Public

Calculation of the Global Security Factor

CMP432: NESO Teach-In

21/03/2025

NESO
National Energy System Operator

Agenda:

1. Background
2. Methodology
3. Process
4. Example 1: Radial Network
5. Example 2: Meshed Network

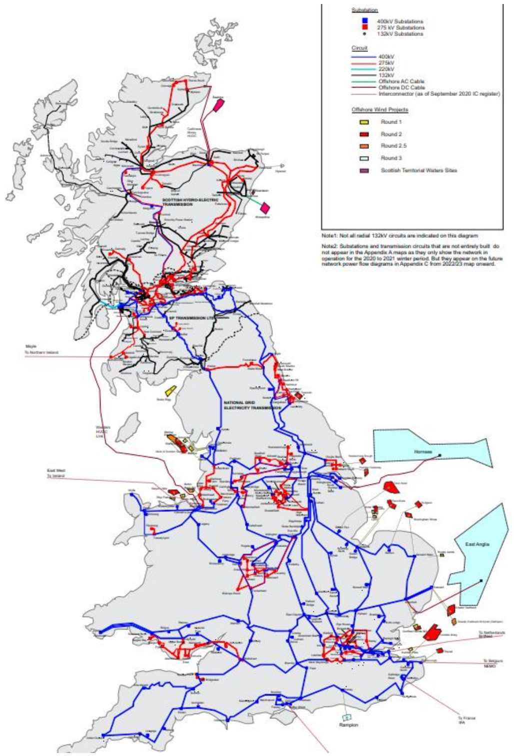
1. Background

Network Redundancy

- TOs have the license obligation to meet the SQSS requirements, and to accommodate flows under both planned and unplanned circuit outages.
- If the network has been designed and built in accordance with NETS SQSS, under specific planning assumptions (generation and demand background etc) and under certain circuit outages (known as contingencies), the **remaining circuits should be able to accommodate flows.**
- The circuit outages have to be deemed **"credible"** under SQSS **(i.e. not an exhaustive list of N-2s!)**
- The **intact network** (with all circuits in service) and the **depleted network** (with "credible" N-1 or N-2 contingencies) have different way to distribute flows, and usually the depleted network is a "stress test"

Modelling of the Transmission Network

- The DCLF-ICRP model is set up for charging purposes, and is **not suitable for replicating operational scenarios or assessing operational limits** (thermal, voltage, stability etc)
- Instead, it is used to measure the indicative costs (long-run, incremental costs) of transmission network **capacities at various locations** (known as the nodal costs)
- The network redundancy can be measured by **comparing the nodal costs under the depleted network, with the nodal costs under the intact network**



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2. Methodology

CUSC14.15.88:

"The locational onshore security factor … is derived by running a secure DCLF ICRP transport study… based on the same market background as used for zoning in the DCLF ICRP transport model …"

Therefore, the **year-round background** is used. **Generation local circuits are excluded** (by setting the length to 0).

The Secure Load Flow **(SECULF) assesses nodal marginal costs of a depleted network under all possible contingencies** (that are deemed **"credible" under SQSS** Chapter 4).

For each node, the nodal marginal cost under SECULF run (which picks up the worst N-1 or N-2 contingencies to "stress" each circuit, and then calculate nodal marginal cost associated with the stressed circuits), is compared to those derived from the intact network DCLF to get a ratio.

The list of ratios for all relevant nodes is used to determine the security factor of the wider network, using the Least Squares Fit method.

