Impact of Shunt Reactor Bank Switching on Transformer Neutral Geomagnetic Induced Current (GIC) Monitoring

Larry Anderson

Cigre GOTF – Houston, TX

October 20, 2014

AEP AMERICAN ELECTRIC POWER®

Background

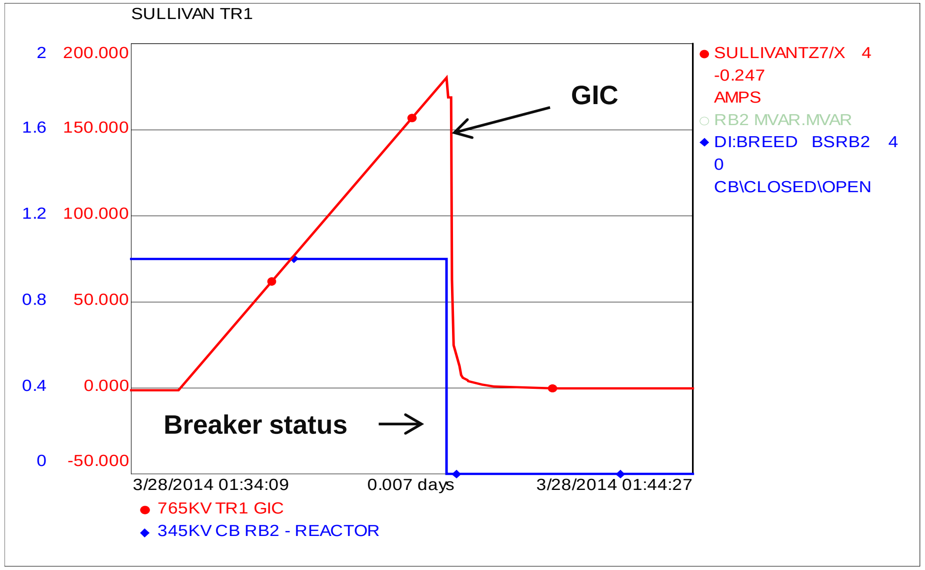
- AEP started installing GIC monitors in 2012
- Currently 13 EHV transformer installations are monitored with more on the way
- Presently most installations are on 765 kV autotransformers (10 out of 13 installations)
- AEP utilizes switched shunt reactors at specific locations on it's EHV system to assist with voltage regulation
- Shortly after monitor installation large DC transients were observed at locations with switched shunt reactors on site or nearby

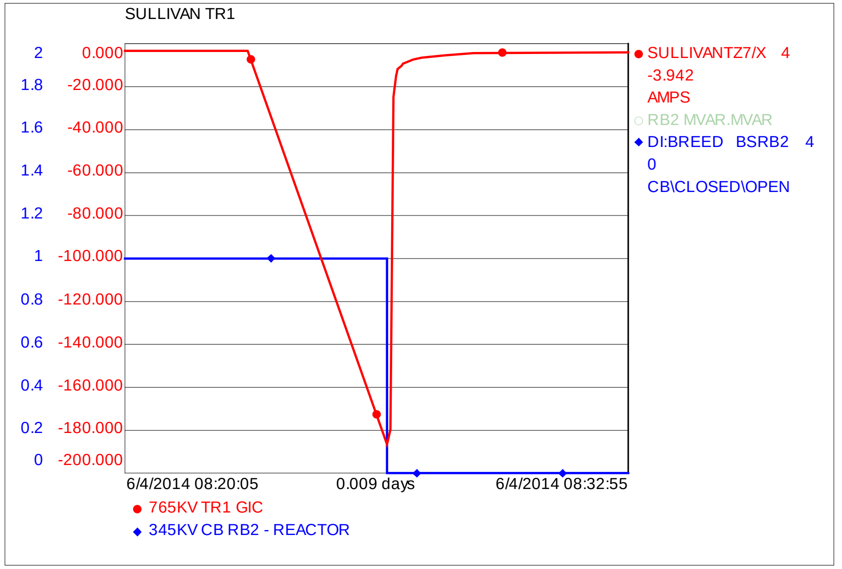
Background Cont'd

- Initially reactor bank switching was overlooked as a source of the DC transient current
- Only after considering what type of transient events could produce such DC transients, were the switched shunt reactor banks investigated more closely
- After looking at reactor breaker closing times in relation to the DC neutral transients, it was observed that they coincided
- At this point it was decided to study these transients more closely to understand their true nature

