-load tap changer) are relevant in order to keep the voltage profiles
- AVR needs to work cooperatively with capacitor and reactances to control voltage and Q
Purpose of AVR

- AVR commands the OLTC to keep stable the LV busbar voltage according to a set-point, compensating voltage variations due to:
  - Voltage variations on transmission system
  - Load and/or cos\(\phi\) variations on the feeders
  - Line impedance variations seen from the substation
Purpose of AVR

- Settings:
  - Voltage set-point ($V_{CON}$)
  - Insensitivity degree (GI)
  - Delay time (T)
For the right performance of power transformers in parallel, the coordination between AVR is a MUST:

- Master-follower method: for identical or very similar power transformers
- Circulating current method: for power transformers with different characteristics
Master-follower method

- **Operation principle:**
  - One AVR behaves as master
    - Master AVR controls the busbar voltage with the traditional criteria for this function
  - Rest of AVR (followers) follow master’s decisions to rise or lower the tap

- **Implementation modes:**
  - Following the “current” tap of master AVR (typically admitting an offset)
  - Following **commands** of master AVR’s
    - As drawback, it might keep an unbalance situation if taps are not normalized from the beginning
  - Centralized (RTU, PLC) or decentralized
Exchange of information between AVR is essential for the implementation of this method. For example:

- Master / follower role
- Taps
- Rise / lower commands
- Success or failure of the command
- Parallel group 1, 2,… (based on breakers and isolator status)
- Blocking signals
Circulating current method

- Unequal tap positions between the parallel transformers create a circulating current
- The circulating current is mainly reactive because transformer impedance is basically inductive
- The operating principle is based on minimizing the circulating current
Circulating current method

\[ I_{\text{circulating}} = \frac{V_{\text{TAP}}}{X_1 + X_2} \]
There are some basic data that needs to be exchanged between AVRs:

- A magnitude that allows determining the reactive power flow between transformers (Q, I)
- Parallel group 1, 2,… (based on breakers and isolator status)
- Blocking signals
Conventional solutions are normally based on wiring or proprietary protocols.

New solution uses a decentralized scheme based on communication between AVRs by means of GOOSE messages.

Each AVR will subscribe to the GOOSE of the rest AVRs.

GOOSE Control Block dataset will contain:
- Analog signal: Reactive power
- Digital signals: tap, parallel group, blocking signals, etc.

Control for up to, i.e., 5 transformers in parallel.

\[
I_{\text{circ}} = I_1^m \cdot R_T^m \cdot \text{sen} \phi_1 - \left( \frac{Q_2^m + Q_3^m + Q_4^m + Q_5^m}{V_1^m \cdot R^m_T} \right)
\]
RTDS Testing for 3 parallel trafos.
10% Secondary Voltage Reduction
Start with Different Taps
Conclusions

- A solution based on IEC61850 GOOSE message for both the circulating current and master-slave methods has been described.

- The advantages regarding to the conventional solution are:
  - Cost reduction due to less wiring and simpler engineering (faster commissioning and less maintenance)
  - Open solution that makes use of a more and more familiar standard
  - Flexibility that allows customizing the final solution easily
  - Reliability provided by:
    - GOOSE messages (Repetition-failure detection, information about “quality”, low transmission time)
    - Redundancy protocol (PRP, bonding)
Thank you

Roberto Cimadevilla
r.cimadevilla@ziv.es

Jose Miguel Yarza
jm.yarza@ziv.es