1. **SCOPE**

This document details the application of overhead line switchgear and protection systems and is commonly referred to as the Overhead Protection Policy (OHPP).

This document supersedes ESDD-02-015 “HV Network Design – 11kV ABSDs” (now archived).

2. **ISSUE RECORD**

This is a Controlled document. The current version is held on the EN Document Library.

*It is your responsibility to ensure you work to the current version.*

<table>
<thead>
<tr>
<th>Issue Date</th>
<th>Issue No.</th>
<th>Author</th>
<th>Amendment Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 2017</td>
<td>6</td>
<td>Ewan Gilliland</td>
<td>Revision of time delay for fast operating reclosers with re-settable smart links down circuit (e.g. Noja). Inclusion of guidance for ABSD design criteria from ESDD-02-015 (now archived)</td>
</tr>
<tr>
<td>November 2018</td>
<td>7</td>
<td>Ewan Gilliland</td>
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</tr>
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<td>Ewan Gilliland</td>
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</tr>
</tbody>
</table>

3. **ISSUE AUTHORITY**

<table>
<thead>
<tr>
<th>Author</th>
<th>Owner</th>
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</tbody>
</table>

4. **REVIEW**

This is a Controlled document and shall be reviewed as dictated by business / legislative change but at a period of no greater than 5 years from the last issue date.

5. **DISTRIBUTION**

This document is part of the SP Distribution (DOC-00-206) and SP Manweb (DOC-00-310) System Design Virtual Manuals maintained by Document Control but does not have a maintained distribution list. It is also published to the SP Energy Networks website.
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7. REFERENCE AND RELATED DOCUMENTS

SWG-03-021  Primary & Secondary Substations Specification for 12kV Indoor Switchgear
PROT-03-019  Primary & Secondary Substations Protection and Control Equipment
OHL-25-007  Earthing and Bonding Pole Mounted Equipment

8. INTRODUCTION

Overhead lines in the distribution system are prone to interference and damage which result in both transient and persistent faults. These incidents are often weather related (in the form of lightning, windblown debris and clashing conductors) or due to bird strikes.

Typically, 80% of all such incidents affecting overhead lines are of a transient nature.

This policy shall apply to new overhead line construction and refurbishment work, and existing circuits which are known to have a poor performance.

This policy outlines the application of overhead line switching apparatus which provides protection against transient and persistent faults. It also sets out guidelines to be considered when determining the positioning of overhead protection equipment.

9. 33KV AUTO-RECLOSEING

Any single transformer Primary substation should have a load transfer scheme installed in the associated 11kV network.

As an alternative to this, single shot auto-reclosing of the 33kV circuit on High Set Overcurrent only should be considered. This will be accompanied by automatic re-closing of any 11kV incomers which have tripped due to a back energised 33kV fault.
10. **11KV OVERHEAD SYSTEM PROTECTION**

10.1 **Design Requirements**

The following sections describe the methodology of overhead protection design. Guidance on the location and selection of the devices is given in Appendix 2.

10.1.1 **Ground Mounted Auto-Reclosers**

Circuit-breakers controlling overhead line feeders shall incorporate multi-shot auto-reclosing features as standard on all new switchboards in accordance with SWG-03-021 and PROT-03-019.

Protection shall normally be 2 pole overcurrent and 1 pole earth fault having both instantaneous and IDMT elements. Sensitive Earth Fault (SEF) protection with a definite time setting shall also be provided. The "normal" setting to be selected for Sensitive Earth Fault delay shall be 3 seconds at 20 Amps.

Where necessary, existing single shot ground mounted auto-reclosers shall be converted to multi-shot operation by the installation of an approved multifunction protection relay to meet the requirements of this policy.

Where a ground-mounted circuit breaker is equipped with multi-shot auto-reclosing facilities the motorised spring charging time shall be less than 10 seconds.

In a retrofit situation, switchgear modification costs and maintenance requirements may prove uneconomic. Consideration shall then be given to the installation of a PMAR at the first suitable location on the circuit.

10.1.2 **Pole Mounted Auto-Reclosers (PMAR)**

The close proximity of the connections and jumpers on a PMAR can cause flashovers due to wildlife which can damage the bushings. Suitable shrouding shall be fitted to the terminations, arrester connections and the jumper connections.

PMARs shall be purchased with relays providing Standard Inverse protection characteristics with 2-pole Overcurrent and 1-pole Earth Fault. A Sensitive Earth Fault element shall also be provided. The "normal" setting to be selected for Sensitive Earth Fault delay shall be 3 seconds at 20 Amps.