Observed Transients

- **Sullivan Transformer #1**

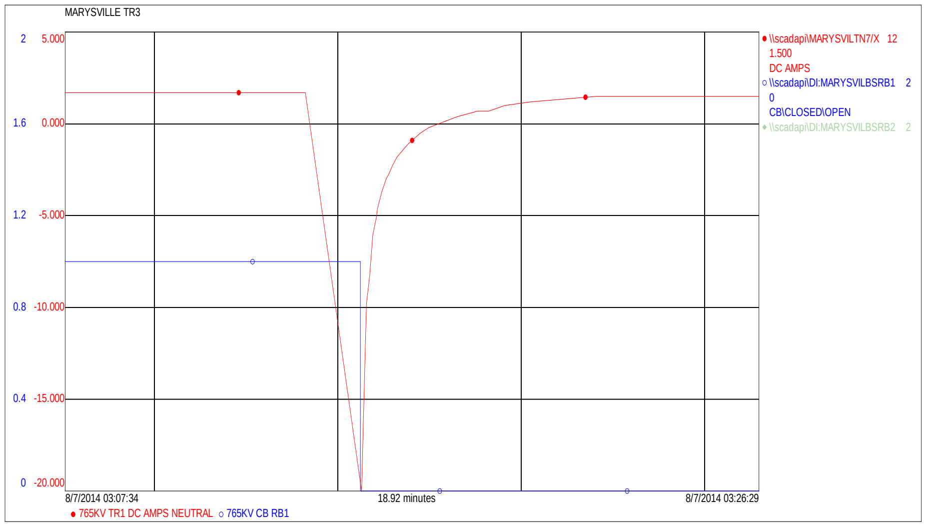


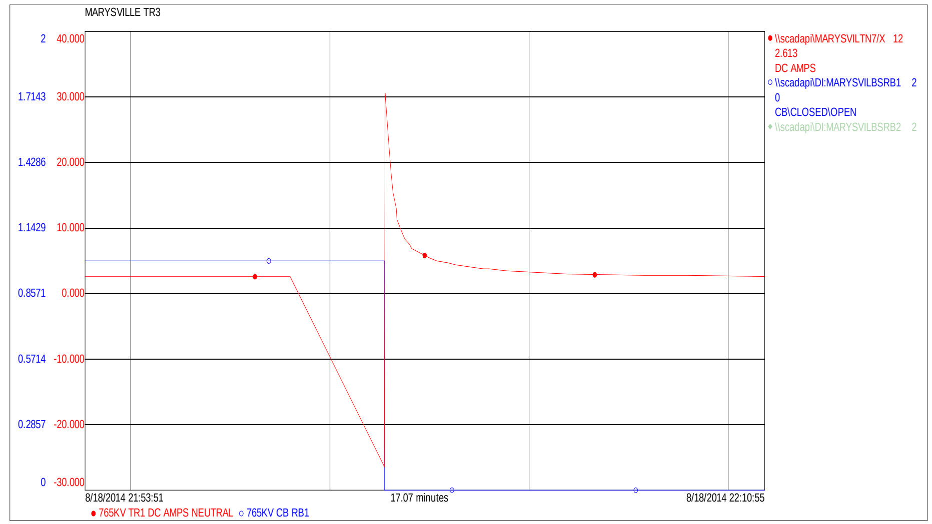


- **Data from AEP's SCADA system**
- **Low sampling rate**
- **Modified by data historian (swinging door compression)**

