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EPS UK LIMITED REPORT

for

ELECTRICITY NORTH WEST LIMITED

Cable Connected Switchgear
Margins of Safety during a Short Circuit

7 April 2014

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1 CONTENTS

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2 EXECUTIVE SUMMARY

This report is the first in a series looking at short circuit withstand safety margins in cable connected switchgear on the ENWL network.

The report proposes a series of Short Time Withstand tests at various rated fault currents and durations related to the I^2t capabilities of the RMU's and cable terminations/types.

These calculations will be predicated upon manufacturer's data, real test data and known Short Circuit Levels at each site. This will allow ENWL to have confidence in up to 96% of the ENWL RMU asset base.

The budget for the testing including a report of performance and an allowance for ENWL and EPS engineers in attendance is £35,000. (First approximation)

The statistics suggest that up to 96% of configurations will have been validated, and the results will be representative of short circuit performance on the ENWL network.

There would be a short sequence of tests described under the section called Test Configurations.

These tests will be conducted at a High Power Laboratory.

It is proposed that the equipment will undergo routine maintenance before test.

3 INFORMATION SOURCES

The report presents statistics in the main extracted from the ENWL asset database named:

RMU Data.xslx

Cable data is extracted in the main from the ENWL document:

CP203.docx

Further information extracted from Ellipse and RMU Tables.docx, Joint_list.docx and CP411 pt 2 Proc 8_xxx series.

The main backing information comes from these documents to produce this report and a database extraction called RMU Dataamddmmyr.xlsx. Where ddmmyr is a date.

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4 ABBREVIATIONS

RMU	Ring Main Unit
SFU	Switch Fuse Unit
CB	Circuit Breaker
PILC	Paper Insulated Lead Covered (sheathed) Steel wire armoured to BS 6480
PICAS	Paper Insulated Corrugated Aluminium Sheath

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5 Background

Protection systems for distribution networks work on sequence currents and voltages.

Simply put with no fault on a network, it behaves as a symmetrical system and therefore only positive sequence currents and positive sequence voltages exist. When there's a fault, positive, negative and perhaps zero sequence currents and voltages exist. Protective relays use these sequence components along with phase current and/or voltage to detect and respond to faults.

Switching elements such as RMU's SFU's and CB's are coordinated to respond in such a way as to minimise the amount of network to be switched out to remove the fault.

As networks are extended and additional generation is brought on line (including wind, wave, solar, and heat pumps) then network impedances drop and fault levels increase at points on the Network.

As a consequence times to clearance can extend raising questions as to the ability of the connected equipment to "survive" a fault current episode.

The situation is further exacerbated with aging switchgear and cabling.

The main assets under consideration in this report are Ring Main Units (RMU's) and associated cabling.

There is a wide spread of plant ages. This wide flat distribution is as a direct result of a long term rolling asset replacement policy.

Notwithstanding this, the average age of RMU's is approximately 20 years.

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6 STATISTICAL ANALYSIS

There are a total of 11580 RMU's.

Of which:-

67% are T3GF3 or T4GF3

17.7% are RN2C

10.2% are Sabre

Therefore looking at the distribution:-

There are 581 RMU's in the lower quartile being more than 40 years old.

Type	Qty	Percent total
T4GF3	6909	59.66%
RN2C	2044	17.65%
T3GF3	869	7.50%
SABREVRN2A	641	5.54%
SABRE-VRN	318	2.75%
Sabre-VRN2	219	1.89%
T3/OF	133	1.15%

Table 1

There are 4900 less than 25 years old.

There are 4261 RMU's less than 15 years old

The majority of the installed RMU's at 6.6kV and 11kV were manufactured by Long and Crawford/GEC.

95% of all RMU's are covered by 6 of the 7 types shown in Table 1.

The RMU's are typically cabled up using historic or modern cables or joints.

There are a number of cable types in use and a range of approved transition and branch joints.

Generically the cables are single and 3 core copper or aluminum paper or polymeric.

PILC, PICAS are the majority installed.

There is a mix of dry type, cold shrink, hot shrink, compound filled and cold pour cable joints and cable box connections.

Modern transition joints are sourced from a range of manufacturers including 3M, Pirelli, Prysmian and Raychem.

Cable box jointing systems are also supplied by the same range of manufacturers. There are some separable connectors and elbows.