A "Protection Disable" facility shall be fitted to render all automatic features inoperative when required (e.g. the line is being fed abnormally).

A "One Trip to Lockout", "Non-Auto" and/or "Live Line" facility shall also be provided to comply with operational requirements.

All new PMARs shall be fitted with approved surge arresters across both incoming and outgoing bushings or as specified by the manufacturer.

Fault level at the location must be less than the manufacturer’s rating. Noja OSM devices are rated at 230MVA (12kA).

All new PMARs shall be equipped with remote control.
10.1.3 Smart Links

Smart links discriminate between a transient and persistent fault by counting the passage of fault current during the auto-reclose sequence. They operate during the dead time of the auto-reclose sequence after a pre-determined number of passages of fault current. They shall only be fitted to circuits protected by a multi-shot auto-recloser with the minimum number of trips to lock-out being one more than the highest smart link count.

Smart links are available with an operating sequence of 1, 2 or 3 “counts” of fault current. The selection of the number of “counts” of the smart link shall be as detailed in Section 11.3 and in Schemes AR1 to AR8 of Appendix 1.

Re-settable smart links (no actuator) have been introduced since 2017 and have the same basic principle in their operation as the chemical actuator type.

For new installations of S2 smart links of 63A and 100A, an Auto-sectionalising disconnector shall, where practicable, be installed instead.

ASLs, or any form of HV fuse units, shall not be installed on spurs with more than 500 kVA aggregate transformer capacity or more than 500m of cable.

Auto-sectionalising disconnector (e.g. Soule switch), shall be installed as an alternative on spurs with more than 500 kVA aggregate transformer capacity, or where cable sections of more than 500m are involved.

10.1.4 Auto-Sectionalising Disconnectors

Auto-sectionalising disconnectors (e.g. “Soule” switches) discriminate between transient and persistent faults in the same manner as smart links. When called upon to operate during the dead time of an upstream auto-recloser, all three phases open simultaneously to disconnect the faulty section in the same manner as an ABSD.

Due to the height and pole installation position, it cannot be installed at a tee-off pole. It will require a stout pole to be installed at one of the optional points, in preference order:

1. A mid-span pole on the spur or
2. The first pole on the spur

These devices have current transformers (CTs) on each phase which communicate to the control box via an umbilical cable. Typically, standard settings will be applied, i.e. 100A O/C; 20A EF and 3 bursts of fault current to initiate a trip.

Auto-sectionalising disconnectors shall be utilised where design criteria previously required 63 or 100A smart links. The earth fault detection capability of these units, down to 20A, greatly improves grounded conductor detection when compared to the performance of 63 and 100A smart links.

Auto-sectionalising disconnectors shall be utilised for network open points (NOPs) and where automation schemes require remote operation.

Due to the need for control boxes, these devices will be solidly connected to earth using a site-specific earth system design, based on ENATS 41-24. Further guidance is found in OHL-25-007.

Due to the hazards associated with ferroresonance, any new cable connected spur lines shall where practicable be installed with an auto sectionalising disconnector. This enables ganged switching operations which reduces the risk of the effects of ferroresonance. Auto-sectionalising disconnectors shall be installed when feeding HV generation substations. It may be required to construct an additional span of overhead line to accommodate a new auto-sectionalising disconnector.
10.1.5 ABSDs

Main line ABSDs shall, where reasonably practicable, be installed on the network such that one or more of the conditions below are met:

a) There are no more than 30 to 45 customers
b) 5 spurs
c) 4km (30 to 50 spans) between ABSDs

They shall also be installed, as close as practicable, to HV cable dips/terminal poles to provide suitable points of isolation.

Note: The requirements above may not be considered reasonably practicable for circuits with flexible jumpers at comparable or suitable alternative locations to ABSDs.

ABSDs shall be hookstick in operation and installed on unearthed poles.

ABSDs shall be installed at the most appropriate place for ease of operational access.

All new ABSDs shall have interrupter heads fitted making them Category 1 or Category 0 and all insulators shall be of a polymeric type material.

Existing ABSDs with frayed flexible connections, stiff operating mechanisms or in generally poor condition shall be entirely removed from the system and replaced.

All existing ABSDs situated above the cross arm as “masthead” units shall be removed and replaced.

Legacy “Bypass ABSDs” that were installed as a temporary switching point shall be removed from the system.

Existing ABSDs on earthed poles shall be removed and, if required, a new ABSD shall be installed on a suitable alternative unearthed pole.

ABSDs acting as Points of Isolation associated with PMARs shall be placed on a pole separate from the PMAR pole and it shall be of unearthed hookstick-operated construction.

