Transformer limited faults: need to modify the Preferred Ratings for Definite Purpose Circuit Breakers for Fast TRV in the draft revision of IEEE C37.06-200x

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Transformer limited faults

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Transformer limited faults

Introduction

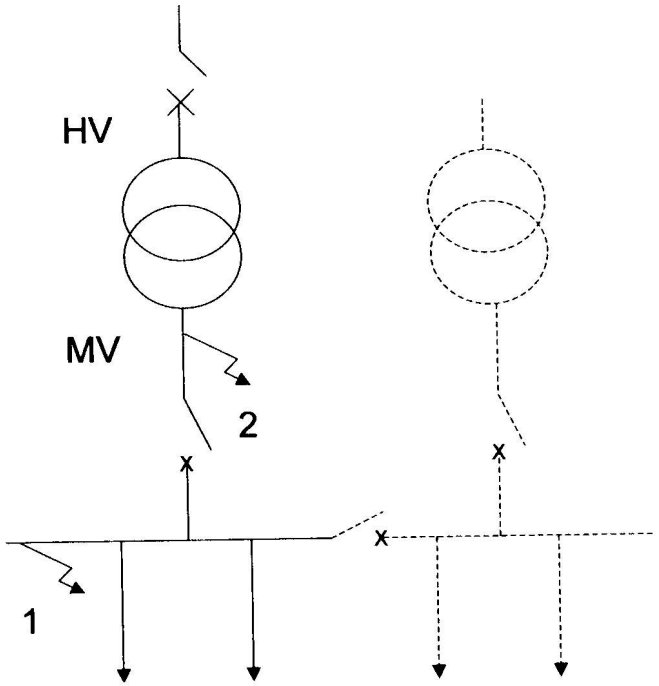
Severe TRV conditions may occur when there is a short-circuit immediately after a transformer without any appreciable capacitance between the transformer and the circuit breaker. In such case, the rate-of-rise of transient recovery voltage (RRRV) may exceed the values specified in the standards, this is due to the fact that the capacitances to earth of transformers are relatively small (i.e. 3000 pF for 550 kV and 800 kV applications).

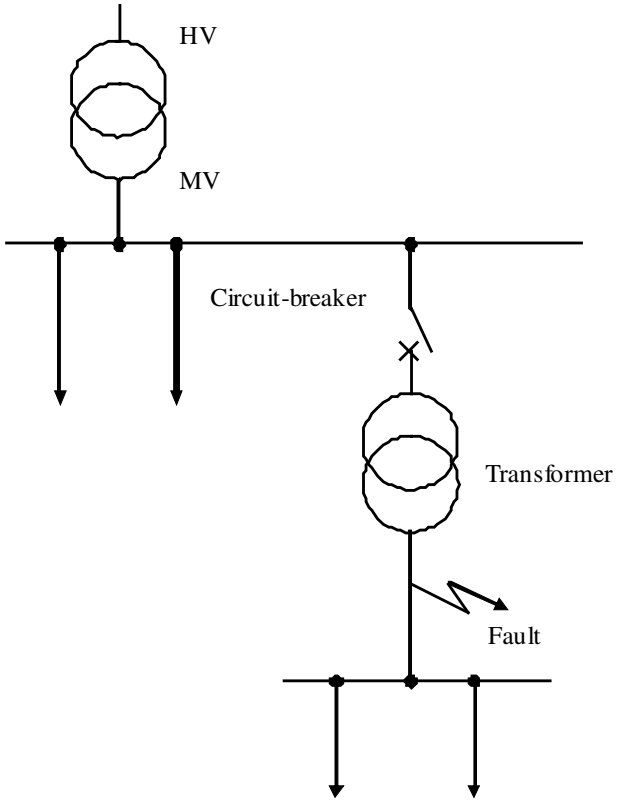
The corresponding natural frequency of the transformer leads to a TRV having a rate-of-rise that is two or three times the value for a terminal fault with the same short-circuit current.

Two cases of transformer limited faults can be met, with the circuit breaker and the fault on the same side of the transformer or on opposite sides of the transformer.

Transformer limited faults

- Two cases of Transformer-limited faults (TLF)





Transformer secondary fault & Transformer fed fault

Transformer limited faults

Standardization in draft 8.3 of IEEE C37.06-200x

In draft 8.3, TLFs are covered in section 9 : Preferred Ratings for Definite Purpose Circuit Breakers for Fast Transient Recovery Voltage

"Circuit breakers identified by the manufacturer to be definite purpose for fast transient recovery voltage rise times applications shall be capable of interrupting short-circuits with TRV parameters as specified in the following tables 17 to 22.

Test current is 10% and 30 % of rated short circuit current value in draft 8.3, it is 7% and 30% in IEEE C37.06.1-2000 "Guide for High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis Designated "Definite Purpose for Fast Transient Recovery Voltage Rise Times".

TRV frequencies are under review by a Task Force of the IEEE Switchgear Committee. Fault currents were not reviewed before introduction in the draft of IEEE C37.06, it is one of the purpose of this contribution to do this review.