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7 RATINGS

There are three main considerations when looking at switchgear ratings:

1. Nameplate ratings:-
   Literally the ratings recorded on the nameplate. However it was and is common practice to populate nameplates with the ratings requested by the purchaser. These values may be lower than the Type Test ratings. For example switch may have been type tested for a 3 second short circuit withstand rating but the nameplate may be stamped 1 second in line with the ENWL purchase order. Likewise the symmetrical short circuit rating could be 12.5kA on the nameplate but 13.1kA on the type test. In both instances this is acceptable as the nameplate is lower than the type test value.

2. Type test ratings
   The actual values of time voltage and current that the “test object” was subjected to at the test station where it was certified to the appropriate standard.

3. De-rating due to restrictions
   Switchgear may have been de-rated due to operational or performance issues.

Cable ratings are relatively readily calculated. A formula is given in Appendix 1.

However it is recommended that if the proposal, to undertake a Short Circuit Withstand tests (through currents), is accepted it is a simple matter to include representative cables and joints.

Where a site is being decommissioned or upgraded and a suitable RMU candidate for test identified, a short length of cable original joint still attached could be secured and transported to test.

8 Short Circuit Ratings of RMU's in Selected Group

Type	kA	kA	kA	kA	kA	kA
T4GF3	21.9					
Count	8011					
RN2C	20	21.10	21.11	21.9		
Count	1	21	21	1077		
T3GF3	13.1					
Count	806					
SABREVRN2A	20	21.9				
Count	321	3				
SABRE-VRN	20	21	21.9	22	28	36
Count	566	47	3	47	1	1
Sabre-VRN2	20					
Count	16					
T3/OF	13.1	21.9				
Count	117	2				

Table 2

Note: The vast majority of installed units have a single Short Circuit Rating

The exception is for the RN2C where 43 have a lower designated rating than the majority of this type of unit.

Type	kA
T4GF3	20
RN2C	20
T3GF3	13.1
SABREVRN2A	20
SABRE-VRN	20
Sabre-VRN2	20
T3/OF	13.1

Table 3

Proposal is to test at two starting levels for sets of circuits based upon

T4GF3,RN2C and Sabres VRN/2/2A at 20kA 1sec

And T3GF3 and T3/OF starting at 13.1kA 1sec

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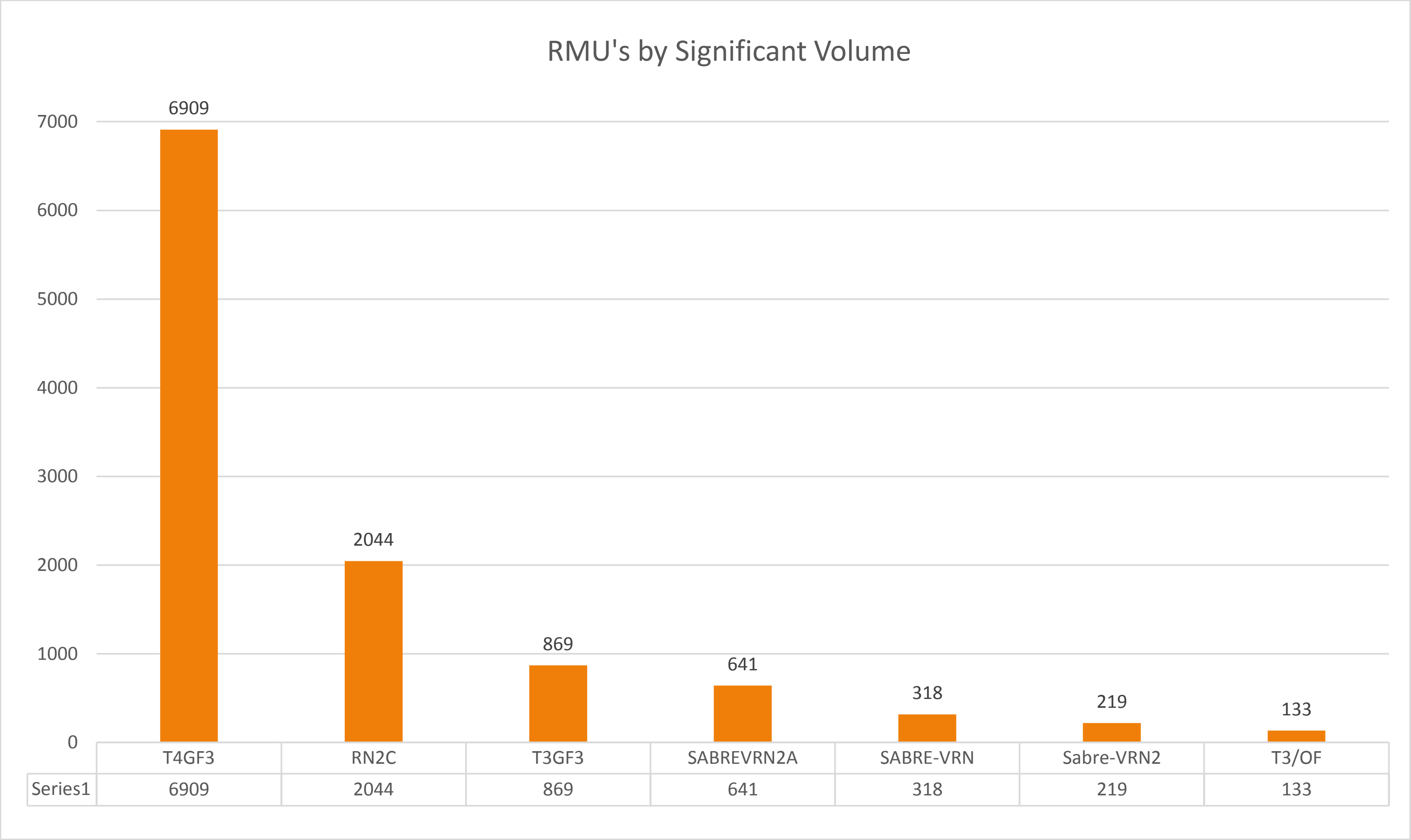
9 GRAPHICAL RESULTS OF ANALYSIS

