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Protection Relay Load Encroachment

Managing the risk of distance protection load encroachment during contingencies

- Traditional use of software tools by protection engineers
  - Modelling of relays considered time consuming/complex
  - Benefit of relay simulation not apparent
  - Unsure of accuracy/reliability of data
  - Hesitance to use DPL
  - Force of habit
- Typical project example
  - Project specific confidential
  - Risk of load encroachment due to network configuration changes
  - Risk of incorrect directional EF relays due to contingencies
  - Altered source impedance impact on all OC and EF relays
  - Impact on breaker failure requirement
  - Formulation of approach
  - Network model: Transformer vector groups

Protection Relay Load Encroachment

Protection relay mix

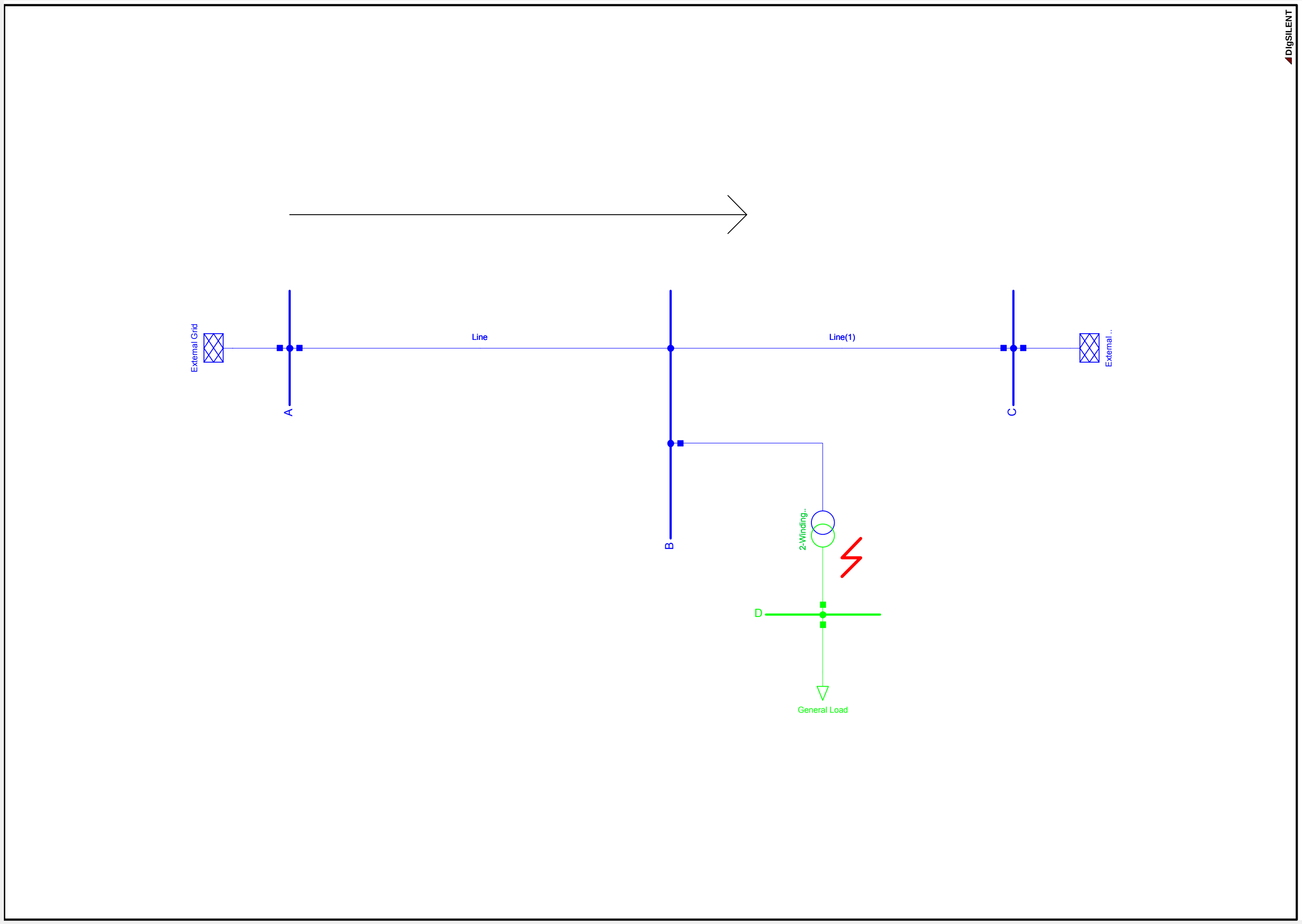
- Many older electro-mechanical distance relays
- Some modern distance relays (SEL 311, SEL 321)
- External starters
- Mixture of OC and EF relays and elements in distance relays
- No documentation was available for some older relays

