Development and Implementation of Test Systems for Protection Schemes using the RTDS Simulator

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Sep 15th 2016

Imagination at work

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Simulink – RTDS Conversion

System Configuration & Reconfiguration to Test Multi-Ended Current Differential Protection

Series Compensation in the UK

Testing an AMU in a System-Wide Context

Q&A

About Ourselves

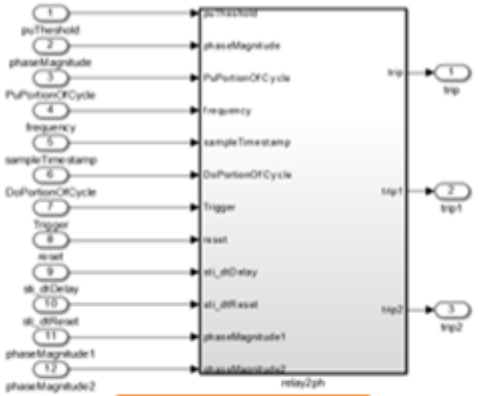
UK Grid Solutions is a leading manufacturer of protection and control equipment with a world-wide customer base. The Grid Solutions site in Stafford UK installed their first RTDS equipment in 1997 and its primary purpose is to test protective relays and systems for validation of products under development or for customer approvals. Since 2011 the laboratory has been accredited by UKAS to IEC17025.

Simulink – RTDS Conversion

Introduction on Simulink – RTDS Conversion

- RTDS technologies provide an interface between Matlab Simulink models and RSCAD.
- The approach is to make use of the C code generator in Matlab Simulink to generate code in a form suitable for RSCAD C Builder. Import the generated code into C Builder and create the RSCAD component
- Benefits of making use of the conversion: make it possible to test algorithms in real time before hardware is available; the converted model could be imported as a component into existing power system protection RTDS test cases.

Conversion Study(1/2)



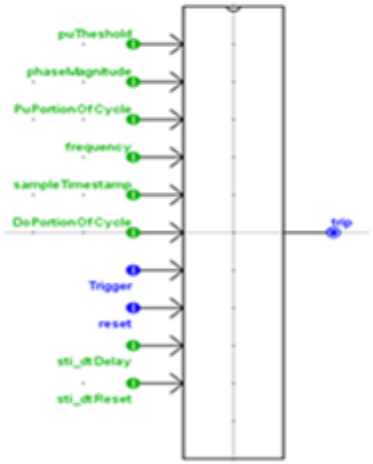
Simulink model

Code Generation

```
// Include file below is generated by C-Builder
// and contains the variables declared as -
// PARAMETERS, INPUTS, OUTPUTS . . .
#include "NewSampler.h"

STATIC:

// We want to sample one time over Cat.
double Cat ;
int cpt ;
double dt ;

RAM_FUNCTIONS:
RAM:

dt = getTimeStep() ;

CODE:

Cat = 1/ (Freq * Num * dt) ;

if ( cpt > Cat-1 ){
     cpt = 1 ;
     Trigg = 1 ;
}
else{
     cpt++ ;
     Trigg = 0 ;
}
```

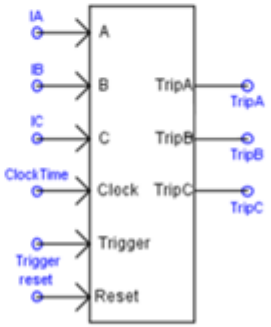
C codes

Import Simulink Model



RTDS component

Change inputs into settings

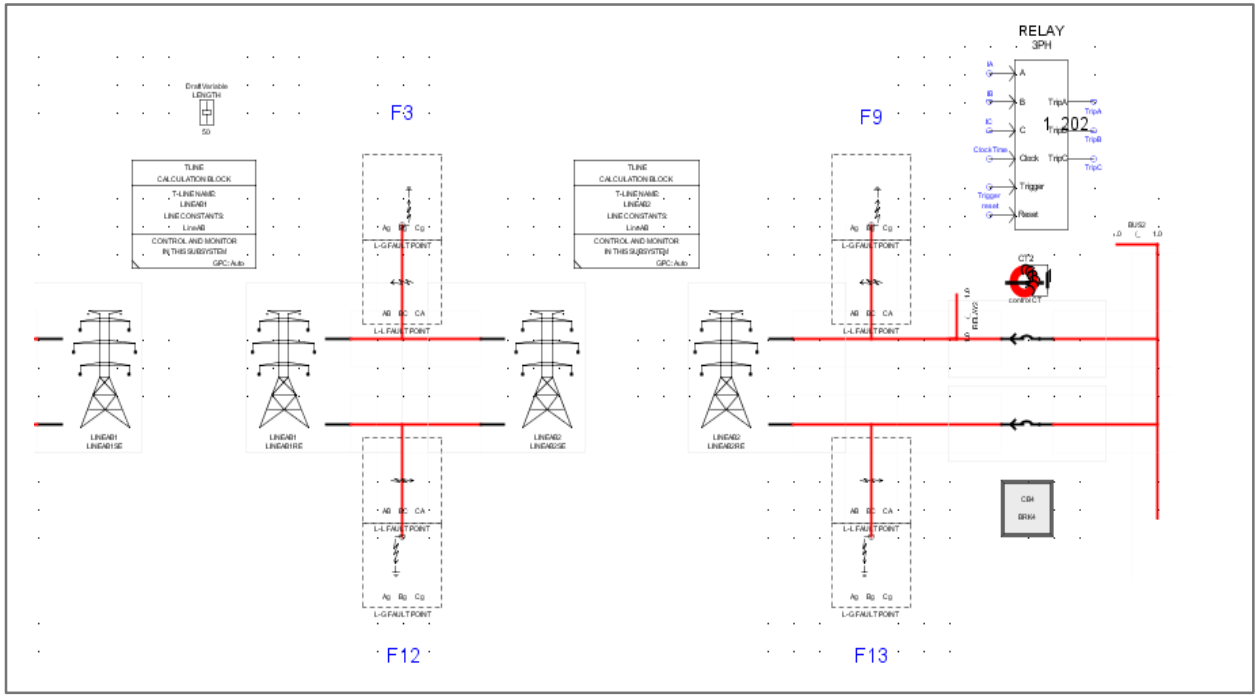


Simplified RTDS component

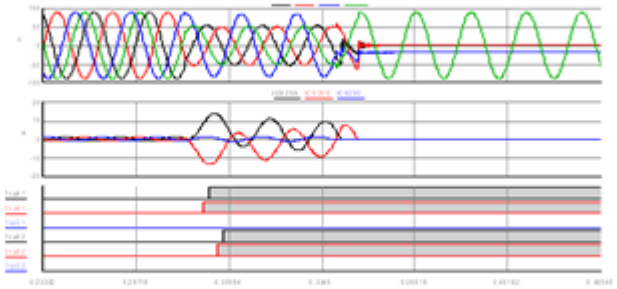
Put component into draft

Conversion Study (2/2)