This graph indicates the dominant numbers of RMU' by type



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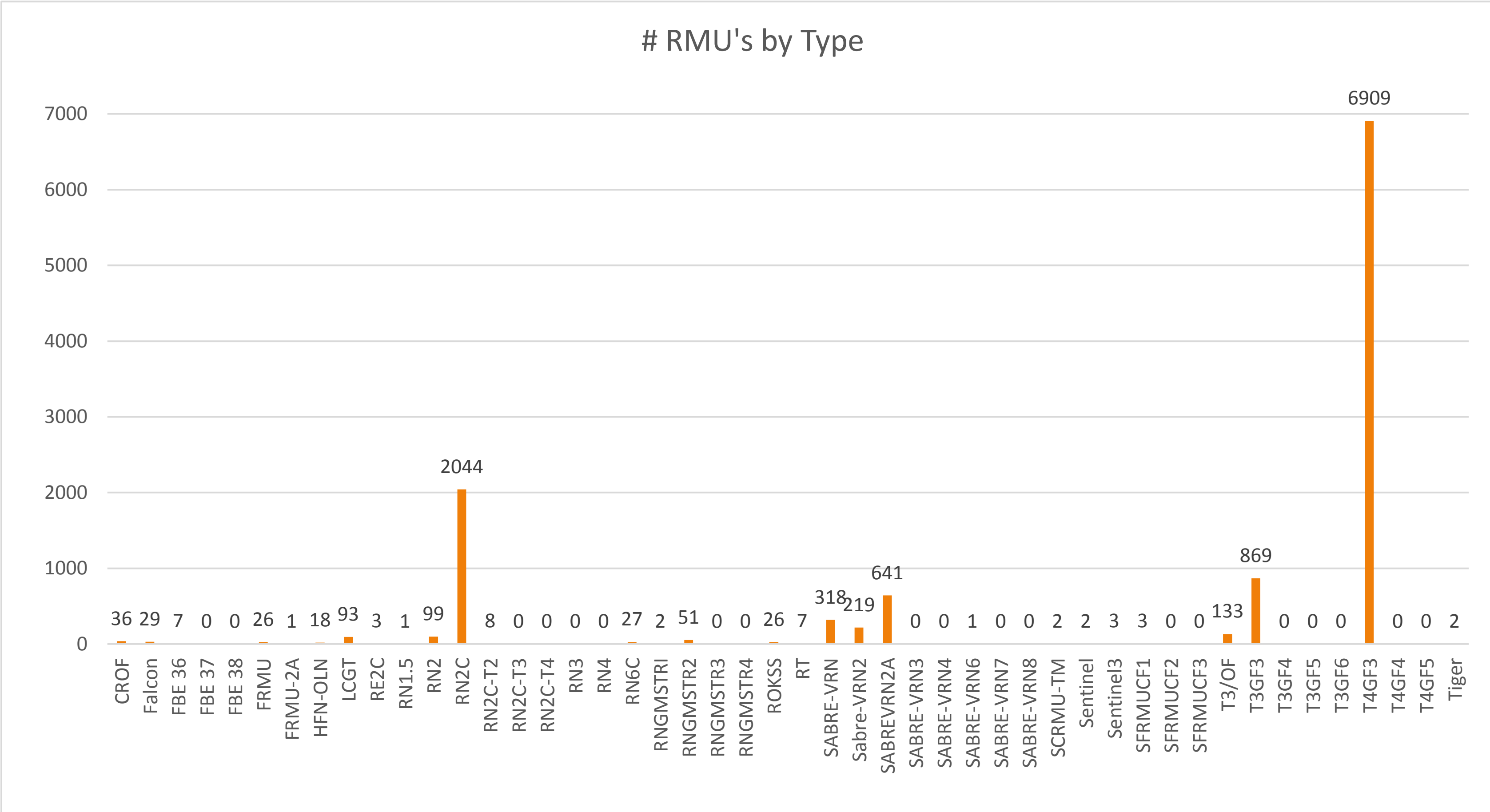
This graph shows that there a wide range of RMU's but many in very small installed numbers