3. Process

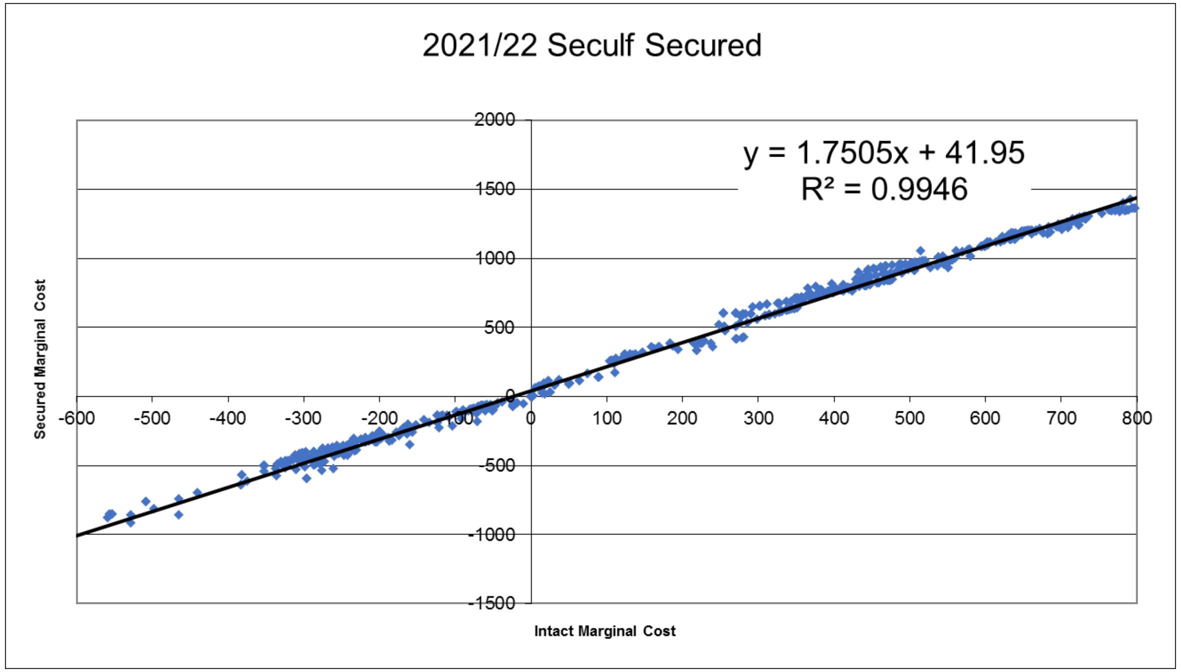
We run SECULF using **year-round background** and **calculated nodal marginal costs** (intact and secured) on wider circuits.

- This gives us two sets of nodal marginal costs**, one for the intact network with under-utilised flows, and the other for the depleted network which makes full utilisation of the circuits,** under SQSS contingencies.

Network investment is made to secure the system under SQSS contingencies (plus other credible scenarios that are not modelled under the CUSC).

To derive the network redundancy, **we plot out the nodal marginal costs (under the intact and depleted networks) for each node, and the overall ratio derived from all nodes (that is, the slope of the trend line in the figure) is the security factor.**

We repeat this exercise for all five charging years and **use the average of all five (annual) security factors, as the security factor for the relevant price control period.**



Example 1:
A Radial Network

Marginal Costs for illustration, assuming 1C is the “slack node”

The Intact Network

- Base case: Total MWkm
= 100MW* 50km * 2 + 100MW*75km *2
=25000MWkm

- Adding 1MW at 1A:Total MWkm =
100.5MW*50km *2 + 100.5MW*75km *2
=25125MWkm
Thus the marginal cost at 1A is
25125-25000 = **125MWkm**

- Adding 1MW at 1B: Total MWkm=
100MW*50km *2 + 100.5MW*75km *2
=25050MWkm
Thus,, the marginal cost at 1B is
25075-25000= **75MWkm**

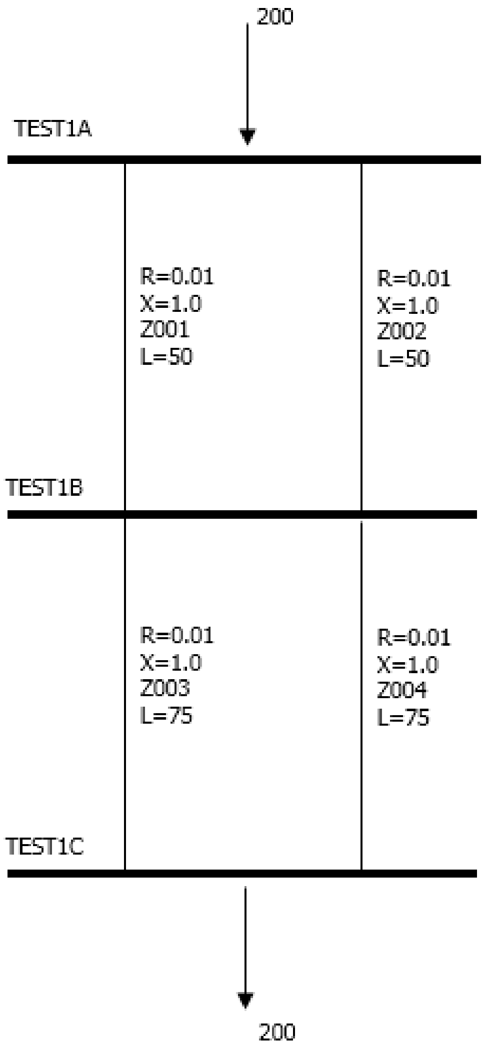
- Adding 1MW at 1C will not impact the flows as it is absorbed there

Alternatively, we can work out the marginal costs by assessing their “incremental” impact