Put component into draft



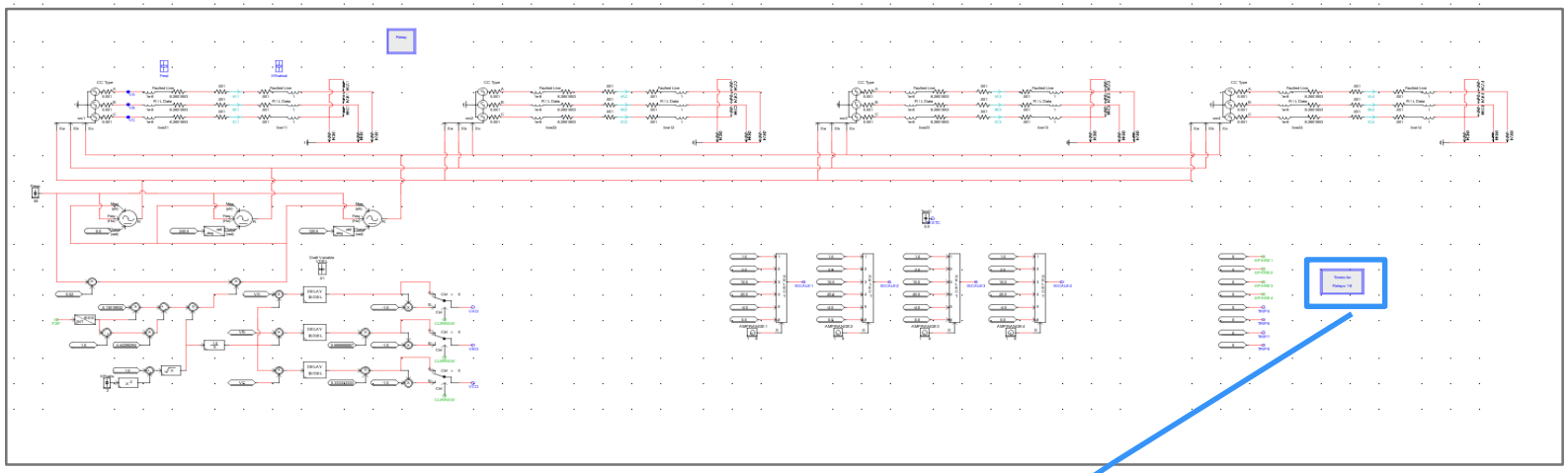
Run the Simulation

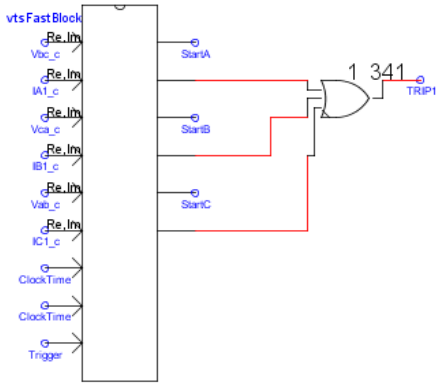


RTDS Simulation result

Case Study

- CT requirement testing system under RTDS environment





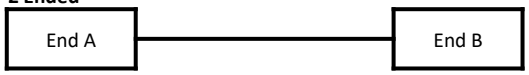
the Converted component in testing system

- Same tests were performed on the converted model and on a real overcurrent relay. The results are very close.

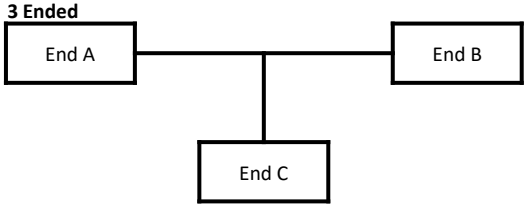
System Configuration & Reconfiguration to Test Multi-Ended Current Differential Protection

System Configurations to Test (1/2)

2 Ended

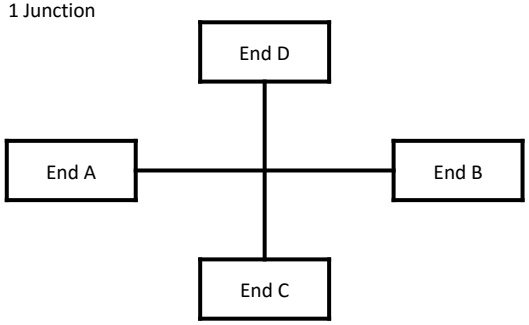


3 Ended

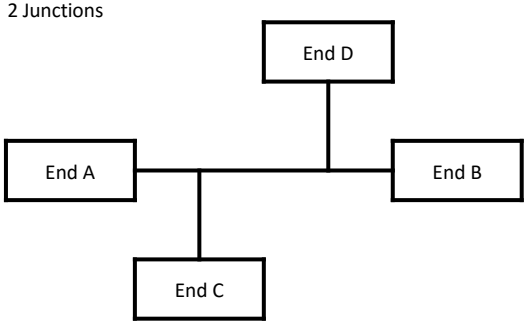


4 Ended

1 Junction



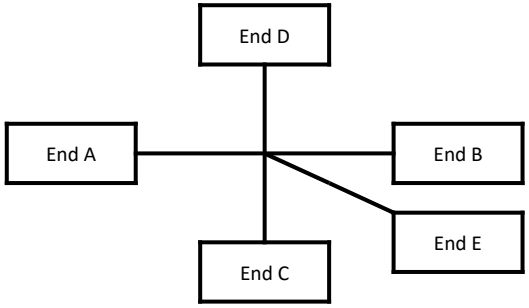
2 Junctions



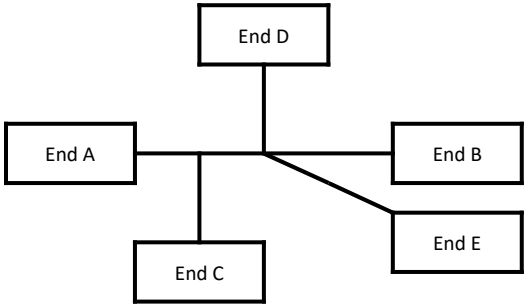
- There are 13 configurations in total to cover for this Multi-Ended current differential protection validation testing.

5 Ended

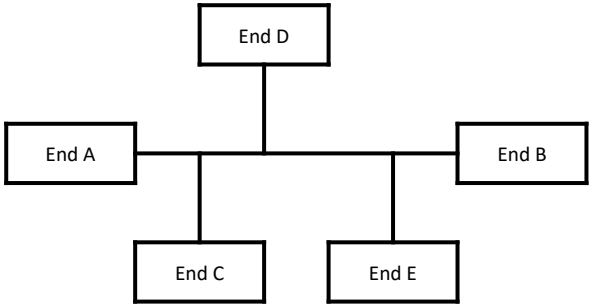
1 Junction



2 Junctions



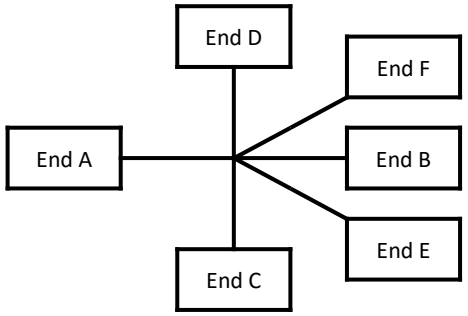
3 Junctions



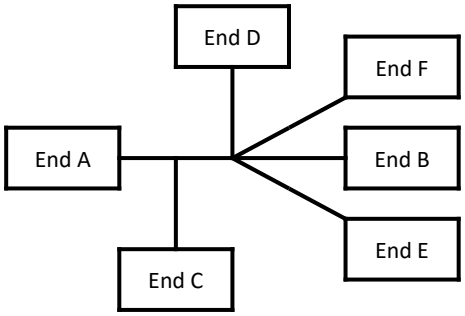
System Configurations to Test (2/2)

6 Ended

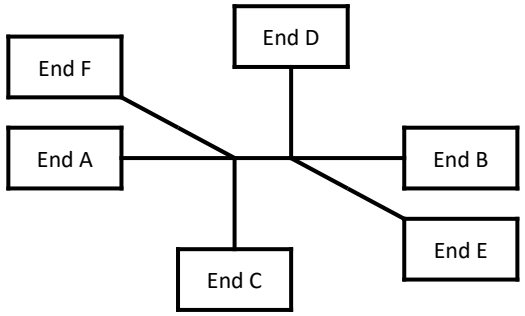
1 Junction



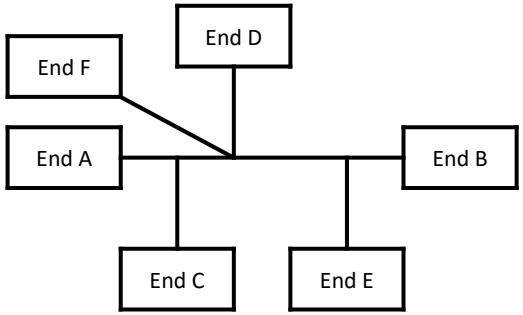
2 Junctions (alt 1)



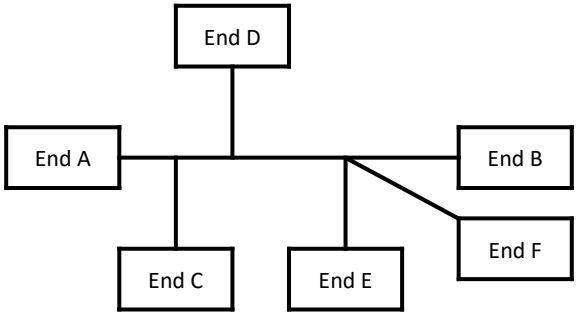
2 Junctions (alt 2)