Project was ideally suited for automation

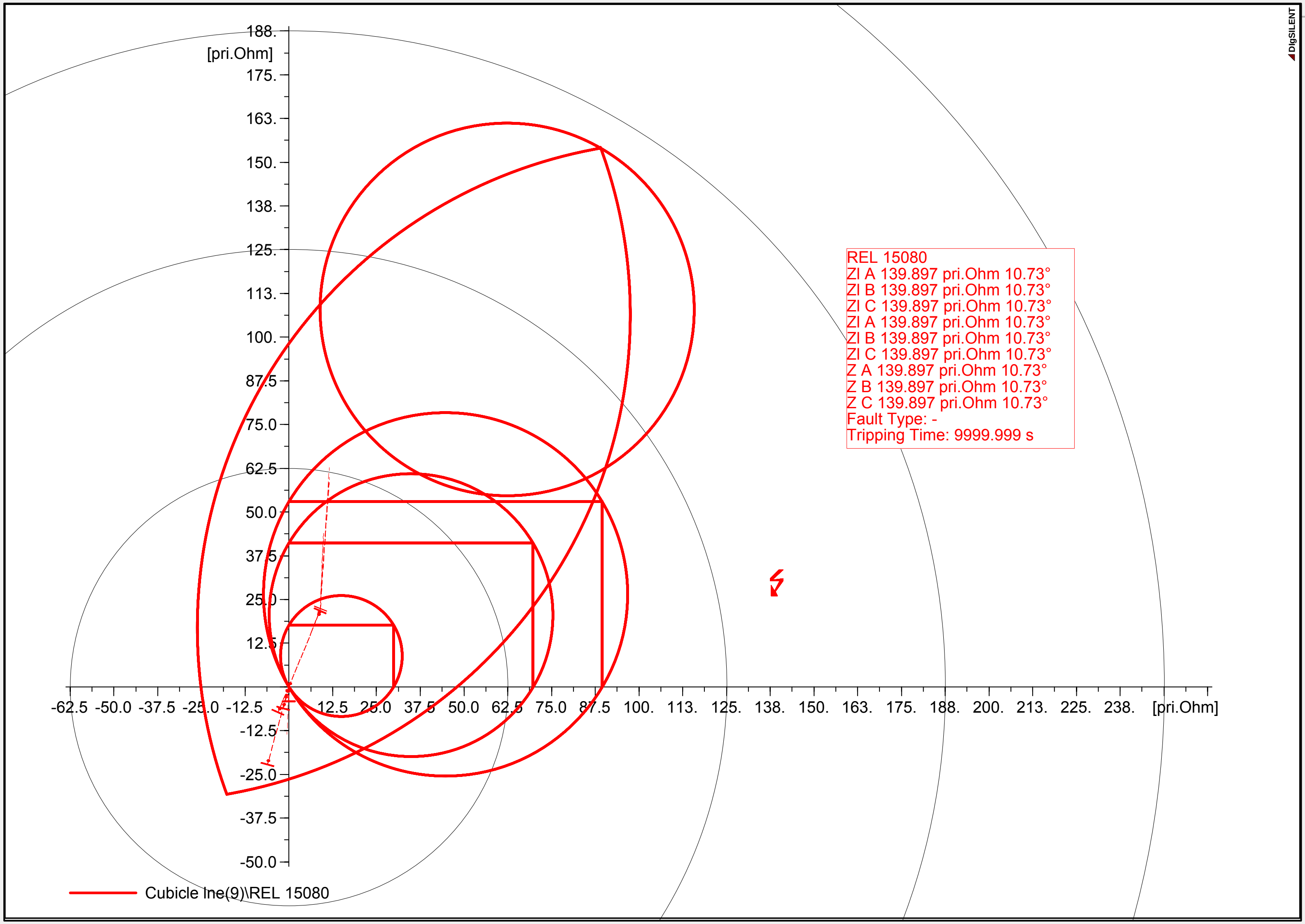
- Large number of contingencies to consider (>40)
- Very complex interconnected 66 kV network
- Different operating conditions (12 base cases)
- Large number of relays (124 relays modelled)
- Various load flow and fault conditions to evaluate (3)
- 40 x 12 x 124 x 3 = 178,560!
- Difficult enough to make sense of such a large number of tests