- Adding 1MW at 1A:
Increases the dominant flow by 0.5MW on circuits Z001, Z002, Z003 and Z004 respectively,
Thus the marginal cost at 1A is
0.5MW*75km*2+0.5MW*50km*2
= **125MWkm**

- Adding 1MW at 1B:
Increase the dominant flow by 0.5MW on circuits Z003 and Z004 respectively,

Thus the marginal cost at 1B is
0.5MW*75km+0.5MW*75km
=75MWkm



The “secured” network - applying a list of circuit trips

N-1 contingencies:

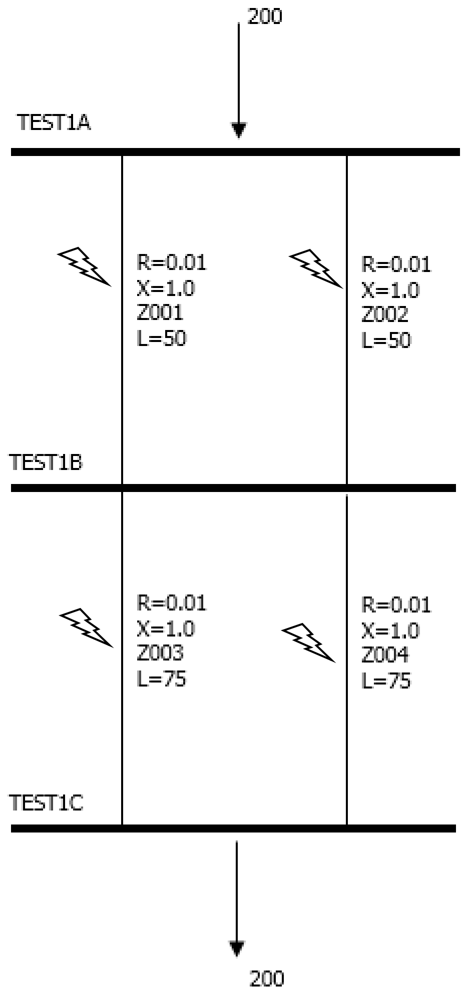
- Z001 is unavailable
- Z002 is unavailable
- Z003 is unavailable
- Z004 is unavailable

N-2 contingencies:

- Z001 & Z003 are both unavailable
- Z001 & Z004 are both unavailable
- Z002 & Z003 are both unavailable
- Z002 & Z004 are both unavailable

What we do NOT consider:

- Concurrent loss of >2 circuits
- Z001 & Z002 are both unavailable
- Z003 & Z004 are both unavailable



Identifying the worst trip for each of the circuits (Maximum Loading)

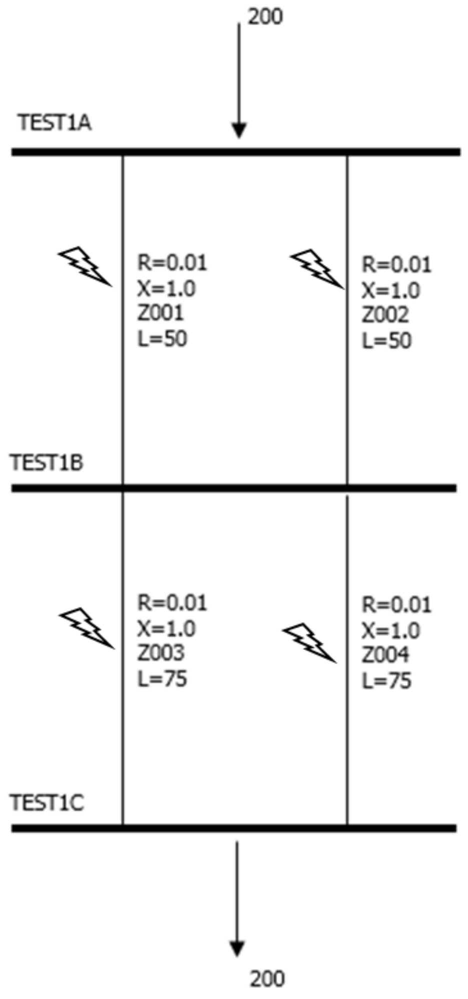
Z001
- Loss of Z002, or
- Loss of Z002& Z003, or
- Loss of Z002 & Z004

Any of the contingencies cause loading of 200MW on circuit Z001

Z002
- Loss of Z001, or
- Loss of Z001& Z003, or
- Loss of Z001 & Z004

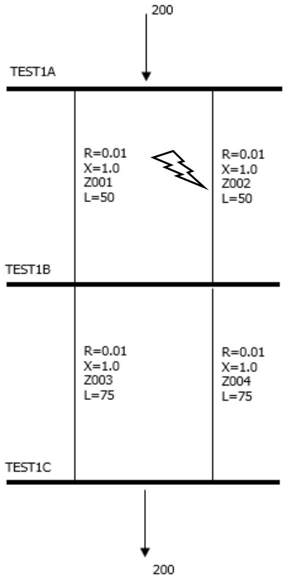
Z003
- Loss of Z004
- Loss of Z004&Z002
- Loss of Z004&Z001