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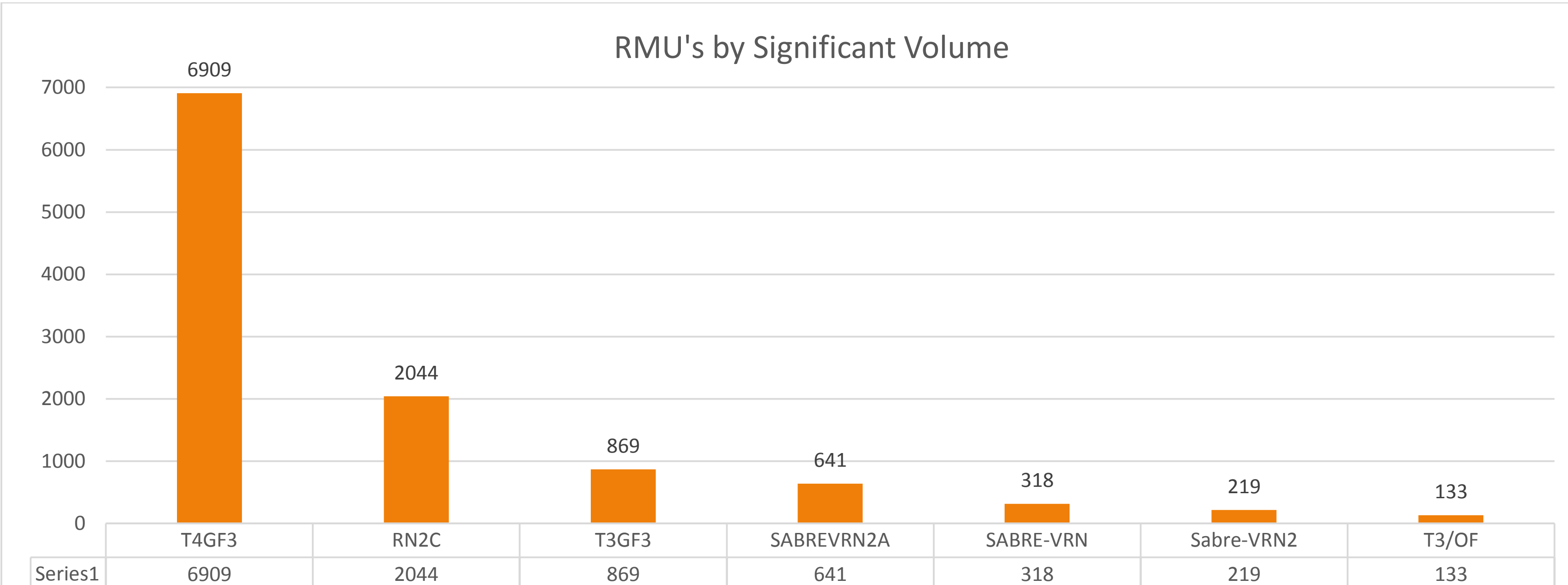
This graph gives the distribution of RMU’s that occupy greater than 96% of the total population



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10 TEST CONFIGURATIONS.