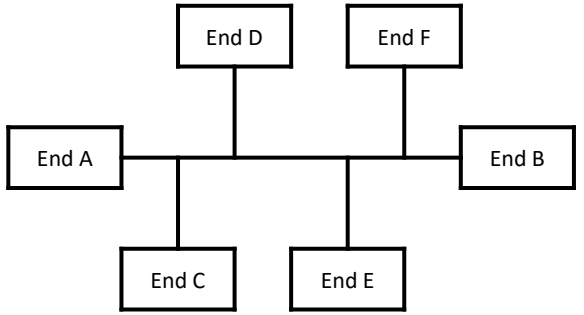
3 Junctions (alt 1)



3 Junctions (alt 2)

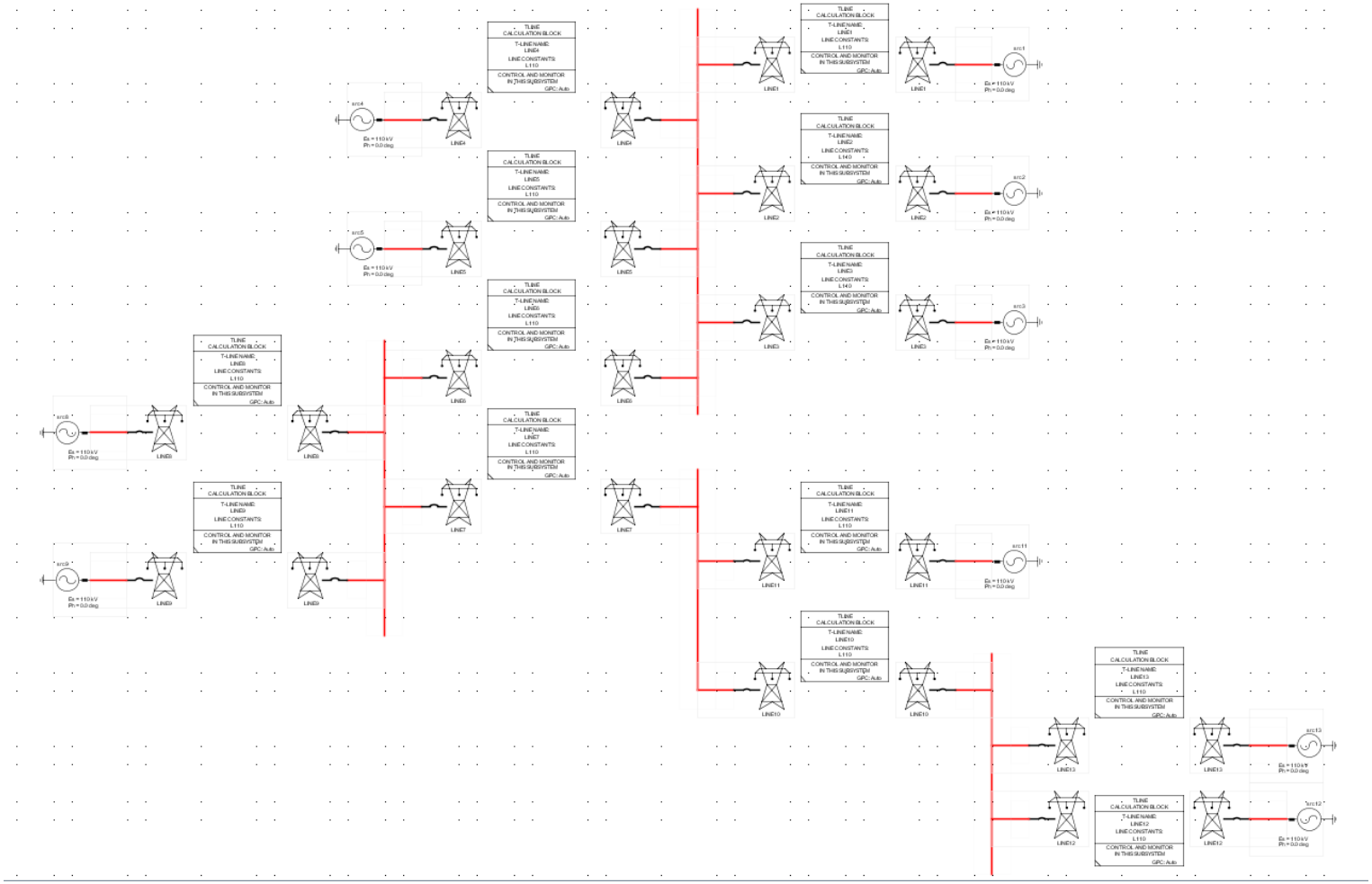


4 Junctions

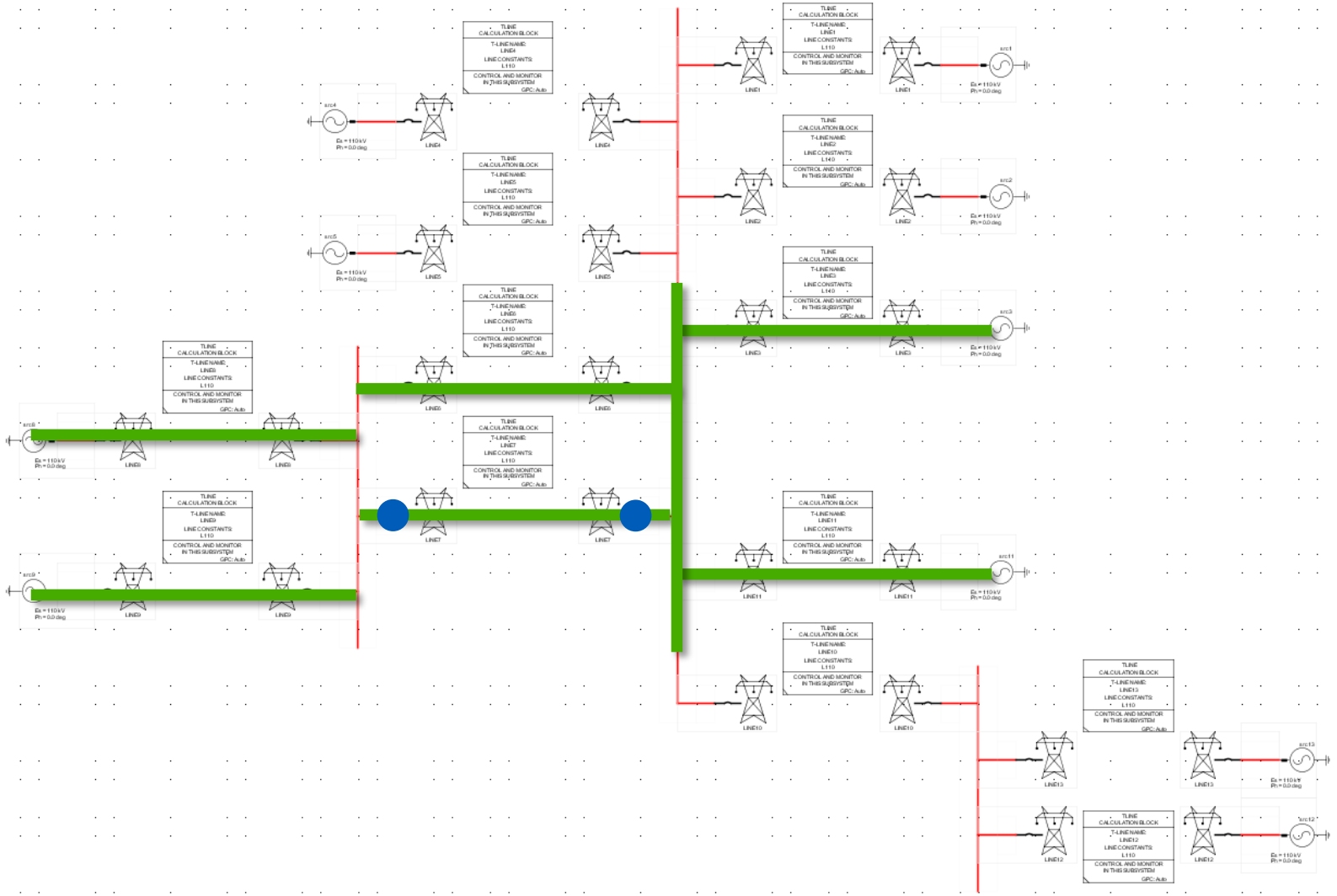


Overall System Configuration

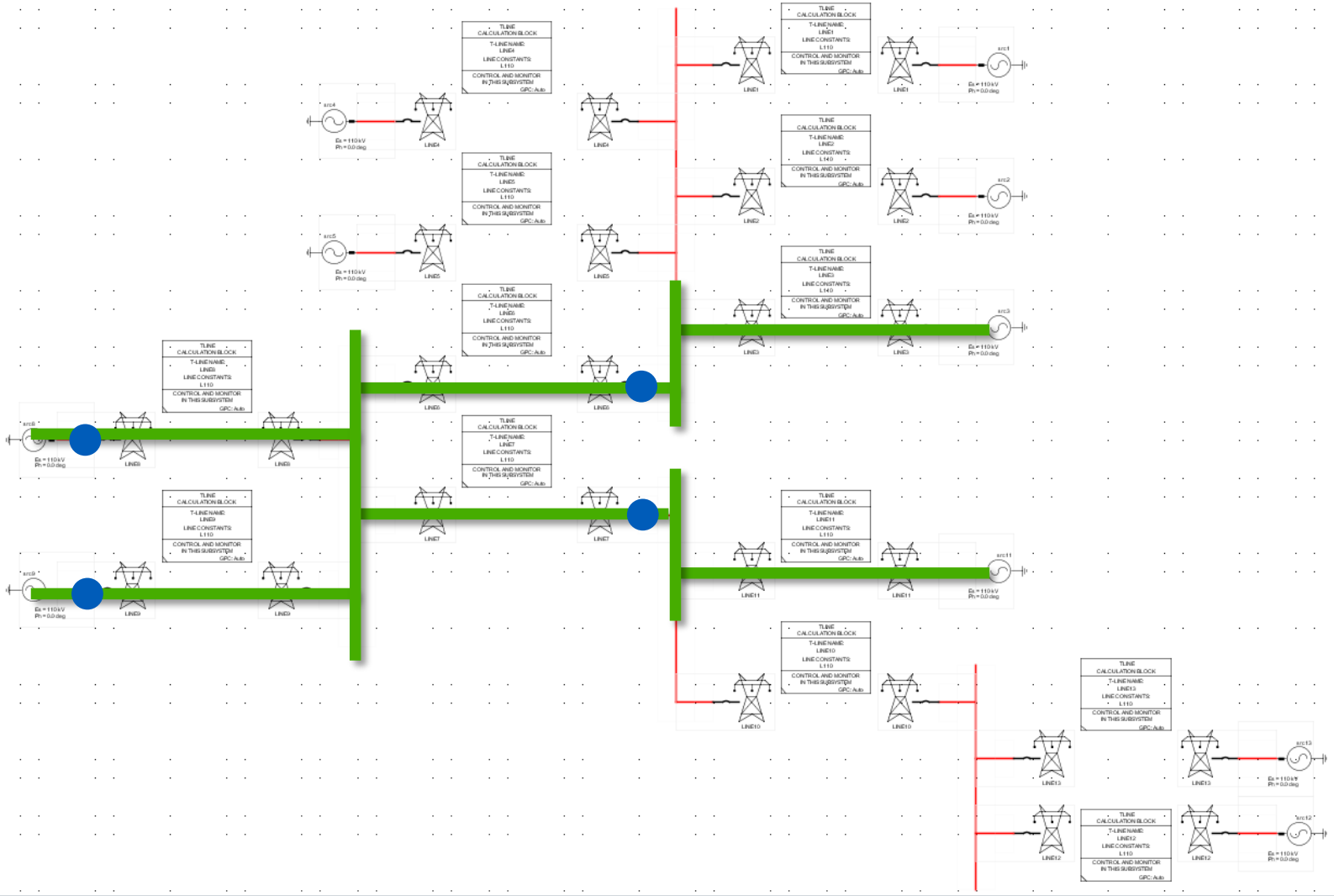
- We implemented 1 single system to cover all of them



