Transient Behavior of Static Fault Current Limiter in Distribution System

by

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Electrical Power and Energy Conference (Winnipeg-Canada)
October 2011
Outline

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Background

- Continuous growth of demand resulted in higher fault current levels.

- An electrical fault occurs when current flows through an abnormal or unintended path.

- Mitigation of fault current levels using newer technology.
Desired Solution

- Responds to faults instantaneously, improves power quality, occupies less space, have less power losses in comparison to conventional fault current limiters

- Extends the life of many protective devices, should be more reliable and allows the usage of existing switches and circuit breakers

- SFCL Transient behavior and Controlled switching
Solid State Fault Current limiter

- Consists of two parallel connected circuit branches
- SFCL is required to have low impedance under normal conditions but to have high impedance under fault conditions
- Speed of the intervention must be fast
X/R ratio and PF

• Impedance has two components:
  • R: resistance to current flow
  • X: depends on:
    • frequency (assumed constant)
    • L: reflects impedance to current flow

• PF = Cos (tan\(^{-1}\) (X/R))

• (Sine wave + Decaying Exponential) = Asymmetrical Current because the waveform does not have symmetry above and below the time axis
DC offset & Asymmetrical Current

- As X/R increases; PF decreases → Asymmetric current to increase

- Transients are influenced by DC offset

- DC offset is determined by the X/R ratio of system

- Asymmetrical fault current is hard to predict because it depends on instant when the fault occurs
Fault Initiation Time \((a \& q)\)

- The time (or angle) of fault initiation is measured along the voltage wave, i.e. in degrees from a known point, such as peak voltage or voltage zero.

- Voltage source is given by: \[ V(t) = V_m \sin(\omega t + \alpha) \]

- Total asymmetric fault current:

\[
I(t) = \frac{V_m}{|Z|} \sin(\omega t + \alpha - \theta) - \frac{V_m}{|Z|} \sin(\alpha - \theta) e^{-\frac{Rt}{L}}
\]

\[
= I_{AC} + I_{DC}
\]
• source voltage angle (\(a\))
• system power factor angle (\(q\)),
• impact of difference between angles i.e. \((a - q)\) on the first peak transient values is studied
System Model

- Power_Source
- Transformer_Impedance
- Solid_State_Switch
- Varistor
- Limiting_Impedance
- Lumped_Load_RL
- 10k V / 0
- 10kV
- 0.05, 0.004
- 11.9mH
- 0.628, 0.05
Fault Conditions

- Initiation of fault at 0.05 sec (after 3 cycles):
  
  a) Fault lasts for 3 cycles, and then cleared at 0.1 sec (NO limiting impedance)
  
  b) Fault lasts for 3 cycles, but now limiting impedance is introduced, and then cleared at 0.1 sec
Line Currents: Without & With Limiter

![Line Currents Graphs](image)
Transients and DC offset

- The instant of current commutation is varied to demonstrate the impact of \([a - q]\) on the transient values.
- DC offset component impacts the envelope magnitude and direction.
- This is used to show severity of transient peak values as well as controlled power electronic switching.
- Fault is initiated at 0.40000, 0.40208 & 0.40417 sec (Uncontrolled Switching).
- Semiconductor switches turn-off after 90°, 120°, 135°, 180° & 240° (Controlled Switching).
DC and Fault Initiation

Load Currents: $I_a$ red, $I_b$ blue, $I_c$ green

\[ e(t), i(t), i_{ac}(t), i_{dc}(t) \]

\( \alpha \)

\( \theta \)
Conclusions

- SFCL has been implemented using EMTP program to study its impact on the system
- Analyzing transient behavior of SFCL assists to improve power quality, to decrease energy dissipation and to reduce stresses on system
- By examining the pre-fault steady-state current waveform, prediction of the instant *when* the lowest transient voltages occur is possible
- Controlling semiconductor switches to turn-off at this optimal instant (angle), results in minimizing peak surges and suppressing transient voltage stresses on the system
THANK YOU

QUESTIONS?