The following base data for RMU's and cable connections will be used to determine the final test program. The test program is built around I^2t calculations.

The results can be used by ENWL to allocate maximum short circuit levels and times for around 96% of the asset fleet.

Through currents based upon the following ratings:-

T3GF4 and T3/OF connected in series 13.1kA

T4GF4, RN2C, Sabre VRN* in series 20kA

Times for proposed test levels

Fault Current rms	Peak	Duration	Modified duration
kA	kApk	secs	secs
13.1	32.75	1.00	1
12.5	31.25	1.10	1.1
10	25	1.72	1.5
8	20	2.68	2.5
6	15	4.77	4.5
5	12.5	6.86	6.5
4	10	10.73	10
3	7.5	19.07	15

Type	kA
T4GF4	20
RN2C	20
T3GF4	13.1
SABREVRN2A	20
SABRE-VRN	20
Sabre-VRN3	20
T3/OF	13.1

Table 4

Fault Current rms	Peak	Duration	Modified duration
kA	kApk	secs	secs
20	50	1.00	1
16	40	1.56	1.5
15	37.5	1.78	1.5
10	25	4.00	4
8	20	6.25	6
6	15	11.11	10
5	12.5	16.00	15

Table 5

Each arrangement to be cabled with a mix of polymeric and paper/lead heat shrink cold shrink and compound type joints. These joints which can include transitions to be representative of those in service in volume.

All RMU's to be maintained immediately prior test using the routine inspection/maintenance used in service.

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All joints to have been prepared in line with Joint List and CP 411 pt2 Section 8 series jointing procedures.

The Cable Characteristics will also been taken into account in terms of appropriate and typical cross-sectional areas.

Not all Short Circuit Current Withstand periods and levels will be tested based upon three factors.

1. Test Station plant limitations
2. Realistic fault level bands on the ENWL Network
3. Cost/Benefit of tests

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11 CONCLUSIONS

Calculations will be undertaken based upon manufacturer's data, real test data and known Short Circuit Levels at each site.

A series of tests in a High Power Test laboratory will be undertaken.

The statistics suggest that up to 96% of configurations will have been validated by these tests, and the results will be representative of short circuit performance on the ENWL network.

This will allow ENWL to have confidence in up to 96% of the ENWL RMU asset base.

The budget for the testing including a report of performance and an allowance for ENWL and EPS engineers in attendance is £35,000. (First approximation)

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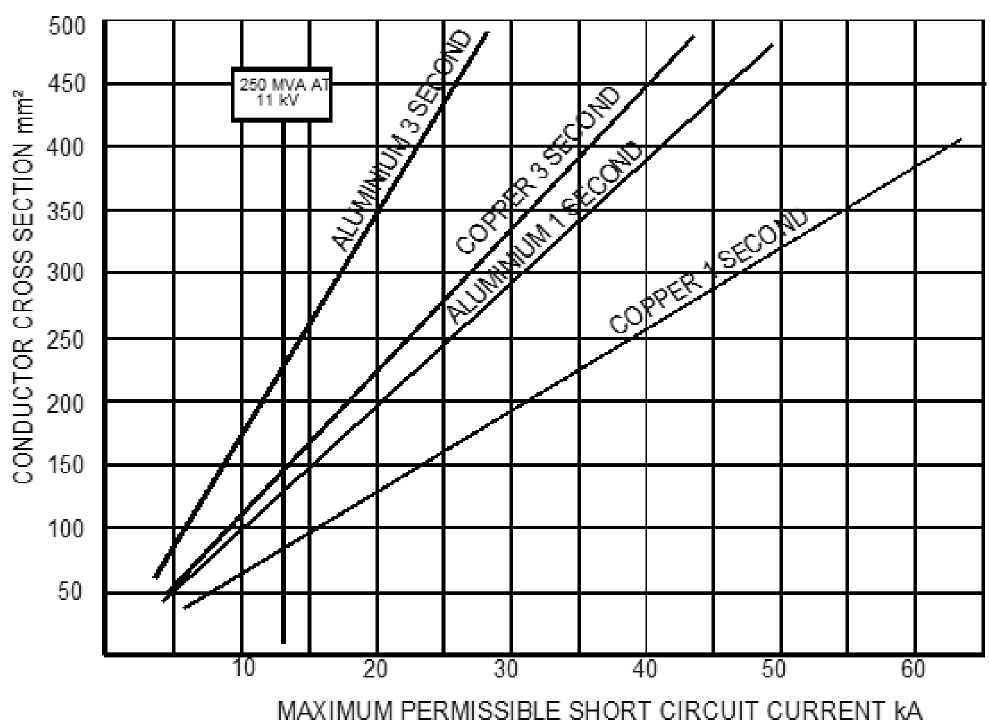
12 CABLE FAULT LEVEL CALCULATIONS

