Why AC transformers “Complain” Noisily About DC Current

Ron Sharp
New Moraga Sub Bank #3

- 230kV/115kV
  - 1 phase auto
  - core form
  - 134MVA per phase
Noise Complaints Begin

- November 2005 – Moraga Sub neighbors start complaining about noise from substation after Bank #3 was energized.
- PG&E measurements confirmed that Bank#3 was above specification.
Mysterious Noisy Transformer

- Not typical 120 Hz hum
- Bank #3 has “Buzz” at 300 Hz and higher
- Produces up to 85dB(A) and varies throughout day
- Transformer was designed to be 76dB(A) or less and stay out of saturation.
- Transformer at factory tested at 66dB(A) at .3 m distance w/o fans
Sound Pressure Harmonics with and without DC Current
134 MVA Single Phase Transformer (B core rated AC = 1.73 T)

Total Sound Pressure
without DC = 67 dB(A)
with 1A DC = 82 dB(A)

Odd multiples of 60 Hz only at DC
Investigation

- Raised Bk#3 NL taps
  - only slight sound reduction
- Field testing found low-level dc current from the system flowing through transformer neutral.
- Blocking dc current at neutral resulted in a short term (5 minutes) drop in noise (8-10dB(A))
We believed the high noise was being caused by DC current, but didn’t know how to stop DC.

- The dc current causes offset flux in the core and partial (1/2 cycle) saturation.
- Same as GIC effect on transformers.

Through switching tests, primary source of dc current was isolated to 115kV source.
Transformer Operating Characteristics

- **Xfmr Without DC**
  - Operating Region
  - \( \Phi \approx 5 \text{ Amps} \)

- **Xfmr With DC**
  - Operating Region
  - \( \Phi \approx 25 \text{ Amps} \)
  - \( \Phi \approx 5 \text{ Amps} \)
Choices for Fixing Problem

Two Concerns:

a) Noise in the neighborhood
b) Possible loss of life for transformer from vibration

1) Build sound walls
2) Change out transformer
3) Active noise cancellation
4) Attempt to reverse saturation with active flux offset control
Short Term
Rented Sound Blankets
Help from up North

- Learned that Bonneville Power Administration (BPA) had dc caused transformer noise problem.
- Contacted them and learned of their method of dc injection to counter stray dc flow.
  - Applied at one location near Seattle on new 500/230kV transformer
Flux Offset Controller

- Uses a low-ohm capacitor to pass ac current but block dc current in the neutral
- Detects when system dc current has caused offset flux to create transformer vibration
- Injects approx. 4 A dc current into neutral of bank and “pushes” flux back out of the saturation region
- Virtually all injected current is expected to stay in Moraga Substation and return to the controller via the ground mat.
Expected Impacts of FOC

- The injected dc current will add to the system dc current entering the Moraga 230kV and 115kV bus.
- The injected current returns to the FOC through the windings in banks 1, 2 and 5.
- Monitors for dc current have been installed in the neutrals of Banks 1, 2 and 5.
- Banks 1 and 2 are single phase autos and Bank 5 is a 3-phase, 3-leg, core-form and should not be affected by dc current.
Moraga Substation Bk#3
Main FOC System Components

- **ISP** – Isolator / Surge Protector: Commerically available self-protected capacitor, 88 mΩ, 18 V breakover.
- **Power Supply** and Polarity-Switching 10 A max. Voltage or Current Controlled
- **Bypass Breaker**: Single-pole vacuum switches
- **Vibration Sensor**
- **Controls and Protection**: GE-N60 Programmable Relay
Sno-king Bank Vibration Before & After FOC

db A - vs - Time
5-min SCADA Data for 3 Days

Feb-05  May-05
What's next?

- To date, operational history looks very good.
- Modified controls for high system voltage.
- So far, no detectable effect on adjacent transformers or system.
- Try to find source
- Other banks?
- ~~~~ Thanks for listening! ~~~~~~