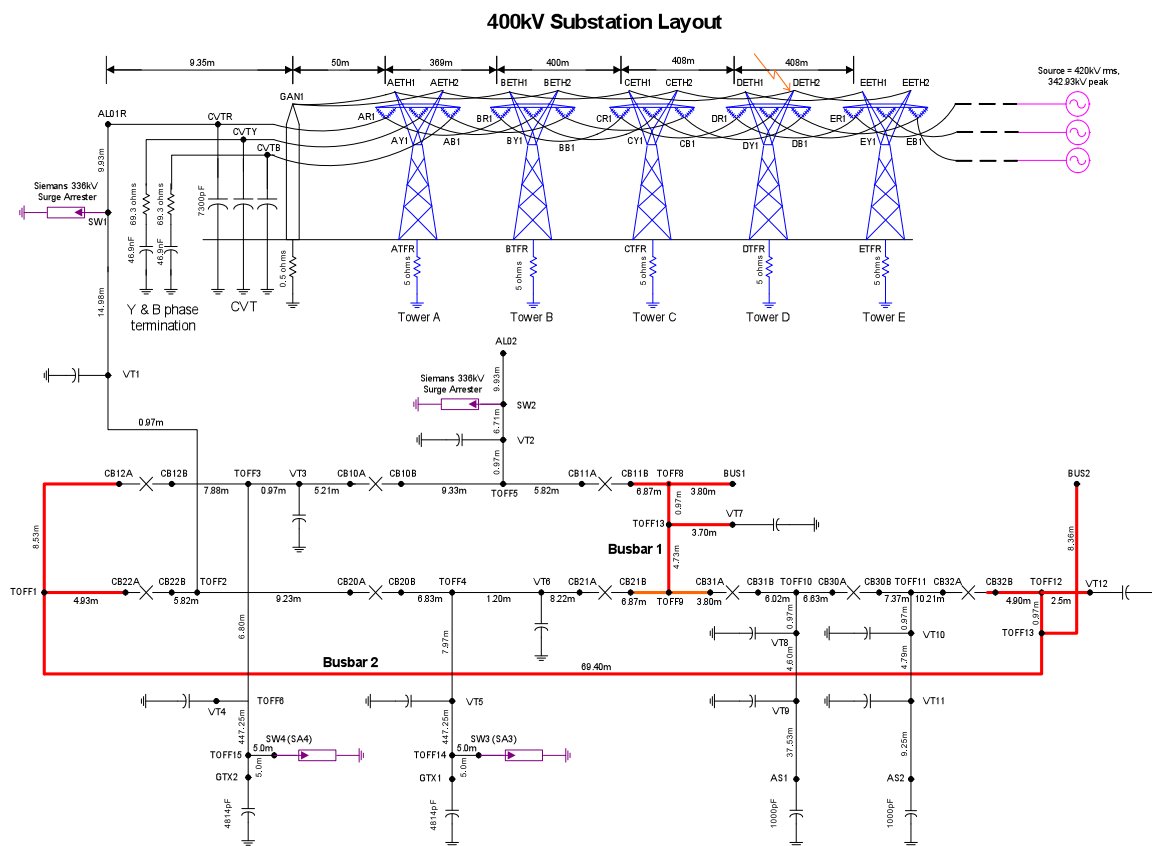


## Case Study 4

Insulation Co-ordination studies for a 400kV gas insulated busbar substation

### Project Scope

To investigate whether the proposed surge arresters afford sufficient protection to the 400kV substation and its associated equipment against overvoltages produced by lightning strikes and switching surges on the overhead line. Other studies investigate whether ferroresonance could occur.