Observed Transients Cont’d

- **Marysville Transformer #3**

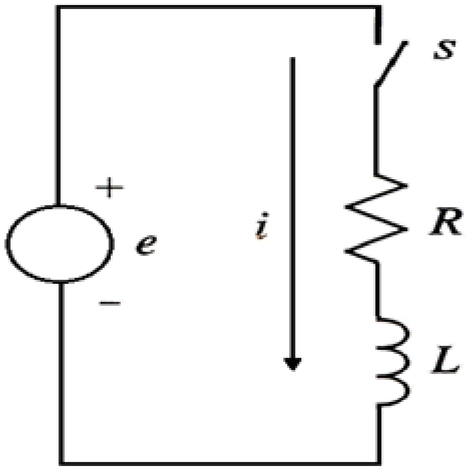




- **Red curves are the currents recorded by GIC monitors**
- **Blue curves are reactor breaker status – “1” indicates open, “0” indicates closed**

Reactor Bank Switching Transients

- **Easily understood by analyzing the switching response of a simple RL circuit**



Where $e = E_m \sin(\omega t + \alpha)$

Solving for i:

$i = Ke^{-\frac{R}{L}(t-t_s)} + \frac{E_m}{Z}\sin(\omega t + \alpha - \varphi)$ (1)

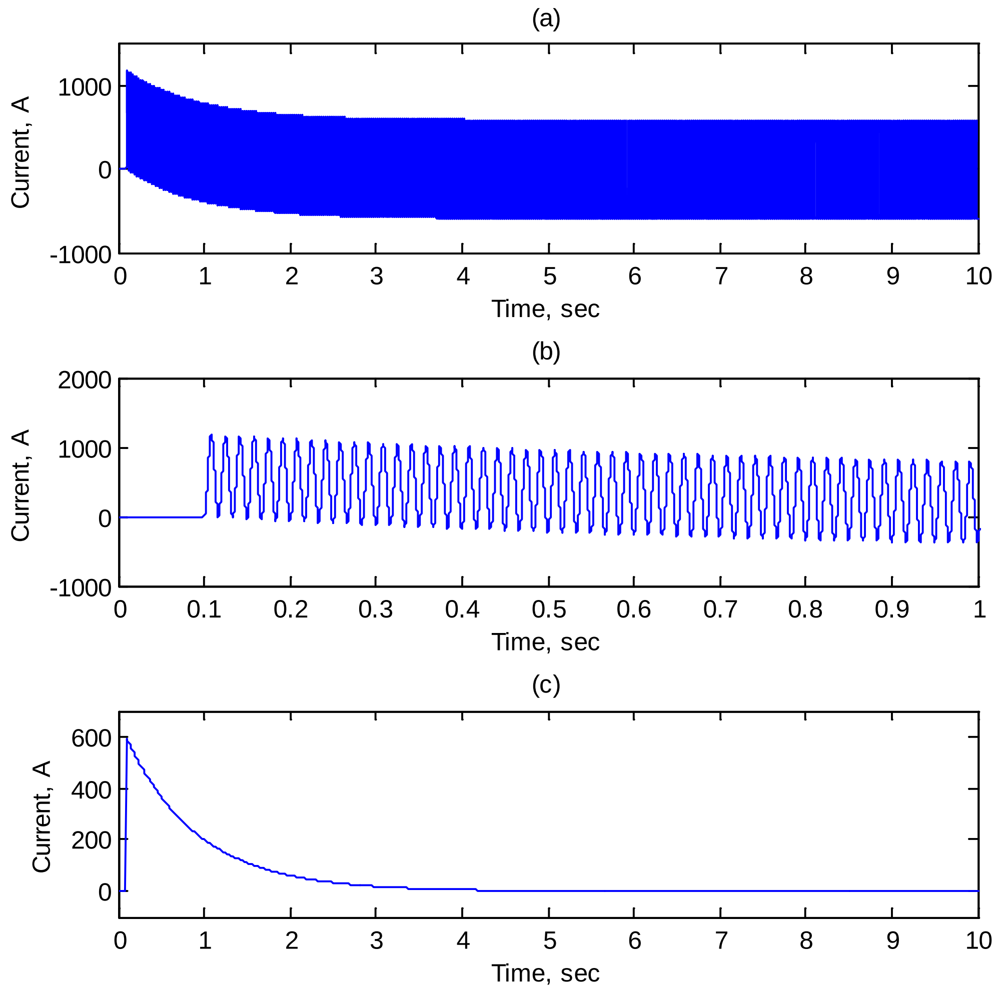
Where $Z = \sqrt{R^2 + \omega^2 L^2}$

$\varphi = \tan^{-1}\left(\frac{\omega L}{R}\right)$

$\alpha = voltage\ phase\ angle$

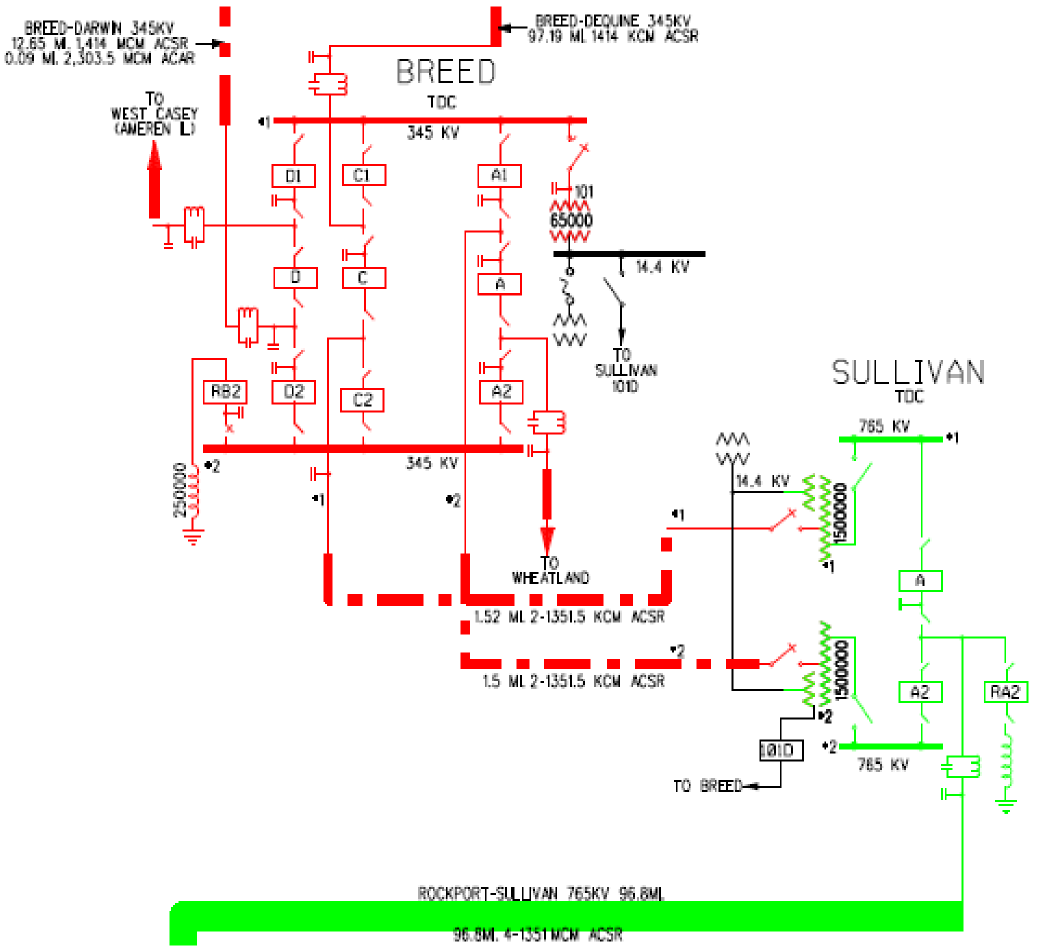
K is a constant such that the current at t_s+ equals the current at t_s- : $K = -\frac{E_m}{Z}\sin(\omega t_s + \alpha - \varphi)$