Z004
- Loss of Z003
- Loss of Z003&Z002
- Loss of Z003&Z001

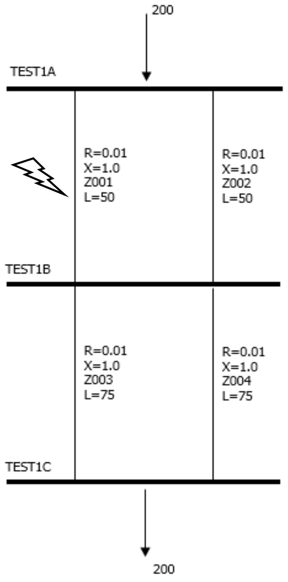


The “secured” marginal costs – Node 1A (Adding 1MW at 1A)

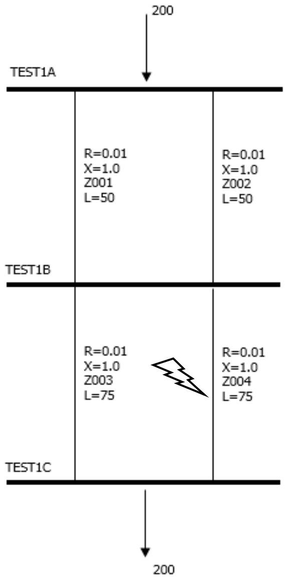
The “secured” marginal cost at 1A
= 1MW*50km+1MW*50km + 1MW*75km
+ 1MW*75km
= **250MWkm**



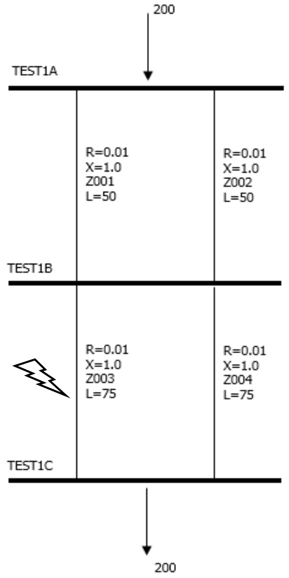
- On Z001 Increasing the dominant flow by 1MW on circuit Z001



- On Z002 Increasing the dominant flow by 1MW on circuit Z002



- On Z003 Increasing the dominant flow by 1MW on circuit Z003

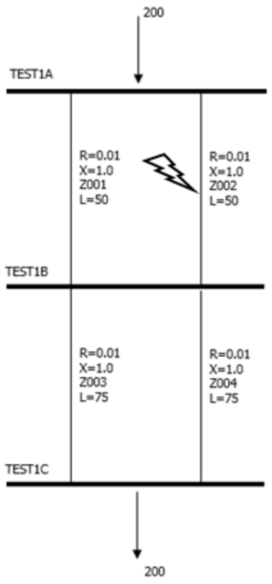


- On Z004 Increasing the dominant flow by 1MW on circuit Z004

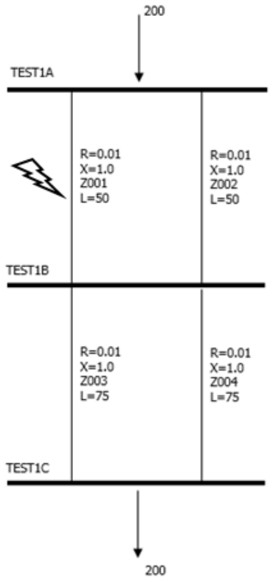
The “secured” marginal costs – Node 1B (Adding 1MW at 1B)

Start by “stressing” each circuit (the diagrams show how each circuit is “stressed”), to get the “secured” nodal marginal cost.