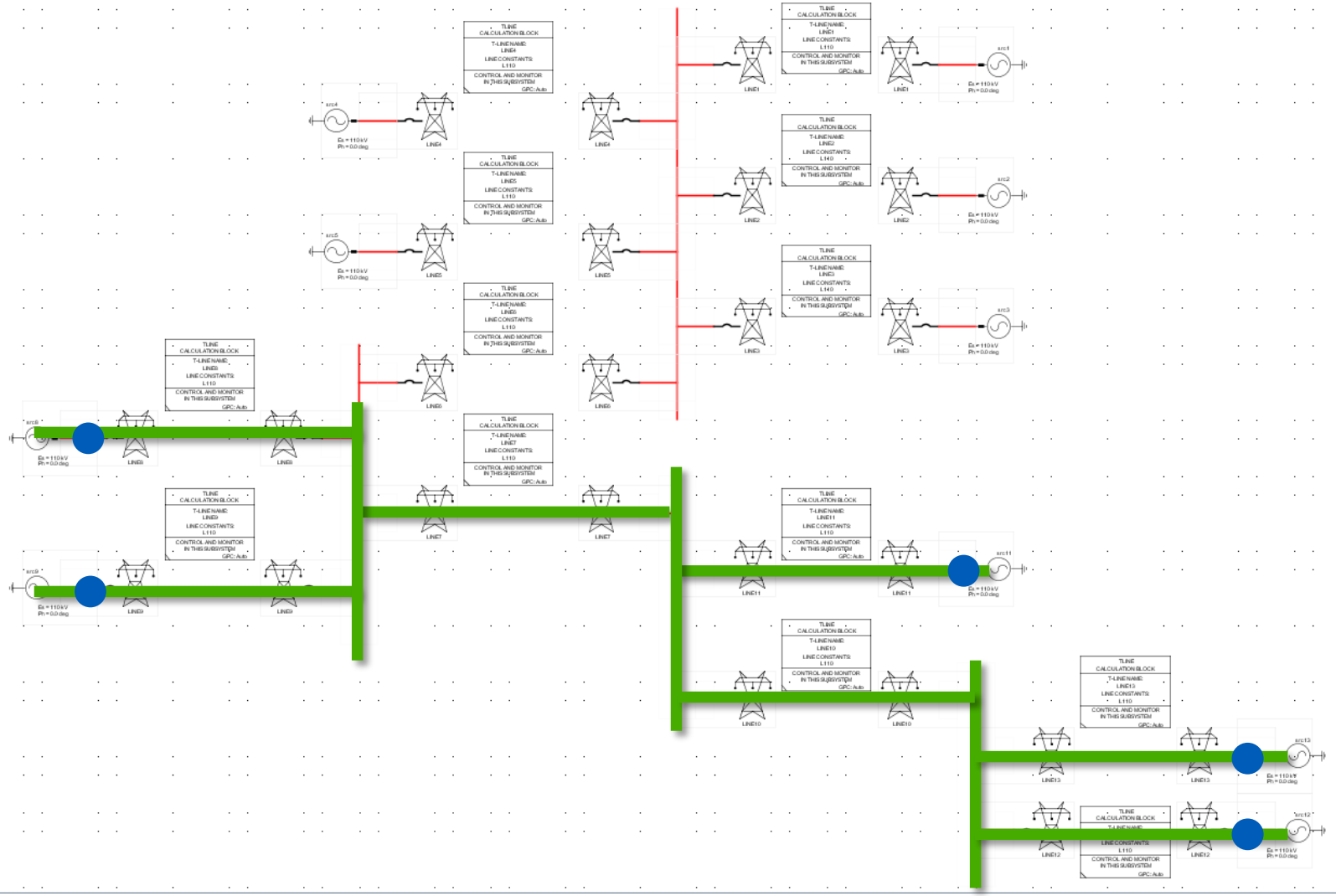
Test Configuration(1/4) – 2 Terminals



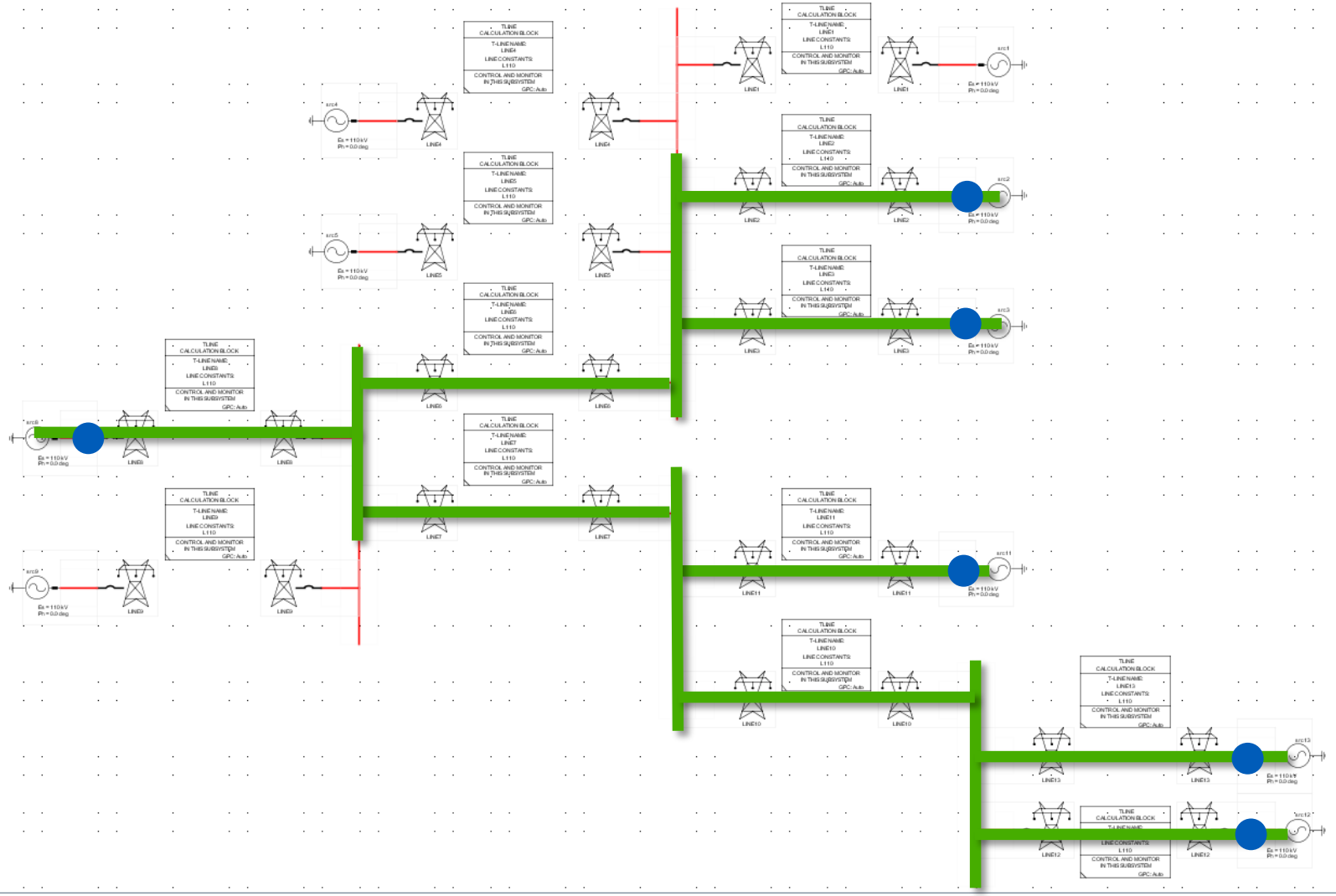
Test Configuration(2/4) – 4 Terminals 1 Junction



Test Configuration(3/4) – 5 Terminals 3 Junctions



Test Configuration(4/4) – 6 Terminals 4 Junctions



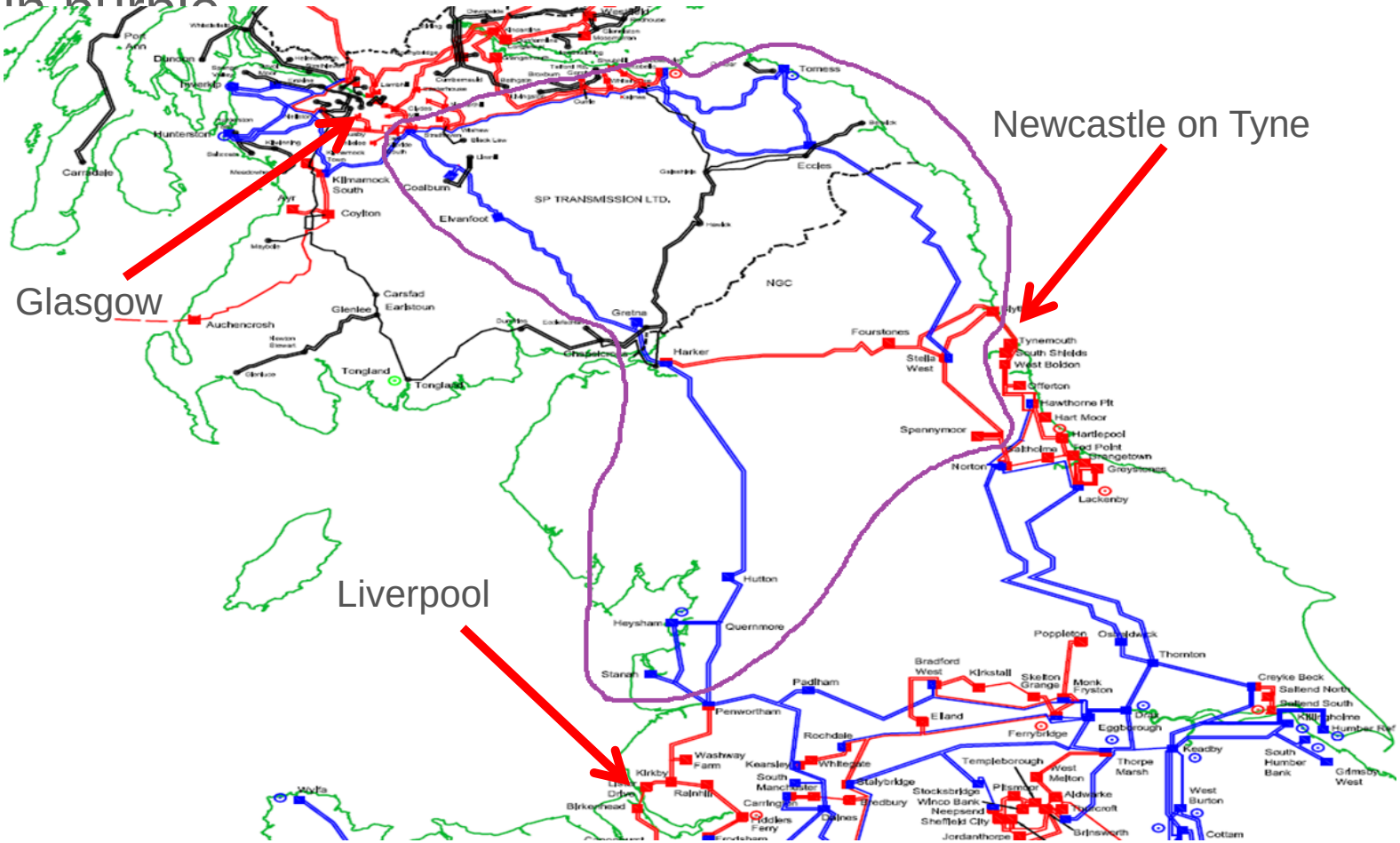
Series Compensation in the United Kingdom

Background

- Changing locations of power generation in the United Kingdom are demanding additional capacity to transfer power from Scotland to England.
- New line construction considered too expensive.
- Utilising series compensation to improve system stability; thus allowing the existing lines to be operated closer to their thermal capacity.
- Dense and interconnected network raises questions over the impact on existing protection on the adjacent lines.
- Important connections close to capacitors; e.g. nuclear generation, feed for major railway.

