NAME: Dzevad Pita
COUNTRY: Australia
REGISTRATION NUMBER: 4503

GROUP REF.: SCA3
PREF. SUBJECT: PS3
QUESTION N°: Q14

Introduction

Controlled switching is a method used for eliminating harmful transients via a time-controlled switching operation. Closing or opening commands to the Circuit Breaker are delayed in such a way that making or contact separation will occur at the optimum time instantly related to the phase angle.

- Switching transients causes stresses on:
    - Circuit breakers
    - System insulation
    - Power transformers
    - Capacitor banks
    - Reactor banks

Control switching in Australia and New Zealand has been implemented for approximately 25 years to the following applications:

- Shunt capacitors/Harmonic filters
- Shunt reactors
- Transformers
- Overhead lines

Suitable Types of Circuit Breakers

- Single pole operated (one mechanism per each CB pole)
- Three pole operated, staggered (one mechanism CB)
- Single pole operated circuit breakers give optimum results in flexibility and are common place
- Three pole operated circuit breakers intended for controlled switching are mechanically staggered and can only perform limited control
    - Mechanically dependant poles
    - Best switching instant is always a compromised solution (dependant adaptation)
    - Observe circuit breaker placement
    - Switching of three-pole operated staggered breaker is possible on a case-by case basis
- Three pole operated breaker **non staggered** breaker cannot be used for POW switching

POW Control Aplications

1. Capacitor Banks or Filter Banks

- Main concern (closing): transient overvoltages or high inrush currents
    - Strategy: Energisation at zero voltage

- Main concern (opening): risk of reignition or restrike
    - Strategy: avoid short arcing times
- Capacitor Bank configuration
    - Star connected
    - Delta connected
- Grounding arrangement
    - Neutral grounded
    - Neutral isolated
- Control switching phase order dependant on earthing arrangement
    - **Grounded bank** -first phase to close at voltage zero followed by remaining two phases to close with 120/240 el.deg delay (3.3/6.6ms)
    - **Isolated bank** - two phases to close at the same time and third phase with 5ms delay

2. Shunt Reactor Banks

- Main concern (opening): Reignitions
- Eliminate reignitions when de-energised
- Reactor cores usually have air gaps
    - Prevents strong saturation
    - More linear than transformer cores
    - Residual flux can be disregarded
- Reactor configuration
    - Three separate single-phase units
    - Complete three-phase unit with common core and tank
        - Five-leg design with (phases magnetically independent)
        - Three-leg design (magnetically dependant, magnetic coupling between the phases)
        - Y or D-connected
- Grounding arrangement
    - Neutral grounded
    - Neutral isolated
- Control switching phase order dependant on type of core, winding and earthing arrangement

3. Power Transformers

- Transformer different designs and situations which have to be considered
    - Three-phase unit with common core and tank, or separate single-phase units
    - Three-phase cores may be of three-leg or five leg design
    - Windings may be arranged in ‘Y’- (grounded or ungrounded) or ‘D’- configuration. Tertiary, ‘D’- connected, windings are sometimes utilized in cases with; Y’ connected primary and secondary windings

- The individual phases in the transformer may influence each other in the following cases:
  - Ungrounded neutral on the switching side
  - Three-leg core
  - 'D' – connected secondary or tertiary winding
- Main concern is: Minimise inrush current during transformer energisation
- Transformer energisation at **voltage peak**, single phase unit - no residual flux
- Transformer energisation with residual flux – Determine the residual flux and energise when prospective flux meets the residual flux
- There are three possibilities for implementing controlled power transformer switching:
  1. Ignore the residual fluxes and energise at the instants that are ideal as if the residual fluxes zero – straight forward method but not giving optimum result.
  2. Take the residual fluxes into account by controlling the opening that precedes the energising and adjust the making instants accordingly to fit for the "locked" residual fluxes.
  3. Use a controller that measures the power transformer winding voltages and calculates the core fluxes (by integration of the voltages) and having a controlled closing algorithm accordingly.

Summary

- Capacitor banks and harmonic filter banks
  - Issues - Transient overvoltages during the energisation is critical
  - Grounding arrangement important for control switching
  - Controlled **closing** strategy is to close at voltage zero across the CBs contacts
  - Controlled **opening** strategy is to avoid short arcing times resulting in reignitions or restrikes
- Shunt Reactors
  - Issues: Re-ignition as result of reactor de-energising is critical
  - Reactor core and winding arrangement important for control switching
  - Controlled **opening** strategy is to select arcing time long enough to avoid re-ignition
  - Controlled **closing** strategy is to energise at instants resulting in flux symmetry
- Power Transformers
  - Issues – Inrush current during the energisation is critical
  - Transformer core and winding arrangement important for control switching
  - Common strategy is to energise transformer from the side having the highest voltage however energisation can be performed from the lower voltage side which is less common
  - Controlled **closing** strategy is to energise no-load transformer at instant resulting in flux symmetry by taking residual flux into account
  - If the residual flux can be ignored energising instants at the voltage peak

    - If the residual flux cannot be ignored, control opening prior to controlled closing is good method to determine residual flux
    - If the residual flux is included strategy is to energise at instants when the prospective flux equals the residual flux
    - Controlled **opening** strategy is important as it serves as support for the consecutive controlled closing operation
- Circuit Breakers
    - Single Pole operations proffered, however three pole staggered could be used in some applications (Capacitor and filter banks and reactors)
    - Poles mechanically dependant for staggering circuit breakers, harder for adaptive control
    - RDDS important circuit breaker characteristic to determine pre-arcing time required for closing operation
    - RRDS important circuit breaker characteristic to determine arcing time for opening operation
- Compensation
    - Ambient temperature
    - Control voltage
    - Operating drive store energy level compensation
    - Idle time compensation
- Adaptive control
    - Adaptive control will adjust the internally created waiting time when needed
    - For controlled closing use adaptive control by detection of voltage onset instant(s), current starts instant(s) or current change instant(s) in the main circuit
    - For controlled opening (or closing) the contact separation instant can be supervised if current is flowing after the circuit breaker pole is supposed to have interrupted the current