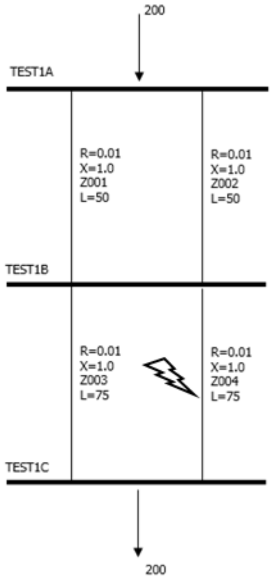
The “secured” marginal cost at 1B
= 1MW*75km+1MW*75km
= **150MWkm**



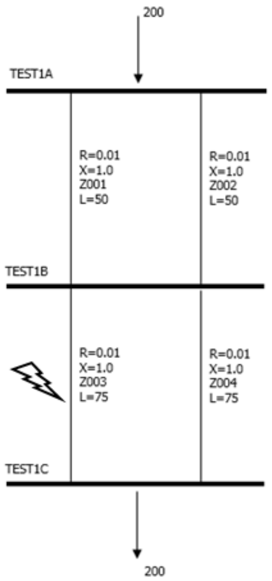
- On Z001
No Impact



- On Z002
No Impact



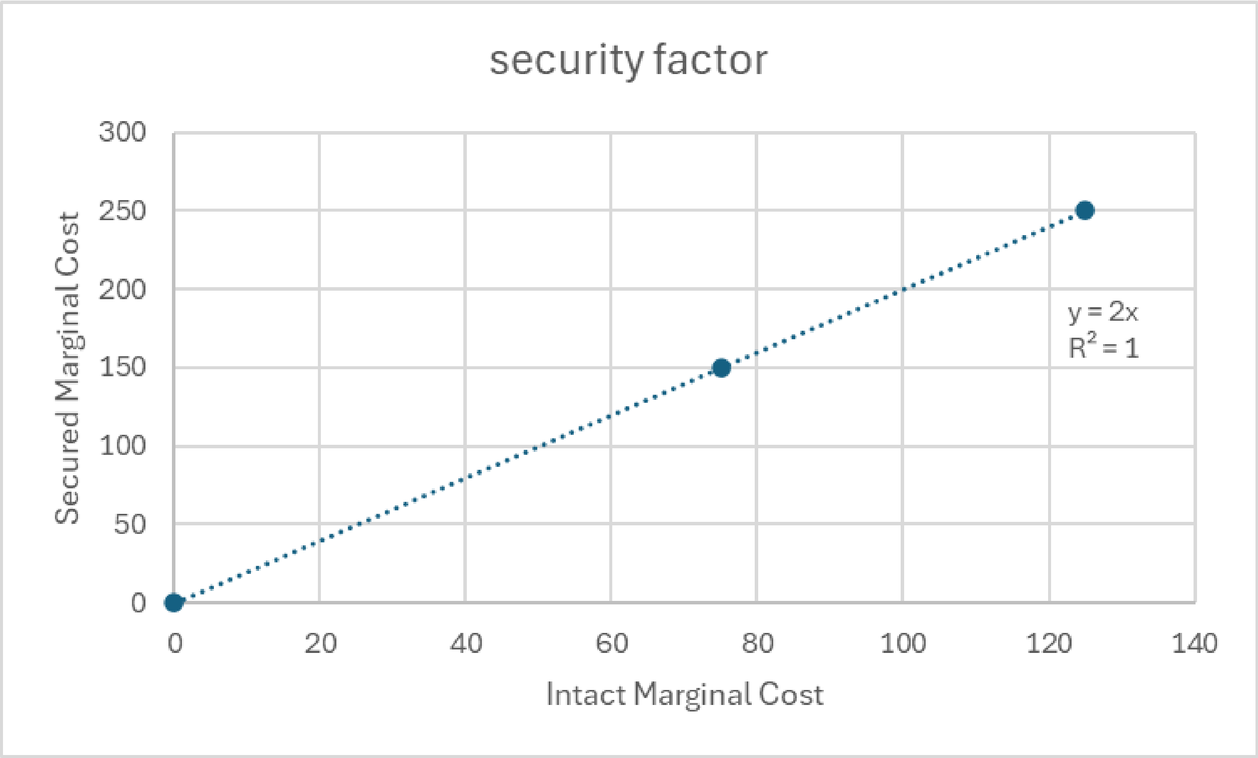
- On Z003
Increasing the dominant flow by 1MW on circuit Z003