Context

- CIGRE WG A3-22 is in presently studying the requirements for circuit breakers in UHV systems and 800 kV systems.
  - In the majority of cases it is found that the TLF current is less than 11 kA and it is not felt relevant to link this fault current to 30% of the rated short-circuit current.
- Transformer limited faults are covered in the new IEEE C37.016 for Circuit Switchers
  - definition in 3.6
  - rating in 4.13

Transformer limited faults

Examples of TLF current in 550 & 800 kV systems

- **Typical case of a 2000 MVA transformer with a short-circuit reactance of 14% (as in ESKOM system)**
  - Assuming a source of infinite power

$$\frac{2000}{0.14 \times 800 \times \sqrt{3}} = 10.3\ kA$$

  - For a circuit breaker rated 63 kA, it represents **16 %** of its rated short-circuit current, if we neglect the reactance of the supply, it will be less if the reactance of the supply is taken into account.
- **Case of the 735 kV system of Hydro-Quebec**
  - 735/230kV x=20% 370 MVA Auto-transformer single phase 53 GVA at 765 kV and 22 GVA at 245 kV
  - 735/315 kV x=20% 550 MVA Auto-transformer single phase 53 GVA at 765 kV and 29 GVA at 330 kV
  - At 735 kV level, maximum fault current is **6 kA**.

Transformer limited faults

Examples of TLF current in 550 kV & 800 kV systems

Case of TEPCO (Japan) 550 kV system

- Transformer short-circuit reactance is 14 to 18 %
- 1500 MVA transformer (14%, C=3500 pF) : I= **11.4 kA** (**18%** of 63kA) and f= 9.9 kHz
- 1000 MVA transformer (14%, C=3500 pF) : I= **8 kA** (**12%** of 63 kA) and f= 8.1 kHz
- TEPCO specification : I= 11 kA, RRRV = 20 kV/µs, Uc= 780 kV

two significant differences with the IEEE draft:

current is 11 kA and not related to the rated short-circuit breaking current (IEEE draft has 30% of 40 kA and 63 kA),

the peak TRV is **780 kV**, to be compared with **1090 kV** in the IEEE draft, is it realistic to require kpp=1.5 in the case of effectively grounded systems ? Three-phase ungrounded faults at the transformer terminal ?

Transformer limited faults

Examples of TLF current in 550 kV &800 kV systems

- **Case of AEP 800 kV system (input from Albert Keri)**
  - the transformer short-circuit impedances are as low as 9.24 %. But, typically they are about 12%. However, the 765 kV / 500 kV transformers that connect AEP system to the neighboring systems have impedances as low as 6.35%.
  - For a 1500 MVA transformer with a short-circuit impedance of 6.3%, and a 2250 MVA transformer with an impedance of 10%, the fault current is respectively equal to **17.2 kA** and **16.2 kA** (assuming a source of infinite power).

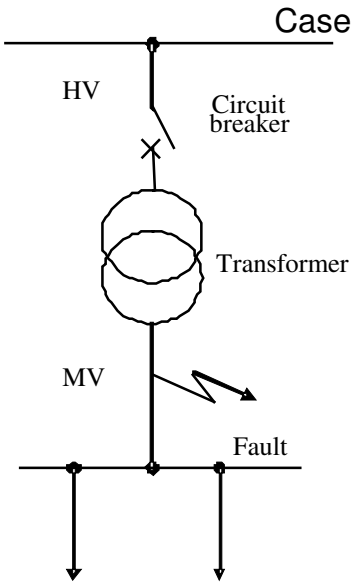
TLF currents vary in a wide range, depending on the application.

Transformer limited faults

Input from Bill Bergman

Transformer Fed Faults

Case	Bank MVA	System HV	Transformer LV	Infinite Bus Bank Impedance	Infinite Bus HV fault KA
1	720	500	245	12,0%	6,93
2	1200	500	245	11,0%	12,60
3	240	245	138	6,0%	9,43
4	400	245	138	10,0%	9,43



Case	Fault Current as a % of Rated Interrupting Current 40 kA Breaker %	50 kA Breaker %	63 kA Breaker %
1	17%	14%	11%
2	31%	25%	20%
3	24%	19%	15%
4	24%	19%	15%

Conclusion and proposal

- **What is found for 800 kV systems is also valid for lower rated voltages : TLF currents vary in a wide range and cannot be required to be in all cases up to 30% of the circuit breaker rated short-circuit current**
- **As done in IEEE C37.016-2007 for circuit switchers, a possible solution is to introduce a rated TLF breaking current, defined as follows**

The rated transformer-limited fault breaking current is the highest transformer-limited fault current which the circuit breaker shall be capable of breaking under the conditions of use and behavior prescribed in this Standard in a circuit having a power-frequency recovery voltage corresponding to the rated maximum voltage of the circuit breaker and having a transient recovery voltage equal to the value specified in Tables XX. The preferred rated transformer-limited fault breaking current are selected from the R 10 series.

Transformer limited faults

- **R10 series**

  5 - 6.3 - 8 - 10 - 12.5 - 16 - 20 - 25 kA

- **Testing**

  As done in IEEE C37.016-2007 for circuit switchers:

  Test-duty TLF consists of three opening operations at the Rated Transformer-limited Fault Current with a dc component of less than 20% and a transient recovery voltage as specified in Tables XX

Expected benefits

To users

they won't have to pay extra for a performance they don't need (higher currents associated with very high RRRV can lead to a higher number of chambers or the addition of a capacitor)

To manufacturers

they won't have to develop a solution for an application that does not exist