POWERGRID’S EXPERIENCE ON
CONTROLLED SWITCHING
OF 765KV TRANSFORMER & REACTORS

Deo Nath Jha
POWERGRID
AC Transformers Based on Voltage class

132kV: 13 Nos.
220kV: 47 Nos.
400kV: 412 Nos.
765kV: 280 Nos.

Total: 752 Nos.
Reactors Based on Voltage class

- Tertiary: 16 Nos.
- 220kV: 12 Nos.
- 400kV: 598 Nos.
- 765kV: 564 Nos.

Total: 1190 Nos
**Principle**

- **Controlled switching:**
  - Operation of a switching device at a specific, pre-determined point in relation to the power frequency current or voltage

  *Equivalents: Synchronized switching / Point-on-Wave switching*

- **Controlled switching system**
  - Combination of circuit-breaker, controller and necessary sensors and auxiliary equipment required to achieve controlled switching
Need for Controlled Switching

- High Power Equipment requires extra safe guards
- Prevents re-ignition of arc during opening
- Controls in-rush current/magnetizing currents during charging
- Reduces stress on electrical devices, since fewer transients develop during circuit breaker switching.
Synchronous Closing Operation—Reactors

- Voltage phase A
- Zero crossing detection
- Manual closing command
- Synchronised closing command to the closing coil
- Breaker contacts

\[ t_{\text{breaker}} = f(\theta, p, U_{\text{DC}}) \]
Synchronous Opening Operation–Reactors
Controlled Switching Opening Reactors

- Reference voltage
- Closing command
- Output opening command
- Opening command
- Target opening point
- Arc extinction moment
- Arcing
- Sample analog values of controlled side
- Contact state
  - Closed
  - Opening
  - Opened
- N × T + Topntarg
- Topnwait
- Topnlag
- Topn
- Tarcing
- Time (t)
Power transformer switching issue

Closing on no load transformer

The objective of this type of synchronisation is to limit the inrush currents in the transformer.

These currents can be equal to the transformer fault currents (10 pu).

Synchronisation is carried out by electrically closing at peak voltage, on the source side, (or more complex configurations under 3-phase operation).

synchronisation on an inductive circuit is, generally, carried out at maximum voltage.
Power transformer inrush currents

Saturation characteristics of Transformer

Random instant of energisation (core flux high level)

⇒ High inrush currents
Typical Waveform of Transformer

Closing on off-load transformer

Single phase representation

1. Time delay
2. Target
3. Circuit breaker operating time
4. Pre-arcing time

Time
Large flux grading,
Transformer core driven into saturation,
→ High inrush currents
Optimized switching sequence

Optimal energizing sequence

Energizing transformer when: Prospective flux = Remanent flux

Needs remanent flux measurement to be achieved
Case Study – I (High Switching Over Voltages during tripping)

- Regular Increase in Lightening Arrestor of a Shunt Reactor counter noticed
- Circuit Breaker parameters checked and found to be as per specifications & no drift
- Signals from CT & CVT at input of CSD relay checked and it is found that the phase difference is $83^\circ$ against $90^\circ$
- The timing of CSD relay is accordingly changed by 0.5 ms and reactor is again taken in service
Case Study – II (High inrush current during closing of Transformer)

- During charging of ICT, high humming noise was noticed– suspicion of large inrush current
- Charging waveform shows high current at time of charging 1000–1200 Amps
- CSD relay was considering equal pre-arcing time for all phases
- However with closing of the first pole there is transformational voltage in other phases
- CSD relay ‘tweaked’ to allow adequate pre-arcing time for other poles.
- New waveform shows reduction in charging current to nearly 20 Amps
Case Study – III (High inrush current during closing of Bus Reactor)

- Similar incident of high inrush during closing of Bus Reactor observed
- This time problem is due to incorrectly configured relay
- Relay time corrected to adjust as per CB parameters
Max. permissible Limit (Imf)

Actual setting for B-Pole closing

Current exceeding permissible limit (Imf)

B-pole Closed after a delay of one cycle
Max permissible Limit Imf

B-Pole Closed at set:time and Imf is within Limits.
Key Takeaway

- CSD is an important tool for switching transformer/reactors in a controlled manner.
- Absence of CSD poses high risk to key equipment.
- Incorrect relay settings can also cause problem to expand exponentially – Correct setting to be ensured.
- Operation to be regularly checked/analyzed.
Thank You