- On Z004
Increasing the dominant flow by 1MW on circuit Z004

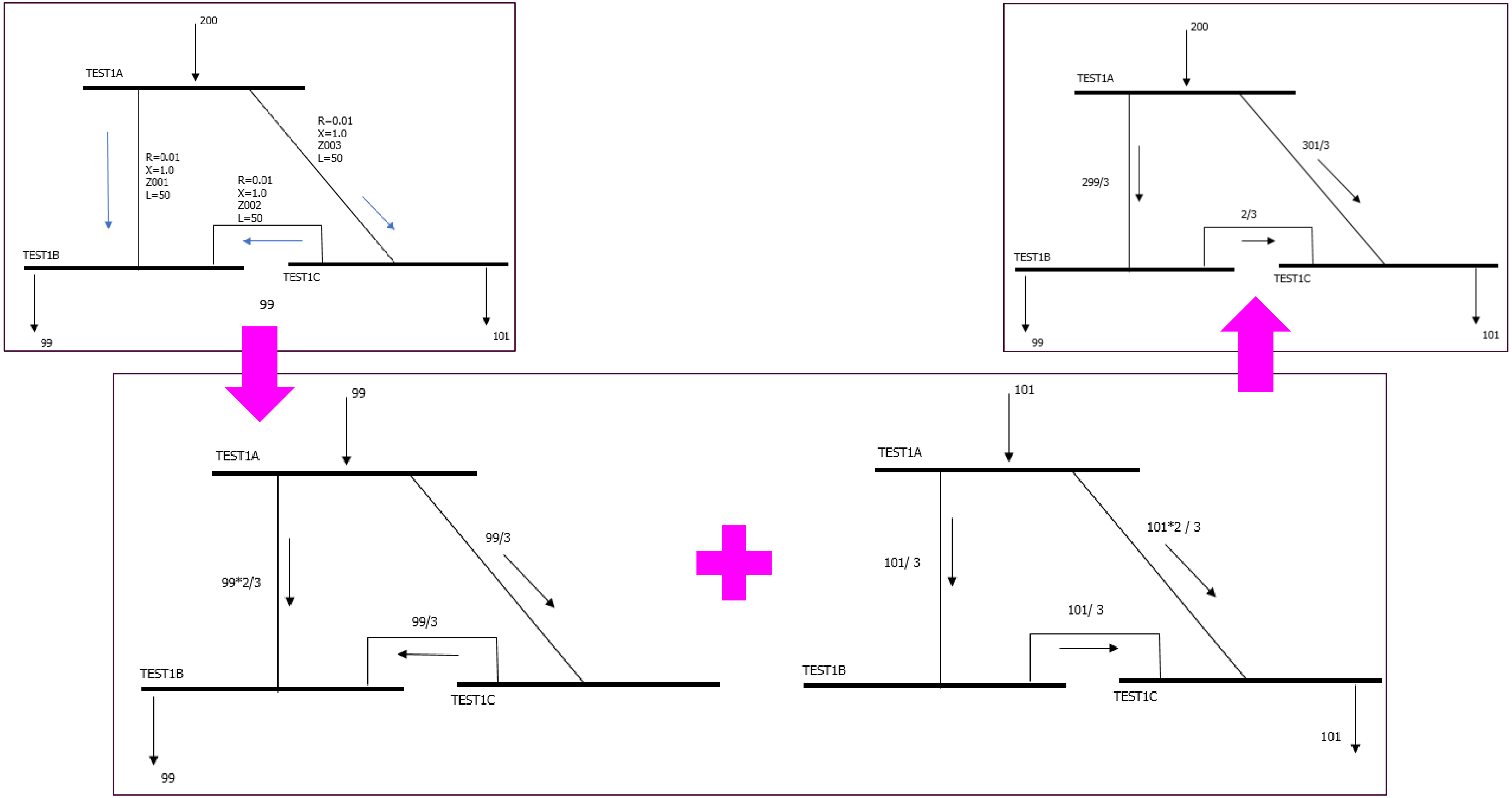
The Security Factor Calculation

We now plot the Secured vs Intact marginal costs at each node to give a ratio which is the slope of the line of best fit
in this example of a double radial circuit with 3 nodes the ratio of Secured to Intact is 2
So the Security Factor in this simple network would be 2