Protection Relay Load Encroachment

Far reaching starter elements for breaker failure backup



Protection Relay Load Encroachment

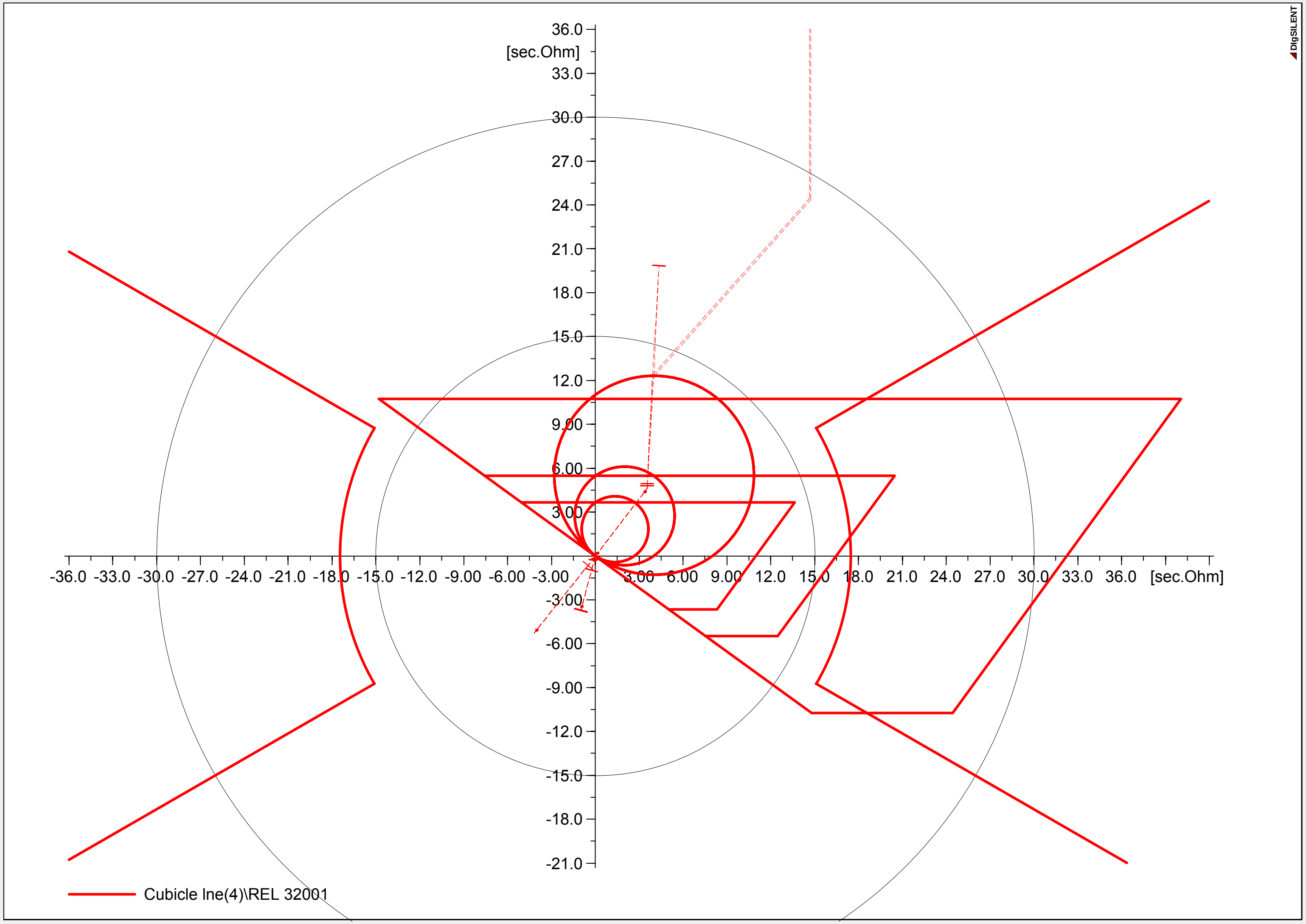


Protection Relay Load Encroachment

Initial study

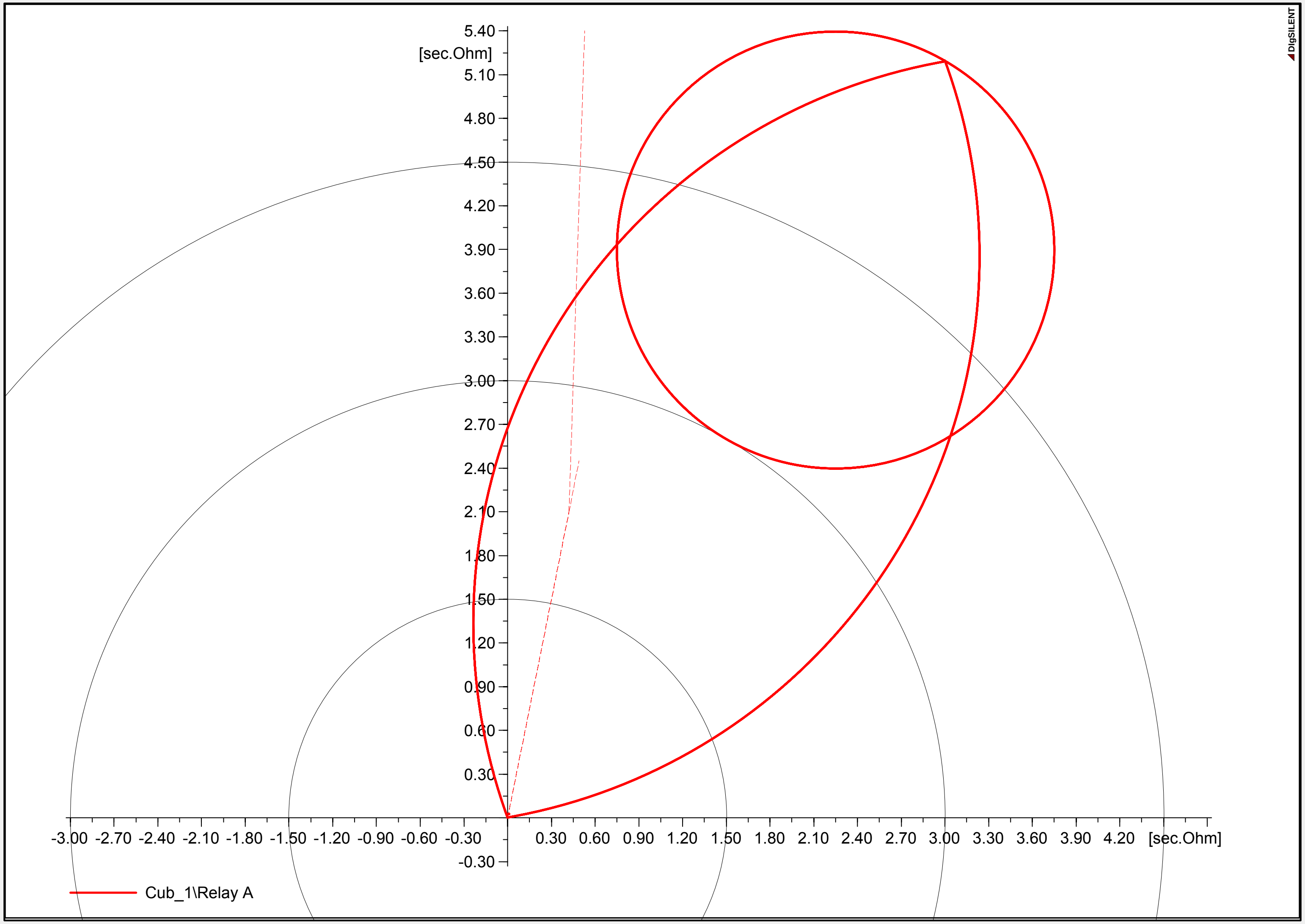
- Simply measured load without system modification
- Repeated study with system modification
- Report load flow for each case and try to make a comparison
- Percentage change meaningless for small loads
- Absolute value meaningless for large loads
- Report concluded that system change would not impact on load encroachment
- Some doubt remained