The following extract is from ENWL document CP203.

Table 1

Conductor cross section mm²	Maximum 1 second current, A, Copper conductor	Maximum 1 second current, A, Aluminium conductor
50	7 980	5 250
70	11,100	7 330
95	15 000	9 900
120	19,000	12 500
150	23 700	15 600
185	29 100	19 200
240	37 700	24 800
300	47 100	31,000
400	62 600	41 200
500	78 300	51 500



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13 Ratings Of The Main RMU's Selected In This Analysis

Sabre VRN2A

		Sabre VRN2a
Rated Voltage		12kV(15.5kV)
Impulse Withstand Voltage		75kV(95kV)
Normal Current	**Ring Switches**	630A
	Tee-Off Circuit Breaker	250A
Short Circuit Peak Making Current	**Ring Switches**	50kA
	Tee-Off Circuit Breaker	50kA
Short Circuit Breaking Current	**Tee-Off Circuit Breaker**	20kA RMS
3 Second Short Time Current	**Ring Switches**	20kA
	Tee-Off Circuit Breaker	20kA
Earth Switch Peak Making Current	**Ring Switches**	50kA
	Tee-Off Circuit Breaker	7.9kA
Internal Arc Rating	**Freestanding**	20kA 1 sec
	Transformer Mounted	20kA 1 sec in ENA housing
Optional Cable Boxes Internal Arc Rating	**Standard Type**	12.5kA 1 sec
Gas pressure	**Min Operating Pressure**	0 Bar G
IP Rating		Up to IP54W
Weight *		350kg
Testing standards		BS EN 60265-1
		BS EN 60129
		BS EN 60694
		BS EN 60298
		IEC 60056
		ENA TS 41-36
		IEC 62271-102
		IEC 62271-100

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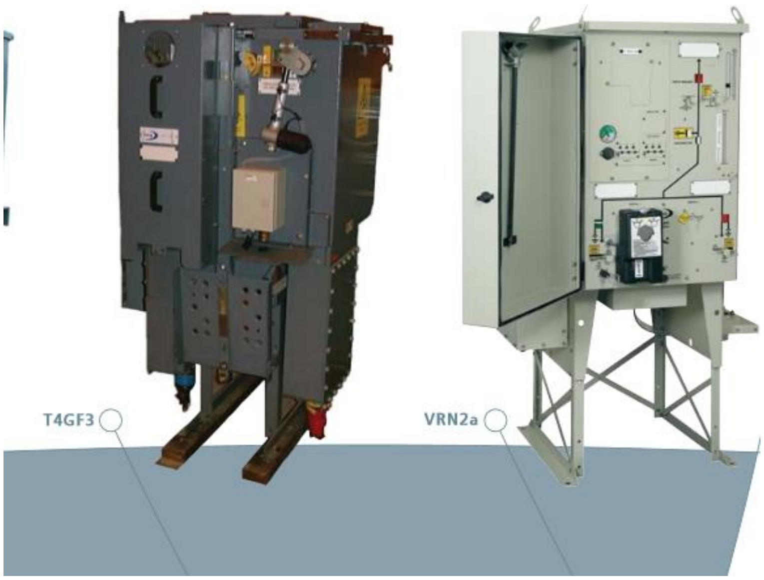
T4GF3
VRN2a

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14 Typical Cable box joint

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15 Termination Types

SECTION 4
(REVISED 18/03/2013)