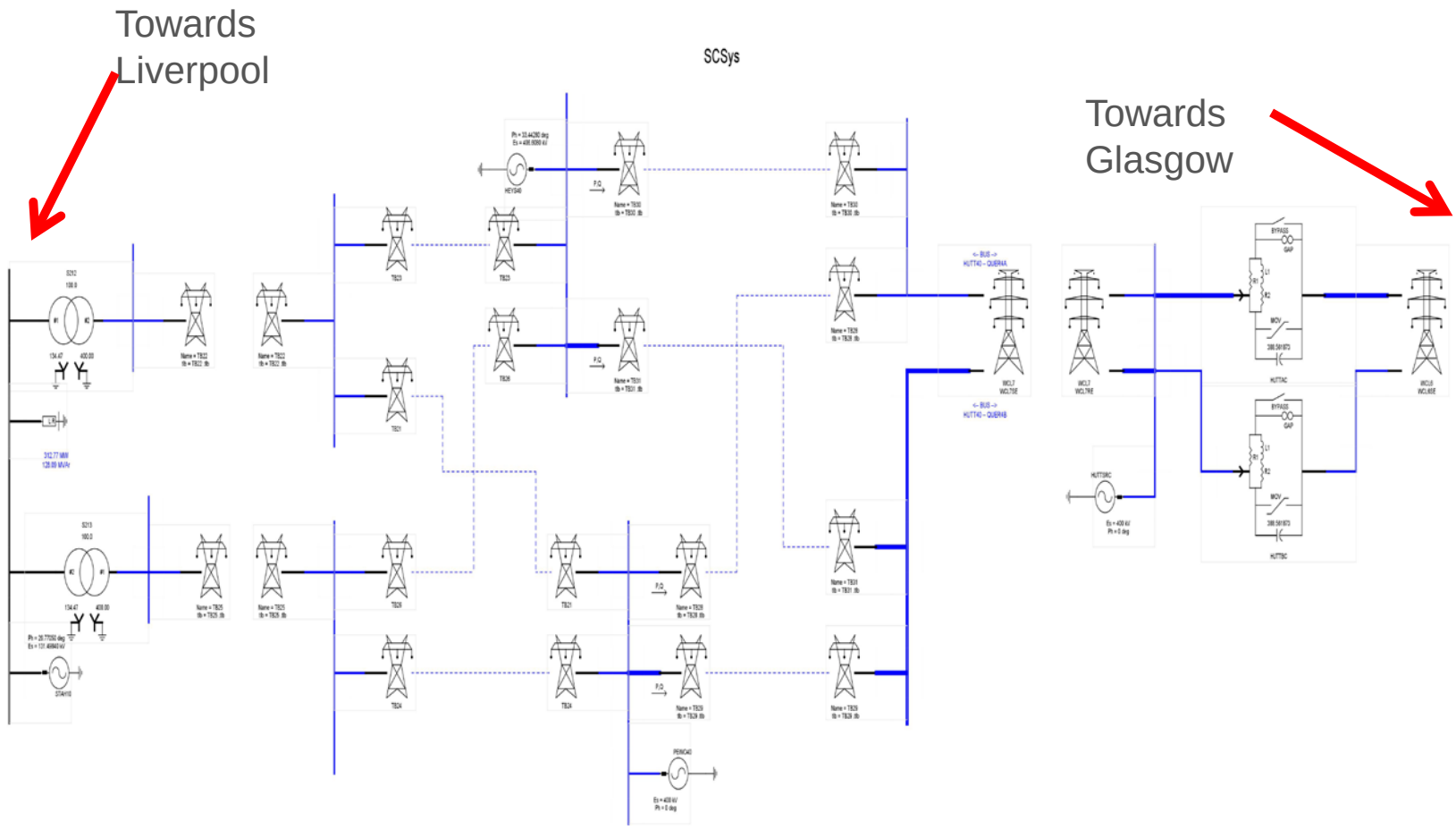
Area covered by Study

- All the 400kV lines (in blue); 275kV lines (in red) and some of the 132 KV lines (in black) in the area enclosed in purple