Protection Relay Load Encroachment



SEL 321

Protection Relay Load Encroachment



RX-plot

Razoa

starter

Protection Relay Load Encroachment

Methodology

- Import network model from PSS/E or other source
- Create relay models not available (made use of generic models)
- Model and set all relay elements
- Set up all load flow cases to be considered
- Prepare DPL script to export all RX plots
- Prepare DPL script for contingency events and reporting (relay identification an operating time; graphics and/or spreadsheet)
- Prepare DPL script for sensitivity analysis and reporting
- Analyse results (relay operation for load flow) and write report

Challenges

- Non-standard relay models
- Lack of protection scheme understanding (no substation level SLD)
- Accurate settings database (StationWare!)
- Complex relay responses

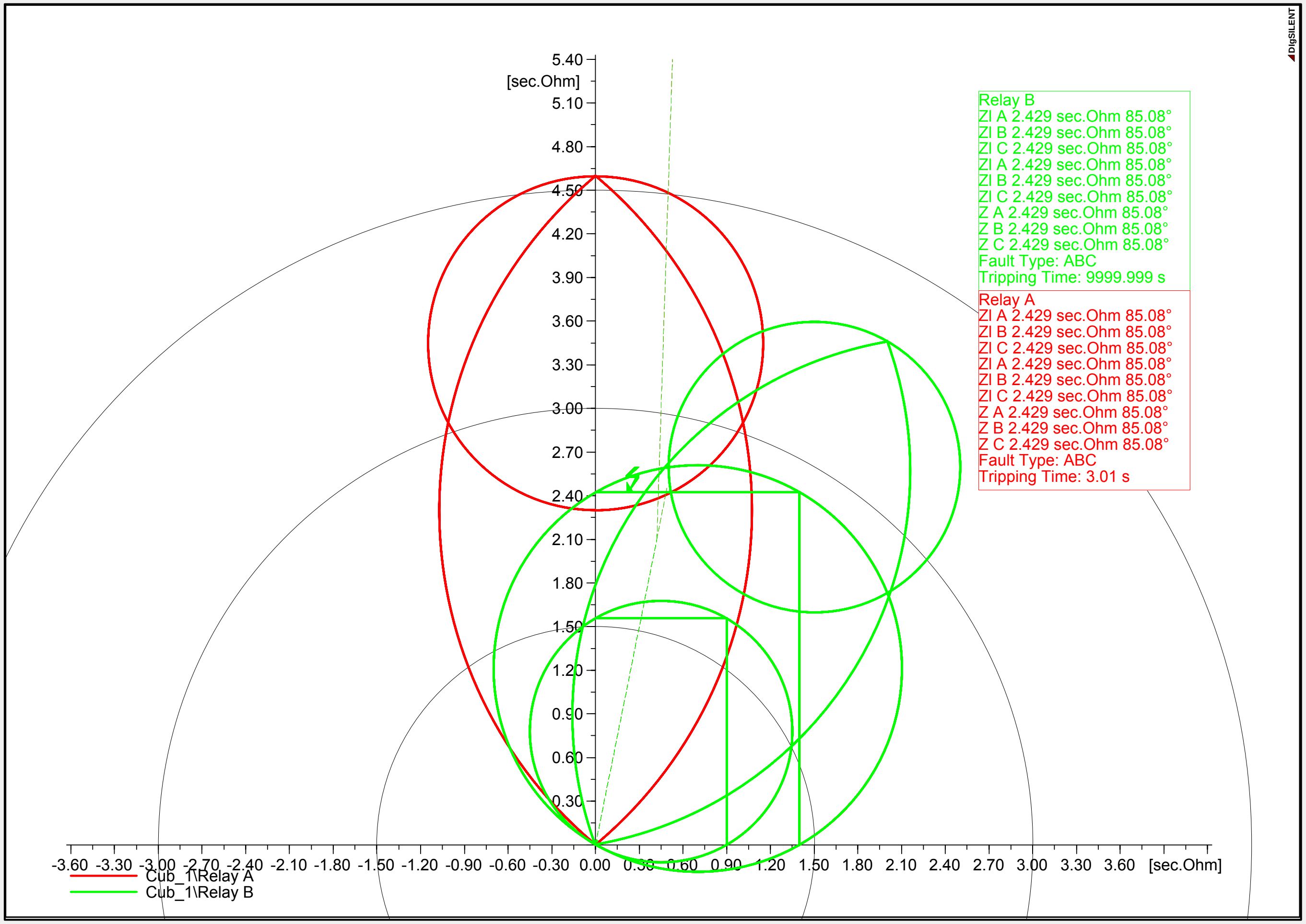
Protection Relay Load Encroachment

RAZOA Starter

- Current measurement is always phase current
- Voltage measurement is either phase to phase (2 or 3 phase faults) or phase to ground (in case of all faults to ground)