MV JOINTING PROCEDURES
(TERMINATIONS JOINTS)

PROCEDURES INDEX

Procedure Number		Description
4/601	Issue 4	Termination 11kV screened elbow (Old Raychem)
4/602	Issue 2	Termination 11kV screened elbow (Pirelli)
4/603	Issue 2	Termination 11kV elbow cold pour compound filled
4/604		Withdrawn
4/605	Issue 2	11kV spare box termination (Raychem)
4/606		Withdrawn
4/607	Issue 2	Installation of cable end shorting kit
4/608	Issue 2	Termination 11kV polymeric indoor (3M)
4/609	Issue 2	Termination 11kV polymeric outdoor (3M)
4/610		Withdrawn
4/611	Issue 2	Termination 11kV polymeric heatshrink indoor & outdoor (Raychem)
4/612	Issue 3	Termination 11kV screened elbow (New Tyco)
4/613	Issue 1	Termination 11kV screened elbow (New Prysmian)
4/614	Issue 2	Termination 11kV screened elbow (3M) for 400mm^2 cable

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SECTION 8

MV JOINTING PROCEDURES
(MAINS JOINTS)

PROCEDURES INDEX

The jointing procedures listed below are currently being introduced and should be used by all jointers trained in the use of these procedures. They will eventually fully replace the jointing procedures in Section 3 of this CP. The Procedures set out in Section 3 remain approved for use whilst stocks of the appropriate joint kits remain in the stores. The jointing procedures in this Section shall be used in conjunction with the modules listed in Section 5 of this CP.

Procedure Number		Description
8/001	Issue 3	Joint, 11kV, Polymeric to Polymeric Straight Single Core Unarmoured Cables, (For cables with copper wire screen)
8/002	Issue 2	Joint, 11kV, Polymeric Bottle End Single Core Unarmoured Cables, (For cables with copper wire screen)
8/003	Issue 2	Joint, 11kV, Polymeric to Polymeric Branch, Single Core Unarmoured Cables, (For cables with copper wire screen)
8/004	Issue 2	Joint, 11kV, Polymeric to Polymeric Loop, Single Core Unarmoured Cables (Um), (For copper wire screen)
8005	Issue 3	Joint, 11kV, Trifurcating Straight, Single Core Unarmoured Polymeric Cables, (For cables with copper wire screen) to Three Core Paper Cables, (For Screened or Belted Cables)
8/006	Issue 3	Joint, 11kV, Paper to Paper Straight, Three Core Paper Cables, (For Screened or Belted Cables)
8/007	Issue 2	Joint, 11kV, Paper Bottle End Three Core Paper Cables, (For Screened or Belted Cables)
8/008	Issue 2	Joint, 11kV, Trifurcating Transition Branch Joint Three Core Paper Cables Main (Through cable) (For Screened or Belted Cables) to Single Core Unarmoured Polymeric Cables 11kV (For cables with copper wire screen)

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Procedure Number		Description
8/009	Issue 2	Joint, 11kV, Combination Transition Branch Joint, 2 x Three Core Paper Cables, (For Screened or Belted Cables) to 3 x Single Core Unarmoured Polymeric Cables 11kV (For cables with copper wire screen)
8/010	Issue 2	Joint, 11kV, Double Poly - Transition Branch Three Core Paper Cables, (For Screened or Belted Cables) to 6 x Single Core Unarmoured Polymeric Cables 11kV (Double Side) (For cables with copper wire screen)
8/011	Issue 2	Joint, 11kV, Combination Transition Loop, Three Core Paper Cables (For Screened or Belted Cables) to Single Core Unarmoured Polymeric Cables (For cables with copper wire screen)
8/012	Issue 2	Joint, 11kV, Combination Transition Loop, Three Core Paper Cables (For Screened or Belted Cables) to Three Core Paper Cables (For Screened or Belted Cables)
8/013	Issue 2	Joint 11kV Trifurcating Transition, Single Core Unarmoured Polymeric Cables (For cables with copper wire screen) to Three Core “H” Type Cable (De-Rated 33kV Cable)
8/014	Issue 1	Joint 11kV polymeric to Polymeric Straight Single Core Unarmoured Cables for 300mm^2 to 400mm^2 and 400mm^2 to400mm^2 joints only (For cables with copper wire screen).