### Modelling

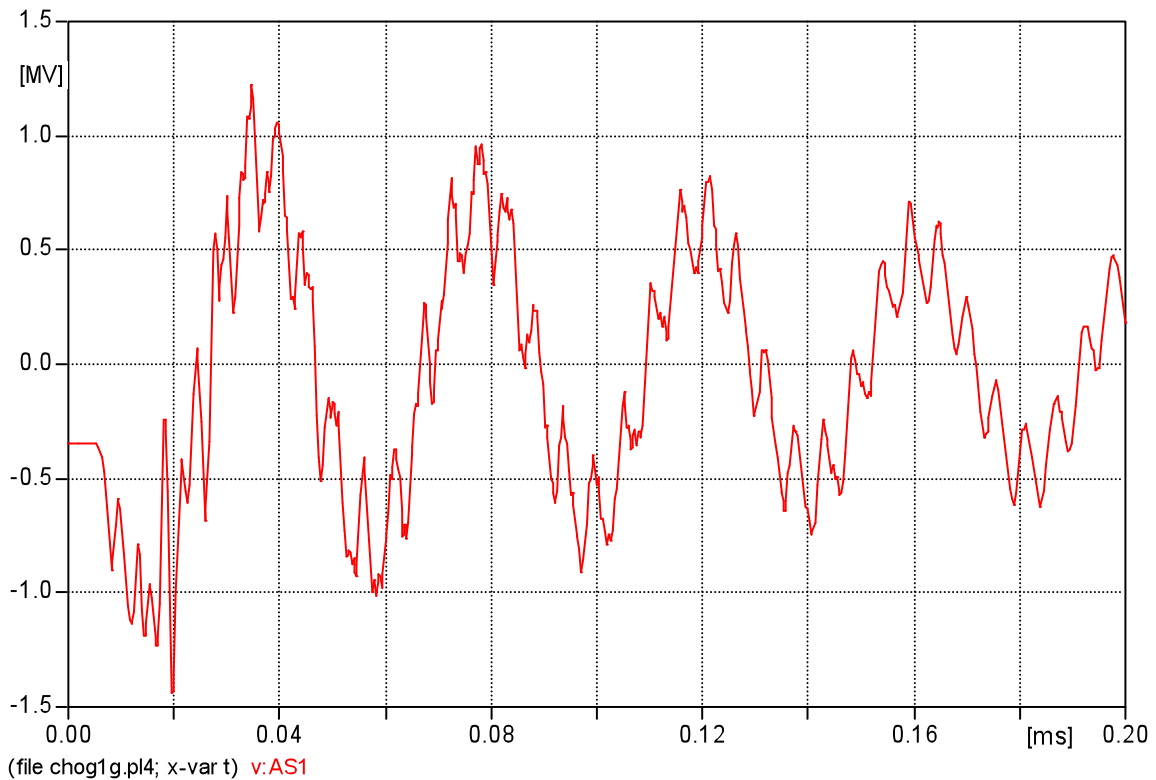
The following network equipment was modelled using the Electro Magnetic Transient Program.

- |  |   |
|--|---|
| 420/27kV, 780MVA 2 Winding Transformer       | (3-phase representation + saturation)             |
| 420/235kV, 240MVA Auto – Transformer         | (3-representation with saturation)                |
| Overhead Line ; Type – Curlew                | (Untransposed, modelling mutual effects)          |
| 336kV, 13kJ/kV Gas Insulated Surge Arresters | (Non linear resistor)                             |
| Towers ; Types – HT                          | (Gap model representing gap breakdown voltage)    |
| Circuit Breakers                             | (Point-on-wave switching, pole scatter variation) |

The lightning studies examined both maximum / minimum shielding failure and backflashover conditions. The switching studies examined substation switching surges resulting from switching circuit breakers remote from the substation. The ferroresonance studies examined various substation configurations whereby voltage transformers are isolated, leading to possible voltage transformer failure.