ABSDs have two fault make ratings:

- Category 1: 3kA<sub>rms</sub> for dependant manual units (up to 60MVA)
- Category 0: 10kA<sub>rms</sub> for independent manual units (spring-assisted)(up to 190MVA)

3kA units shall only be employed in locations where the fault level is below 60MVA.

Spring-assisted 10kA units shall be employed where the fault level is above 60MVA and below 190MVA or at selected locations below 60MVA for other network considerations.

10.1.6 Fault Recorders

Fault Recorders shall be fitted in new and replacement Primary Substation switchboards containing reclosing circuit-breakers. These will enable an assessment of system performance to be made and provide information on the operating duty and condition of the circuit breakers.
11. **APPLICATION**

11.1 Application Summary

When applying approved protection equipment, reference shall be made to the schemes shown in Appendix 1 when building or refurbishing overhead lines to comply with this policy. These schemes, SCHEME AR1 to SCHEME AR8, represent typical overhead circuit layouts and indicate the associated protection requirements to comply with this policy in general:

a) No overhead fuses shall be installed beyond a multi-shot auto-recloser.

b) Spurs with cable sections shall be protected by smart links or auto-sectionalising disconnectors. Where a spur comprises of only cable (no spans of overhead line) a 1 "count" (S1) setting shall be installed.

c) Single shot smart links (S1) should not be rated at less than 40Amps.

d) Smart links count “bursts” of fault current and shall therefore be controlled by a multi-shot auto-recloser.

e) Multi-shot auto-reclosers shall have a minimum of three instantaneous trips to lock-out.

f) Where an auto-recloser controls downstream fused switchgear (e.g. RMU), then the instantaneous protection shall be “delayed” e.g. 150msec.

g) Where PMARs control ASLs, then the instantaneous protection shall be delayed by 30msec.

h) When auto-reclosers are positioned in series, the instantaneous protection on the source side recloser shall be “delayed”. Recommendations as follows:

<table>
<thead>
<tr>
<th>Type</th>
<th>d1</th>
<th>d2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESR</td>
<td>160msec</td>
<td>320msec</td>
</tr>
<tr>
<td>PMR3</td>
<td>200msec</td>
<td>300msec</td>
</tr>
<tr>
<td>GVR</td>
<td>150msec</td>
<td>300msec</td>
</tr>
<tr>
<td>OSM (Noja)*</td>
<td>150msec</td>
<td>300msec</td>
</tr>
</tbody>
</table>

*PMARs with instantaneous settings shall have a 30ms delay added.

i) The “One Trip to Lock-out” or “Live Line Mode” feature on PMARs shall be set to “instantaneous”.

11.2 Protection Settings

The protection settings at source may need to be adjusted to accommodate the proposed downstream PMAR settings.

<table>
<thead>
<tr>
<th>Overcurrent</th>
<th>Mainline</th>
<th>Spur</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>240A</td>
<td>120A</td>
</tr>
<tr>
<td>Earth fault</td>
<td>30A</td>
<td>30A</td>
</tr>
<tr>
<td>SEF</td>
<td>20A</td>
<td>20A</td>
</tr>
</tbody>
</table>

The overcurrent setting may be increased (to no more than the primary protection value) where load current is likely to exceed 70% of the proposed setting above. A setting based on 1.5 times load should be adopted and consideration given to the prospective load of an abnormal feeding arrangement.
11.2.1 Instantaneous Protection

Series auto-reclosers shall provide the appropriate discrimination and this shall be applied as indicated in Section 11.1 and the AR Schemes of Appendix 1.

It has been identified that PMARs can operate quicker than the required for down circuit ASLs to register a fault count. It is therefore required to install a 30ms delay on instantaneous PMARs to ensure successful ASL operation.

A delayed instantaneous protection setting should be retained in the non-auto mode to allow for the decay of large magnetisation inrush currents where there is a large connected load capacity controlled by the auto-recloser.

Some PMARs require a background protection setting based on IDMT characteristics (PMR3 and GVR). The appropriate settings for this are for the “current” setting to be the same as the instantaneous (INST) setting (e.g. 240A with the time multiplier set to 0.2). This will ensure that tripping will always be carried out by the INST protection on the PMAR.

11.2.2 Sensitive Earth Fault Protection

In order to maintain protection co-ordination at low fault currents the SEF shall perform an auto-reclose sequence. This will ensure correct operation of 20A and 25A smart links with permanent faults beyond them.

Where discrimination is required between series PMARs then the SEF time delay should be set appropriately to either 3, 5 or 7 seconds. See AR5 in Appendix 1 for guidance.