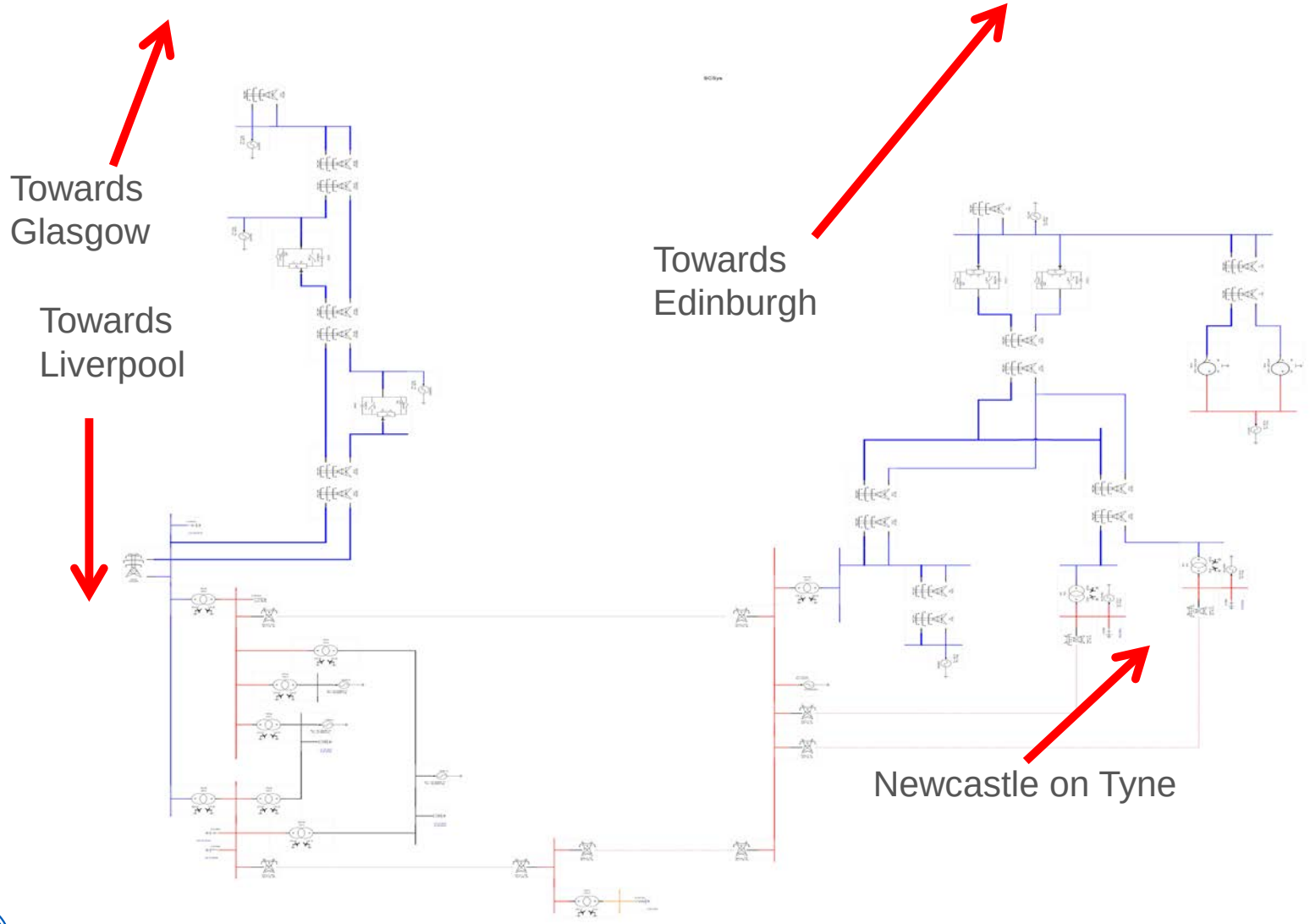
RTDS Case – South Western part

- Thick Lines show which lines were tested



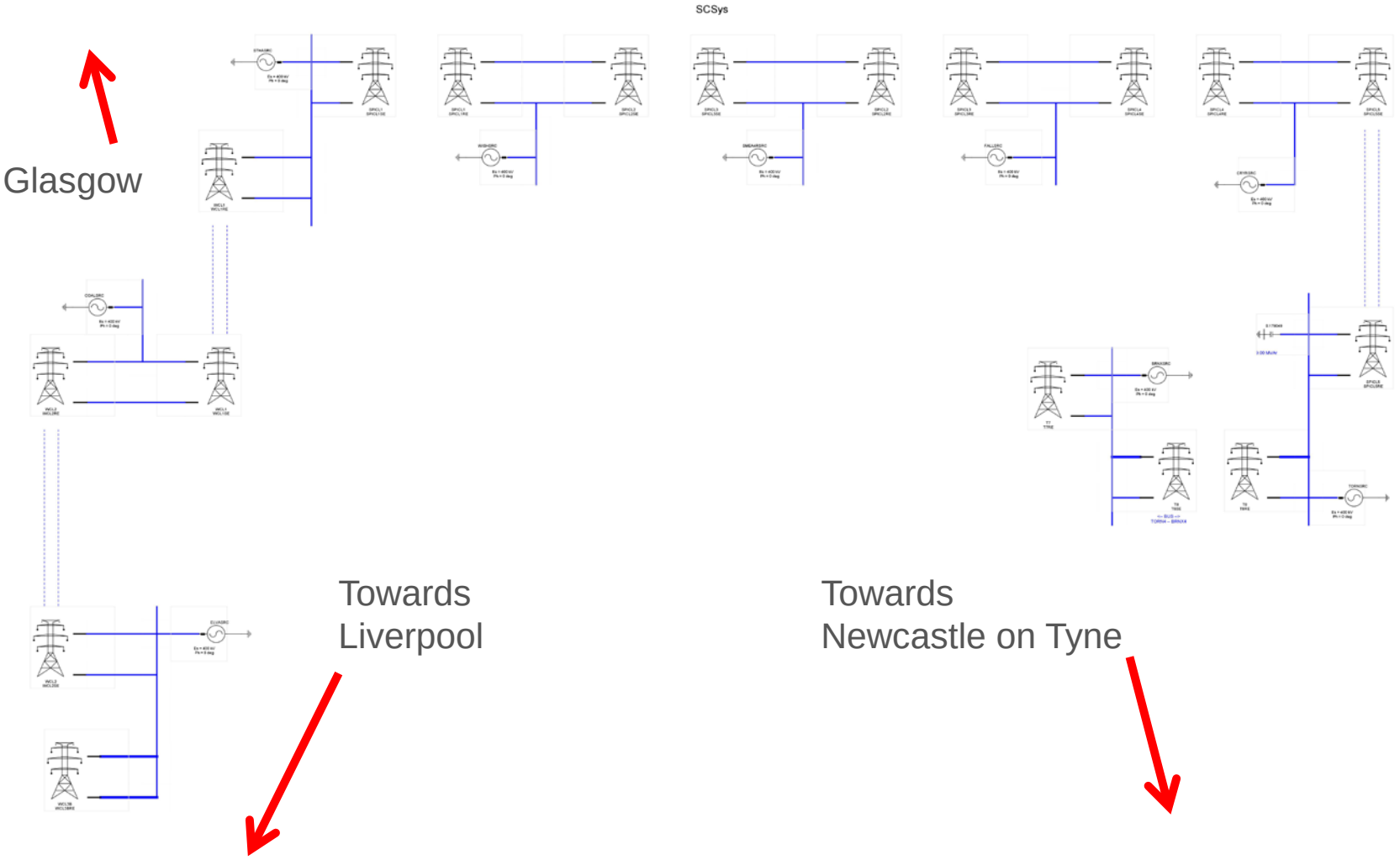
RTDS Case – Central part

- Thick Lines show which lines were tested



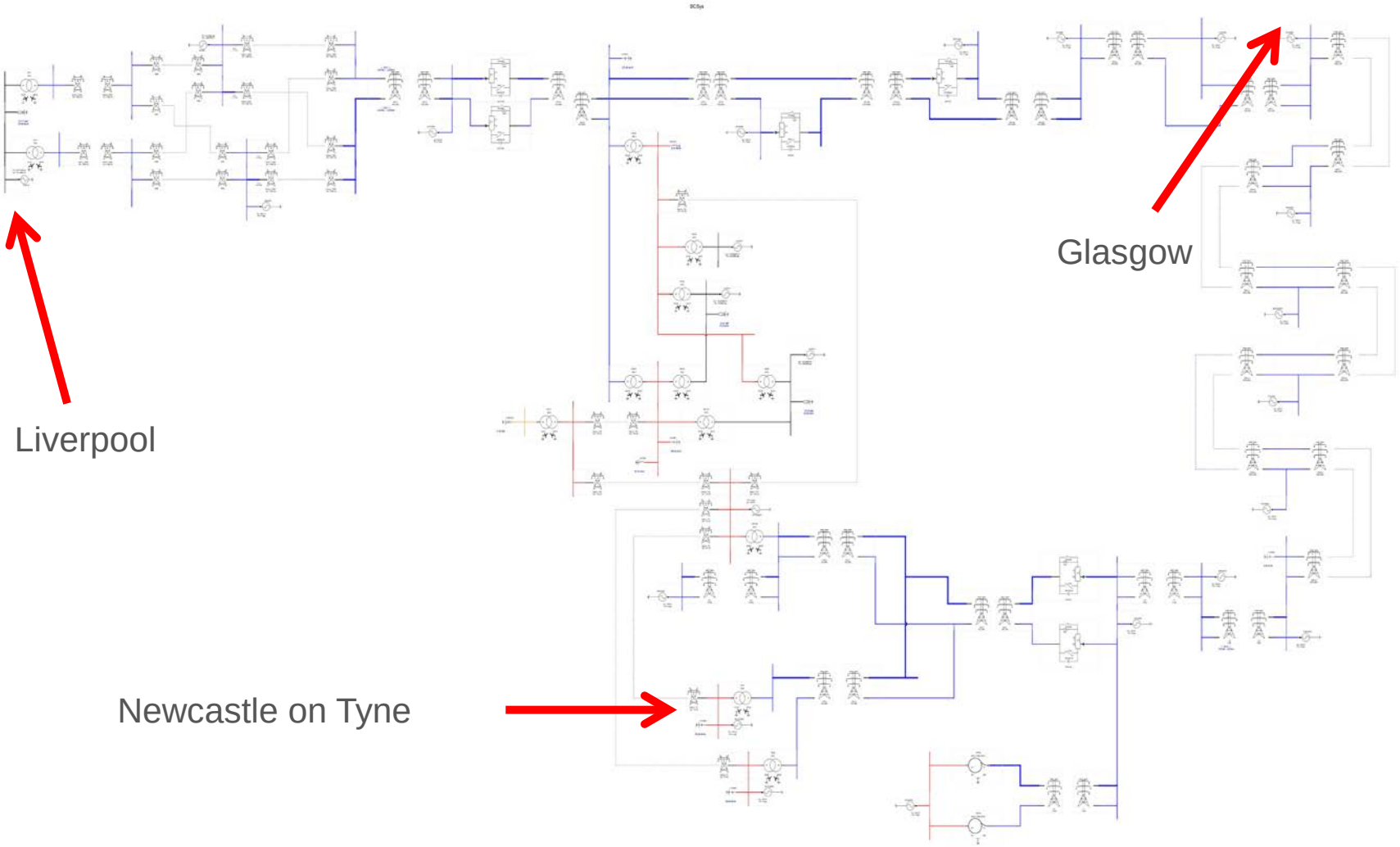
RTDS Case – Northern part

- Thick Lines show which lines were tested



RTDS Case

- Thick Lines show which lines were tested

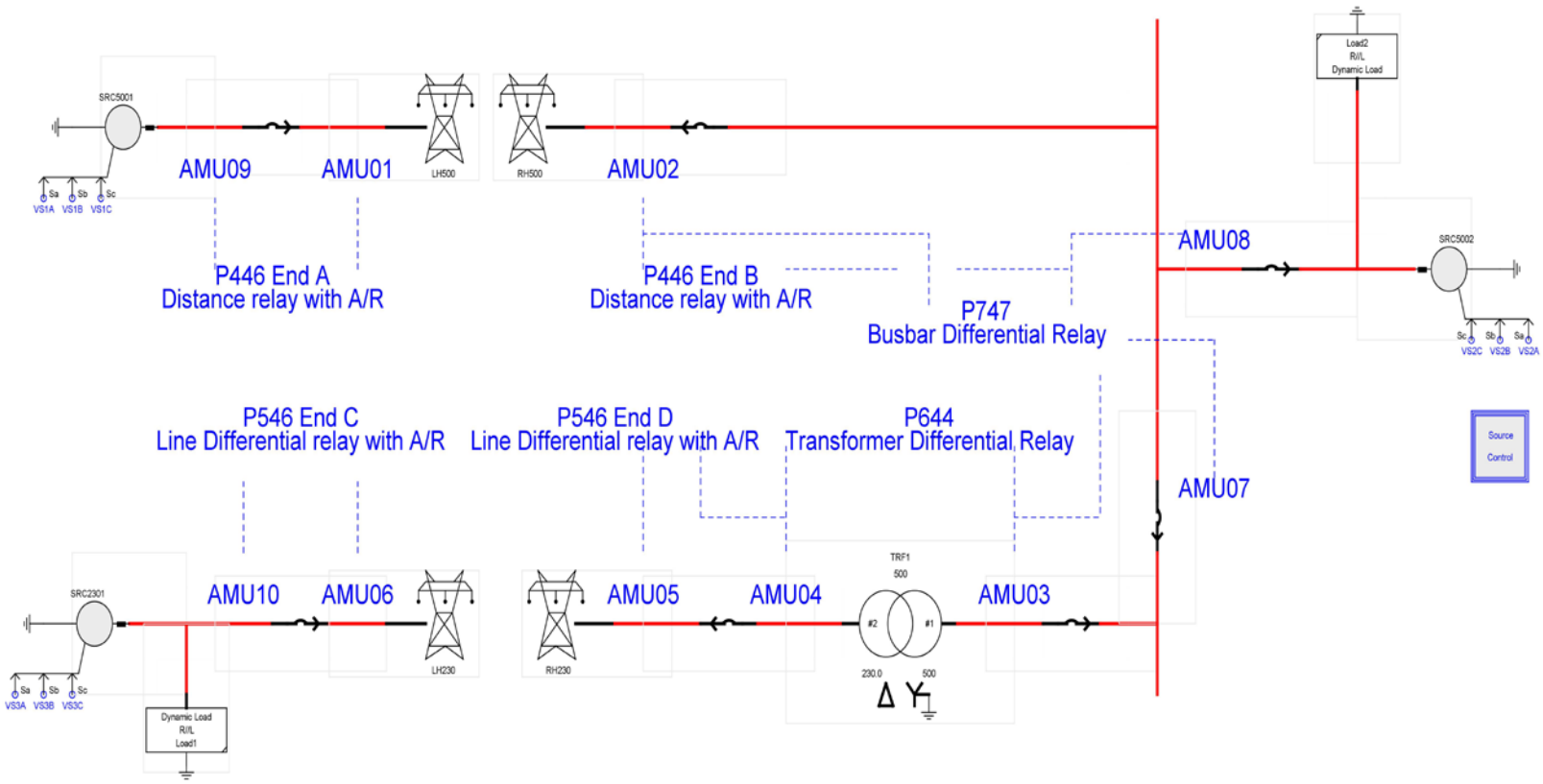


Testing an AMU in a System-Wide Context

Test requirements

- Part of validation of an AMU design before product launch.
- Need to examine performance when used as a complete system.
  - Multiple AMU devices
  - Various protective relays
- Representative of the lead customer’s system (500kV).

RTDS Case


SRC5001
Sa
Sb
Sc
VS1A
VS1B
VS1C
AMU09
AMU01
LH500
RH500
AMU02
P446 End A
Distance relay with A/R
P446 End B
Distance relay with A/R
P747
Busbar Differential Relay
AMU08
Load2
R/L
Dynamic Load
SRC5002
Sc
Sb
Sa
VS2C
VS2B
VS2A
Source
Control
P546 End C
Line Differential relay with A/R
P546 End D
Line Differential relay with A/R
P644
Transformer Differential Relay
AMU07
SRC2301
AMU10
AMU06
LH230
AMU05
AMU04
RH230
TRF1
500
#2
#1
230.0
500
AMU03
Sa
Sb
Sc
VS3A
VS3B
VS3C
Dynamic Load
R/L
Load1

Characteristics of Test System

- Internal faults for one protection are external faults for the others.
  - Reduces overall number of tests
- Complex system to configure.
  - Needs large numbers of amplifiers
  - Space required for relays and network equipment
- Requires synchronisation.
- All ten AMU outputs merged into one datastream sent to all relays.
- Measured operating times to be compared with those expected of conventional protection.