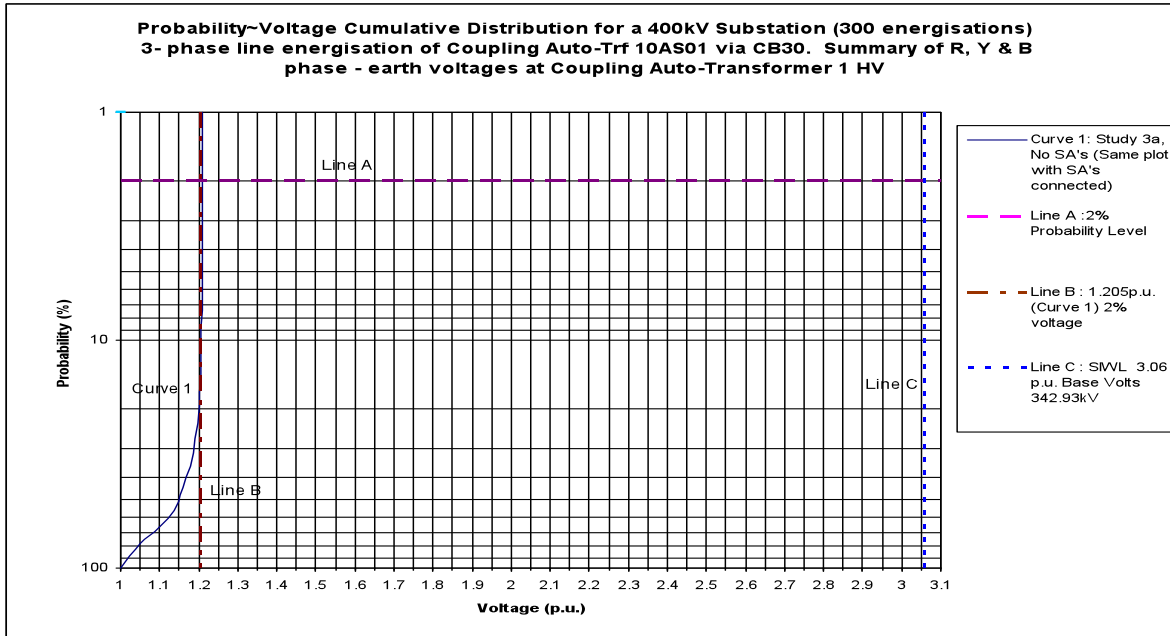
## Results

Lightning Analysis : 13.1kA stroke current applied 1km from substation. Trace shows the lightning impulse propagating to an auto transformer HV terminal



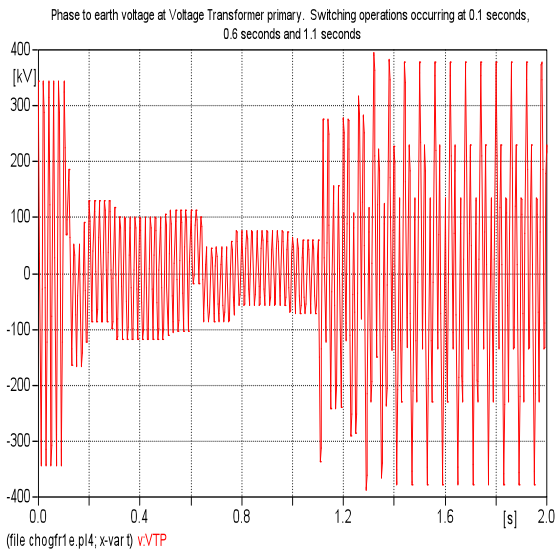
## Switching Analysis :

Statistical analysis showing Voltage–Probability curve for 300 switching energisations

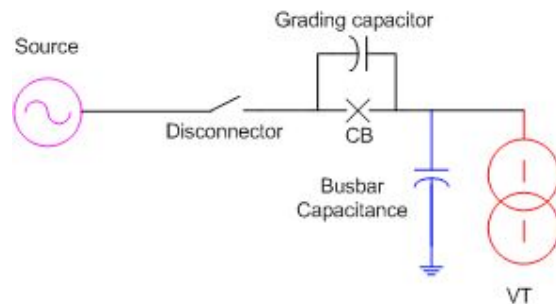


## Ferroresonance Analysis :

Sub third sustained ferroresonance occurring after 1.1 seconds



Circuit diagram for ferroresonance in electromagnetic voltage transformers



The Narec Power System Analysis Section demonstrated to the client that for all lightning and switching conditions studied, the proposed line entry and generator transformer surge arresters provided adequate protection to the 400kV substation and its associated equipment. The studies showed that two possible operating scenarios could possibly give rise to voltage transformer failure due to ferroresonance.