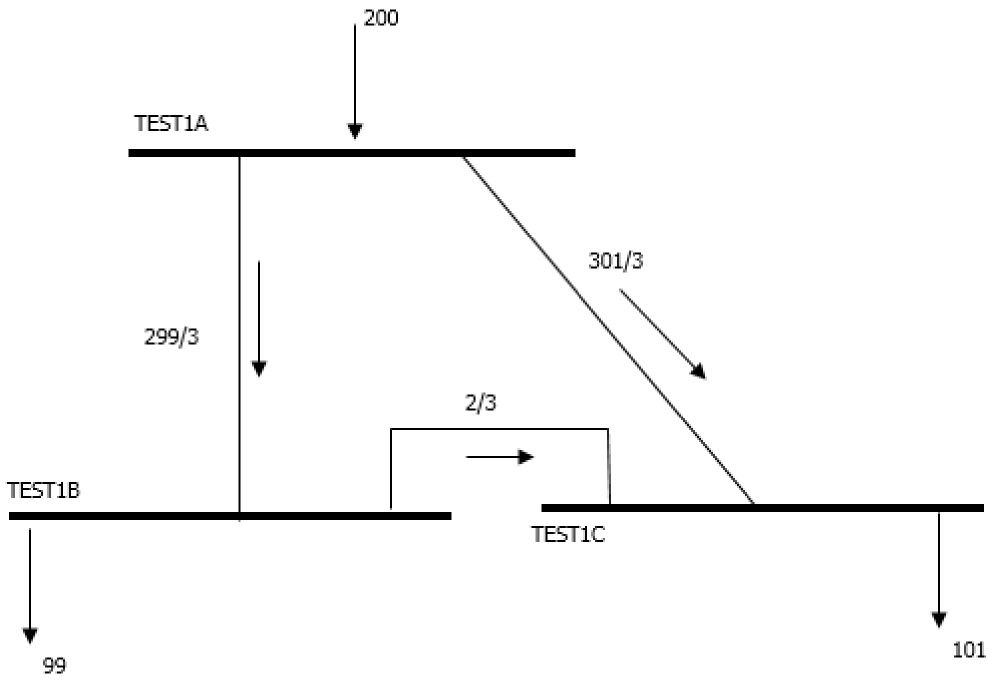


Example 2:
A Meshed Network

Step 1: Calculating the Load Flows



Step 2: Calculating the unsecured marginal costs – assuming 1C is the "slack node"



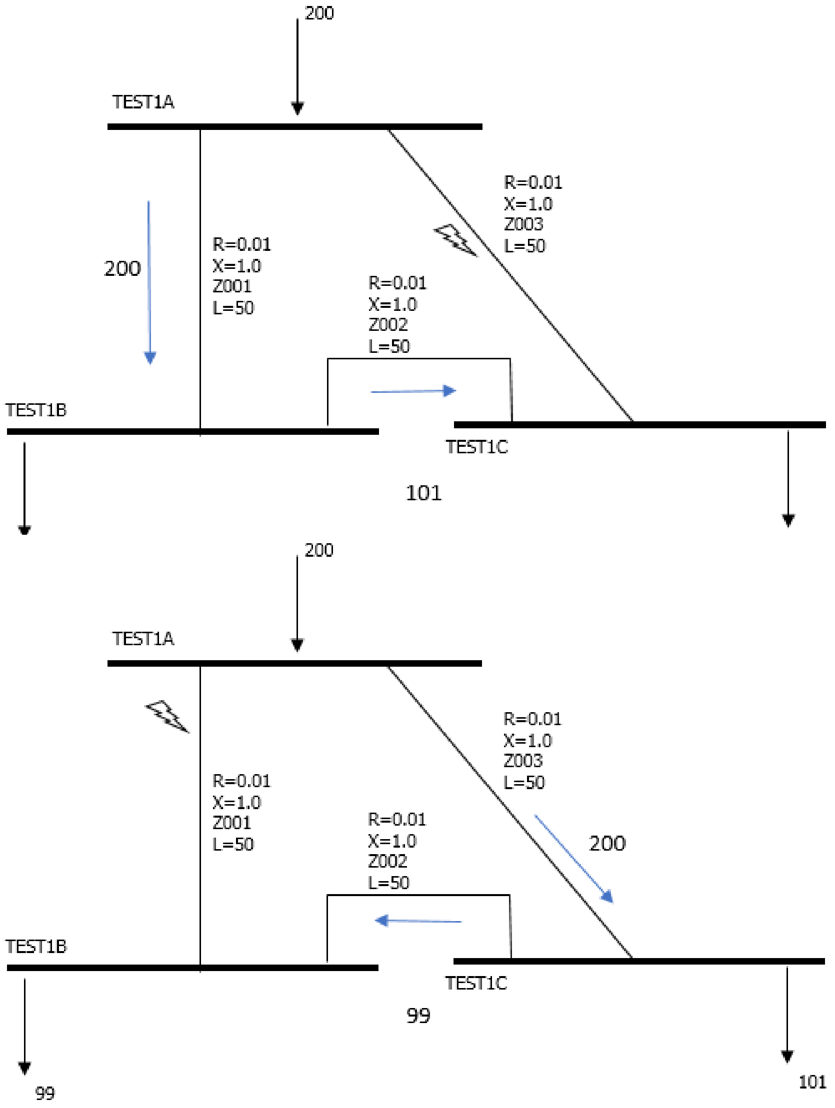
- Adding 1MW at 1A: Increasing the dominant flow by 2/3MW on circuit Z003, increasing the dominant flow by 1/3MW on Z002, and increasing the dominant flow by 1/3 on Z001

Thus, the marginal cost at 1A is 66.667MWkm

- Adding 1MW at 1B: Offsetting the dominant flow by 1/3MW on circuit Z001, increasing the dominant flow by 2/3MW on Z002, and increasing the dominant flow by 1/3 on Z003