Reactor Bank Switching Transients Cont'd

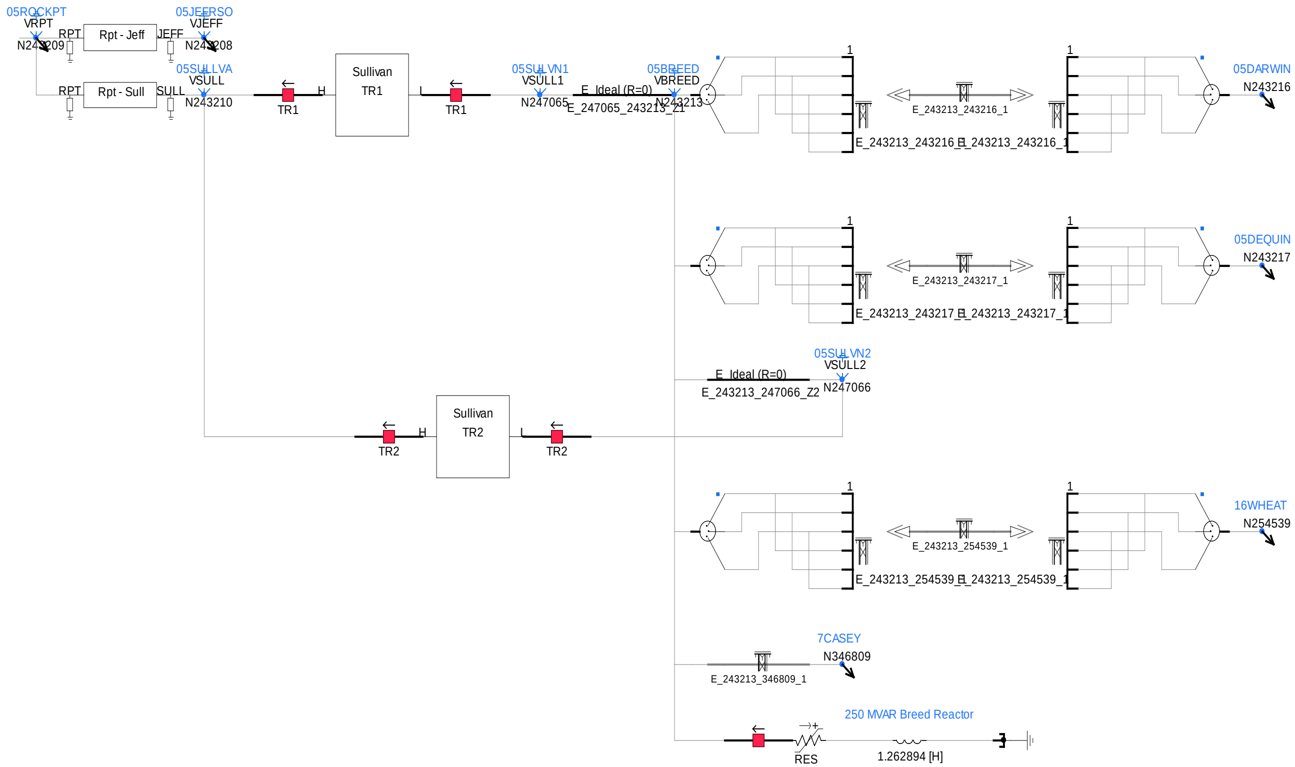


- **Current calculated with equation (1) on previous slide**
- **Reactor switching response is similar to system fault response**
- **DC offset keeps the current just after switching the same as the current just prior to switching**
- **AC current rides on top of DC offset**