- Applied setting measures correct for phase to ground fault with $K_0 = 1$ ($Z_f = U_{an}/I_{an}$) where $K_0 = (Z_0 – Z_1)/3Z_1$
- For a single phase fault with $K_0 = 1$; $Z_0 = 4 \times Z_1$
- $Z_f = (2 \times Z_1 + Z_0)/3 = 2 \times Z_1$
- For a 3-phase fault (similar to load encroachment)
- $Z'_f = U_{bc}/I_b = \sqrt{3}\, Z_1 |- 30°|$
- Hence $Z'_f = \sqrt{3}/2 \times Z_f |-30°|$
- The measurement of the “fault” impedance is therefore less than the setting and hence the relay can overreach the setting to compensate for under-measurement
- Similarly $Z_f = 2 \times Z_1$ for a phase to phase fault

Protection Relay Load Encroachment

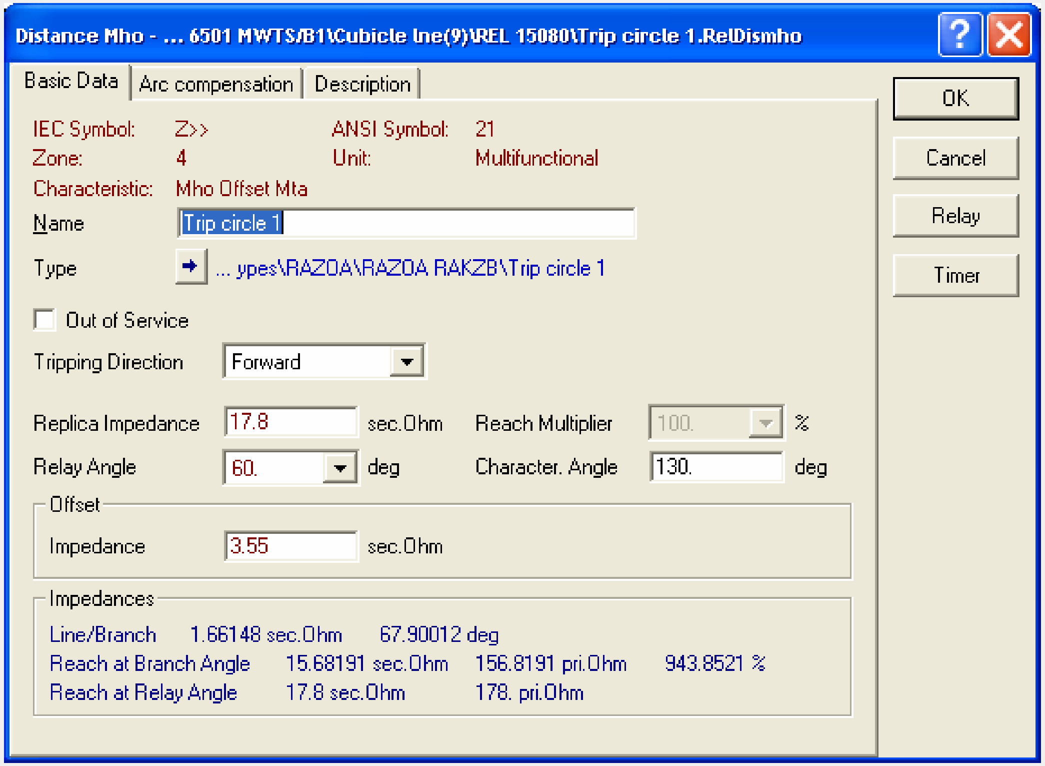
RAZOA Starter continued



Protection Relay Load Encroachment

RAZOA Starter Implementation Options

- Special polarising element
- Relay logic
- Self polarised with parameter characteristics



Protection Relay Load Encroachment

Large spreadsheets were prepared with fields:

- Relay name
- Base case tripping times
- Contingencies
- Contingencies tripping times

Open columns clearly shows where load flows did not converge.