Thus, the marginal cost at 1B is 33.333MWkm

Step 3: Calculating the secured marginal costs



Testing a list of contingencies:

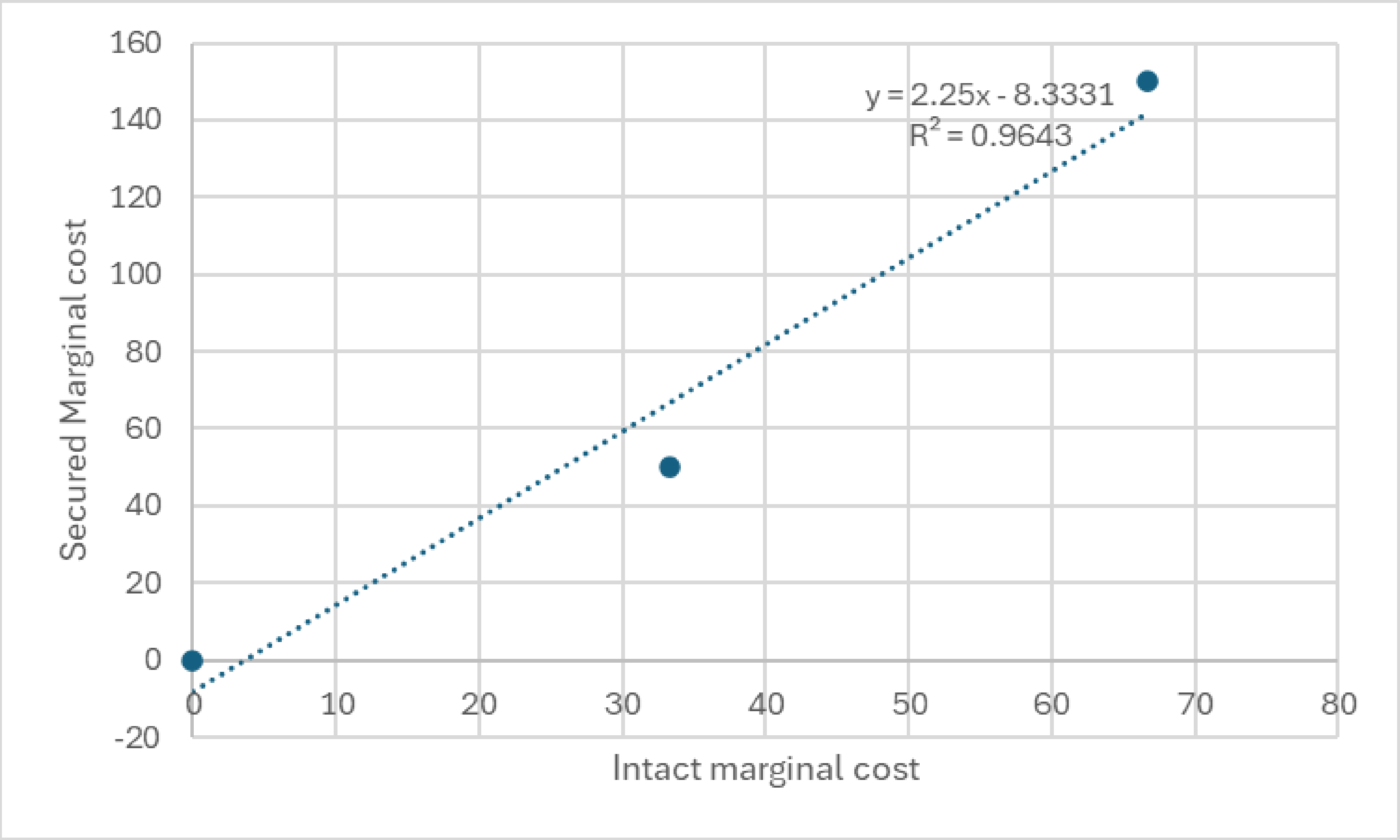
- the worst trip for Z001 (1A to 1B) is loss of Z003
- The worst trip for Z002 is loss of Z003
- The worst trip for Z003 is loss of Z001

The secured marginal cost at 1A is 50MWkm +50MWkm +50MWkm = 150MWkm

The secured marginal cost at 1B is 0MWkm+50 +0MWkm =50MWkm;

Step : Calculating the security factor

We now plot the Secured vs Intact marginal costs at each node to give a ratio which is the slope of the line of best fit
in this example of a simple mesh circuit with 3 nodes the gradient of the line of best fit of the ratio of secured to intact is 2.25
So the Security Factor would be 2.25



Q&A