Single Line Diagram of System Under Study

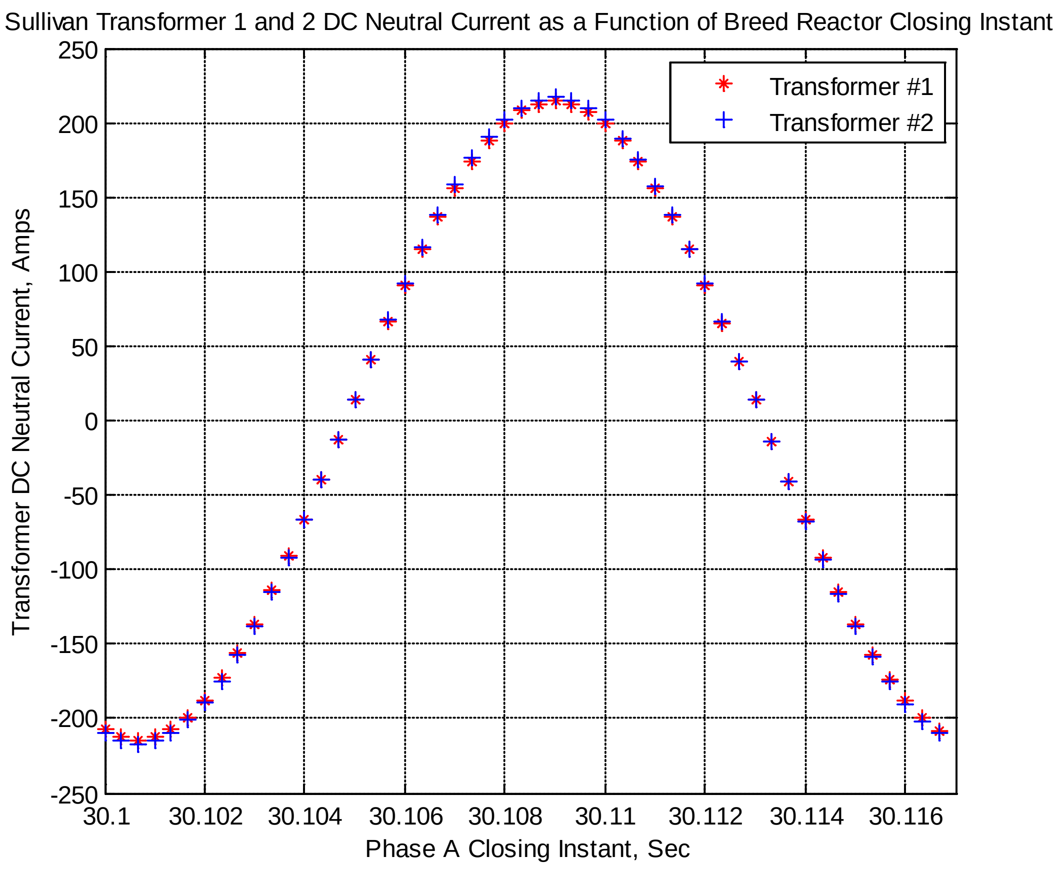


PSCAD Model and Simulations



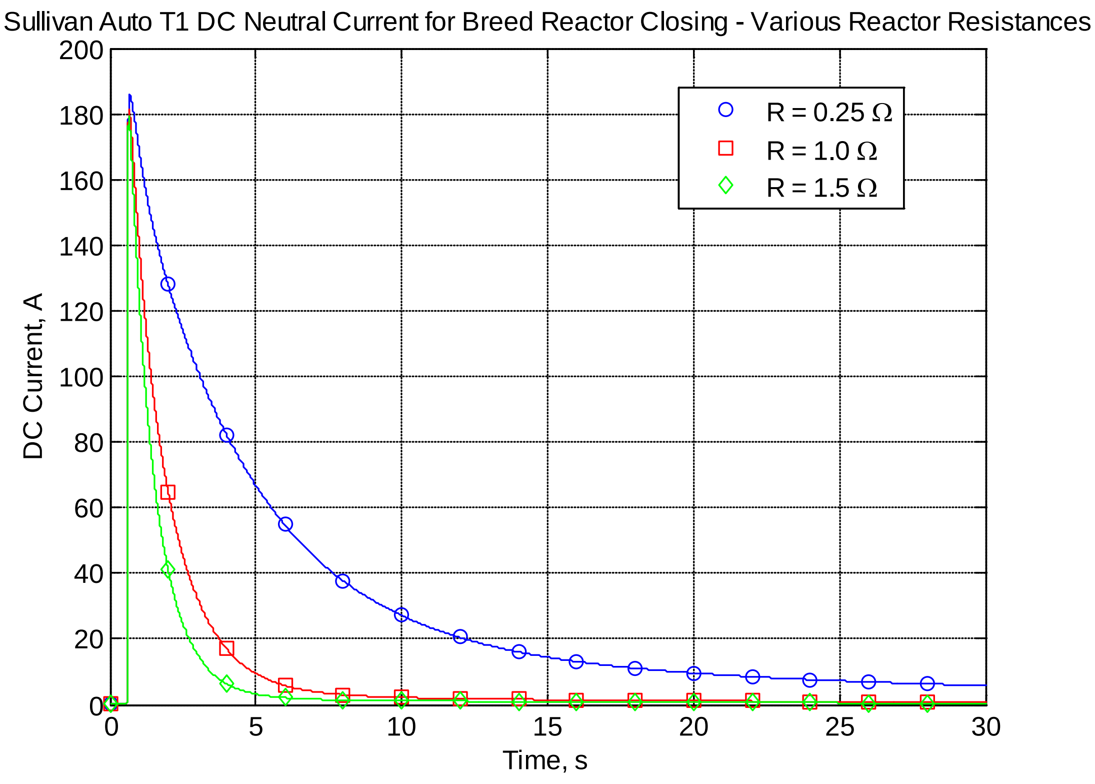
- The system was modeled in detail at least one bus away from the Sullivan 765 kV and Breed 345 kV buses
- The breaker used to switch the reactor was modeled with a pole closing span of 4.16 ms
- All transmission lines utilized full frequency dependent models
- Impact of breaker, point-on-wave closing time was investigated
- Impact of reactor resistance (X/R ratio) was investigated

Simulation Results



- **Peak DC neutral current is a function of the point-on-wave closing instant of the reactor breaker**
- **Peak DC neutral current in the simulations ranged from approximately 200 A into the transformers to approximately 200 A out of the transformers (approx. 400 A range)**
- **This variation was solely due to the point-on-wave closing instant of the reactor breaker**

Simulation Results Cont'd



- **DC neutral current exhibits exponential decay typical of inductive circuits**
- **Time constant of decay is the ratio of reactor plus system inductance over reactor plus system resistance**
- **Time constants for the Sullivan system were typically in the range of seconds (approximately 1 - 10 seconds)**

Conclusion

- Switching of inductive devices inherently produces electrical transients
  - Seen in both the voltage and current
  - Result in a decaying DC component in the current
- DC current:
  - Is a function of the point on the voltage wave that each circuit breaker pole closes
  - Will typically be different in each phase due 120° electrical separation
  - Add in neutral connections of wye-grounded transformers
  - Appear as a DC current transient to monitoring devices
- Effects of switched shunt reactor banks must be considered when implementing GIC monitoring on nearby transformers

Questions ?