Protection Relay Operation

Direction OC and EF Test

- Fault at both sides of each line/feeder
- Single phase to earth fault with 0 Ohm; 50 Ohm and 500 Ohm resistance
- Monitor both forward and reverse relay operation
- List for each relay all elements that operate as well as operating times
- Flag relays that operate for “reverse” faults – some would be non-directional
- Flag relays that do not operate for forward faults – could be according to element class
- Repeat test for all operating conditions and contingencies
- Analyse 178,560 relay operations times the number of relay elements

Challenges

- Script took only two days to prepare
- Long run time 2 hour per base case
- Information overload
- Testing of non-standard relay types

Protection Relay Operation

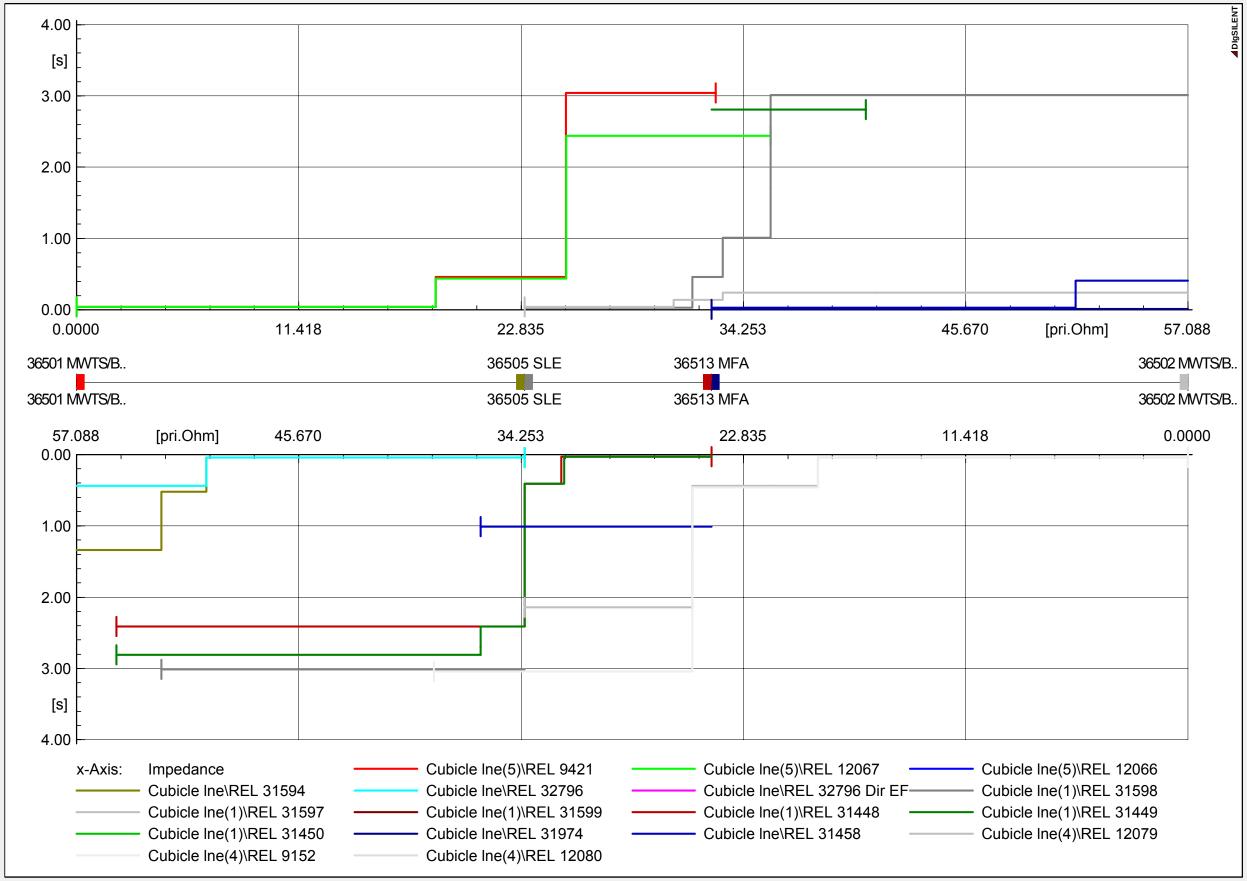
Again large spreadsheets with columns:

- Contingency
- Line
- Relay
- Relay type
- Relay polarity relative to fault (forward/reverse)
- Busbar names
- 0; 50 and 500 ohms fault resistance tripping times
- Name of element picking up for each fault
- Repeat the list for second/remote busbar.

Protection Relay Operation

Time – distance diagram

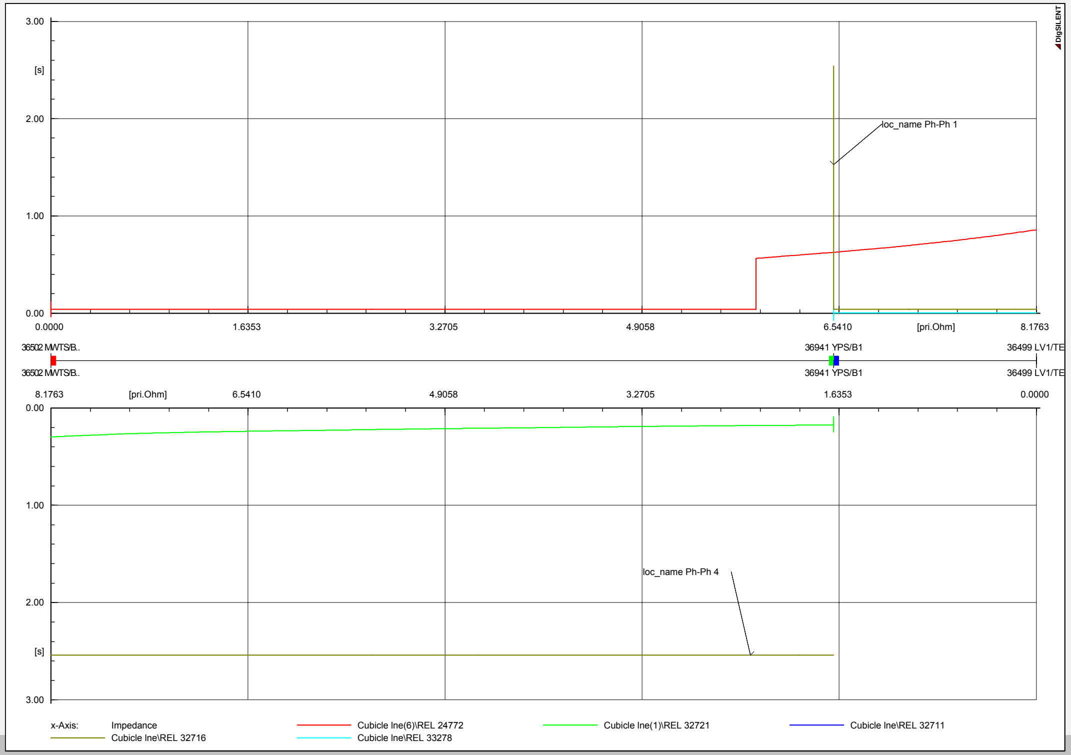
- Easily interpreted as long as not too many relays are involved



Protection Relay Operation

Time – distance diagram

- Ideal for grading evaluation between OC, EF and distance relays
- Ideally a time – distance diagram consisting of two line lengths each
- Repeated definition of paths and diagrams
- Typically 4 relays per cubicle – long paths not sensible



Protection Relay Operation

Lessons learnt

- Scope of exactly what tests and how to test needs to be clearly defined
- Lack of client knowledge about what is possible
- Client has no idea of what tasks are labour intensive and what not
- Interpretation of vast amounts of data could be difficult
- Understanding of PowerFactory relay elements
- Access to good relay manuals not guaranteed