Q&A

Thank you !

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Appendix-
Case Study of Simulink – RTDS Conversion

- Same tests were performed on the converted model and also on a real overcurrent relay. Figures below display tripping time in seconds for internal phase-to-ground fault for a fixed CT knee-point voltage and CT secondary lead burden varying from 0.1 ohm to 13 ohms. Tripping time in green is fast operation and yellow reflects normal operation

	Ftyp	XR	In	If	Shot	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.2
Real relay	PGF	120	1	10	1	0.3427	0.3681	0.3831	0.4024	0.4324	0.4447	0.4632	0.4902	0.4923	0.5168	0.5373
	PGF	120	1	10	2	0.3616	0.3867	0.4028	0.4230	0.4420	0.4649	0.4845	0.5010	0.5114	0.5269	0.5484
	PGF	120	1	10	3	0.3622	0.3870	0.4042	0.4230	0.4422	0.4648	0.4834	0.5010	0.5126	0.5280	0.5473
	PGF	120	1	10	4	0.3218	0.3470	0.3631	0.3840	0.4025	0.4254	0.4440	0.4711	0.4724	0.4977	0.5282
	PGF	120	1	10	5	0.3632	0.3876	0.4030	0.4236	0.4432	0.4641	0.4835	0.5005	0.5120	0.5270	0.5481
	PGF	120	1	10	6	0.3625	0.3868	0.4038	0.4237	0.4441	0.4643	0.4835	0.5007	0.5121	0.5284	0.5489
scientific model	PGF	120	1	10	1	0.3395	0.3595	0.3796	0.3995	0.4196	0.4396	0.4496	0.4696	0.4895	0.4996	0.5296
	PGF	120	1	10	2	0.3496	0.3695	0.3995	0.4196	0.4396	0.4595	0.4796	0.4895	0.5095	0.5196	0.5396
	PGF	120	1	10	3	0.3496	0.3695	0.3995	0.4196	0.4396	0.4595	0.4796	0.4895	0.5095	0.5196	0.5396
	PGF	120	1	10	4	0.3196	0.3395	0.3595	0.3796	0.3995	0.4096	0.4396	0.4496	0.4696	0.4796	0.5095
	PGF	120	1	10	5	0.3496	0.3695	0.3995	0.4196	0.4396	0.4595	0.4796	0.4895	0.5095	0.5196	0.5396
	PGF	120	1	10	6	0.3496	0.3695	0.3995	0.4196	0.4396	0.4595	0.4796	0.4895	0.5095	0.5196	0.5396

Appendix-
Case Study of Simulink – RTDS Conversion

	Ftyp	XR	In	If	Shot	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.2
Real relay	PGF	120	1	20	1	0.2121	0.2318	0.2667	0.2833	0.3182	0.3267	0.3327	0.3476	0.3565	0.3676	0.3897
	PGF	120	1	20	2	0.2330	0.2631	0.2861	0.3030	0.3279	0.3364	0.3537	0.3675	0.3775	0.3870	0.3995
	PGF	120	1	20	3	0.2338	0.2620	0.2862	0.3033	0.3275	0.3368	0.3532	0.3676	0.3763	0.3870	0.3984
	PGF	120	1	20	4	0.1833	0.2127	0.2369	0.2639	0.2977	0.2970	0.3128	0.3381	0.3473	0.3671	0.3884
	PGF	120	1	20	5	0.2329	0.2634	0.2862	0.3028	0.3283	0.3366	0.3525	0.3676	0.3776	0.3866	0.3990
	PGF	120	1	20	6	0.2336	0.2623	0.2863	0.3039	0.3293	0.3358	0.3537	0.3676	0.3767	0.3865	0.3991
scientific model	PGF	120	1	20	1	0.1996	0.2296	0.2495	0.2795	0.2995	0.3095	0.3196	0.3395	0.3496	0.3595	0.3695
	PGF	120	1	20	2	0.2296	0.2495	0.2795	0.2995	0.3196	0.3295	0.3496	0.3595	0.3695	0.3796	0.3896
	PGF	120	1	20	3	0.2296	0.2495	0.2795	0.2995	0.3196	0.3295	0.3496	0.3595	0.3695	0.3796	0.3896
	PGF	120	1	20	4	0.1796	0.1996	0.2296	0.2495	0.2795	0.2896	0.2995	0.3196	0.3395	0.3496	0.3695
	PGF	120	1	20	5	0.2296	0.2495	0.2795	0.2995	0.3196	0.3295	0.3496	0.3595	0.3695	0.3796	0.3896
	PGF	120	1	20	6	0.2296	0.2495	0.2795	0.2995	0.3196	0.3295	0.3496	0.3595	0.3695	0.3796	0.3896

- From the results we could see that the results on the real relay and scientific model follow a similar pattern. Taking account of the noise which hasn't been included in the scientific model testing, the results are really similar. The preliminary conclusion that the conversion of this scientific model is successful can be made.