11.3 Smart Links

Smart links used in SP Energy Networks shall be of an approved type.

Five actuating current ratings are available and the minimum rating shall be chosen to comply with Table 1 (for 11kV circuits) with due consideration given to possible future additional load.

<table>
<thead>
<tr>
<th>SECTIONALISER RATING</th>
<th>MAXIMUM CONNECTED TRANSFORMER CAPACITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 PHASE</td>
</tr>
<tr>
<td>40 A</td>
<td>380 KVA</td>
</tr>
<tr>
<td>25 A</td>
<td>240 KVA</td>
</tr>
<tr>
<td>20 A</td>
<td>195 KVA</td>
</tr>
</tbody>
</table>

Table 1

11.3.1 Calculation of the appropriate smart link rating

For spurs with a mix of single and three phase transformers, assume that the single phase transformers are connected to the same two phases. Calculate the total full load current of these transformers then add the full load line current of the three phase transformers. Use a factor of safety of 2 (for mag inrush). Therefore, double this total full load line current and select the smart link rating above the calculated figure e.g. 15A full load requires 40A smart links (2x15=30; next S2 up is 40A).

With reference to Table 1; where the design of a spur necessitates the use of an auto sectionalising disconnector (Soule) at the tapping point and the spur consists of more than 10 spans, the spur should be further considered for alternative and additional protection measures. Consideration should be given to the use of additional lower rated smart links (20A preferred) for sub-spur sectionalising with several alternatives available for the tapping point.
Auto-sectionalising disconnectors shall be utilised, where practicable, when design criteria previously required 63 or 100A, 3 or 2-shot smart links. The earth fault detection capability of these units, down to 20A, greatly improves grounded conductor detection when compared to the performance of 63 and 100A smart links.

Where sectionalising devices are set to three shot, all auto-reclosers controlling of the corresponding spur must then be set to 4 trips to lockout.

Appendix 1, Scheme AR8 indicates the options.

Where sub-spur protection of a cable tee-off with S1 smart links is considered, this should only be carried out where the transformer is not in the vicinity of the cable tee-off/terminal pole.

Single shot (S1) smart links should not be rated at less than 40 Amps to avoid maloperation for low voltage faults on a lightly-loaded spur.

12. ADDITIONAL DESIGN REQUIREMENTS FOR LOW FAULT LEVELS

Due to low fault levels and network arrangements there are some additional design considerations when applying this policy to all networks in Wales and to other networks with less than 50MVA source fault level and more than 20km of effective circuit length (see 12.2.2 for effective circuit length).

Additional consideration is required, where necessary, for source protection to be modified and for careful application of protection settings to address abnormal feeding arrangements.

12.1 Source Protection Replacement

It may be necessary to modify existing source protection schemes to allow application of this policy. Most existing protection schemes on SPM overhead line circuits use extreme inverse (EI) relay characteristics (CDG34 relays) to give optimum grading with HV fuse characteristics.

Existing electromechanical auto-reclose schemes have no facility to introduce delays into the instantaneous trip times and are, therefore, incompatible with downstream PMARs and must be set to non-auto.

Where source protection has this EI characteristic, the protection must be changed to a standard inverse (SI) characteristic using new or recovered relays (e.g. PBO or CDG31 relays). These schemes will have a PMAR placed as close to the source of supply as possible.

12.2 Overcurrent Protection Setting Assessment

12.2.1 Fault Current Levels on Overhead Line Circuits

Studies to identify typical fault current values on the SPM network produced the data in the following table. These figures are also appropriate for SPD networks where the source fault level is below 50MVA.

<table>
<thead>
<tr>
<th>Fault type</th>
<th>0km</th>
<th>5km</th>
<th>10km</th>
<th>15km</th>
<th>20km</th>
<th>25km</th>
<th>30km</th>
<th>35km</th>
<th>40km</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 phase</td>
<td>2246A</td>
<td>1142A</td>
<td>721A</td>
<td>523A</td>
<td>408A</td>
<td>335A</td>
<td>284A</td>
<td>246A</td>
<td>217A</td>
</tr>
<tr>
<td>Phase-phase</td>
<td>1945A</td>
<td>989A</td>
<td>625A</td>
<td>453A</td>
<td>354A</td>
<td>290A</td>
<td>246A</td>
<td>213A</td>
<td>188A</td>
</tr>
<tr>
<td>E/F 0 Ohms</td>
<td>2452A</td>
<td>867A</td>
<td>526A</td>
<td>378A</td>
<td>295A</td>
<td>241A</td>
<td>204A</td>
<td>177A</td>
<td>156A</td>
</tr>
<tr>
<td>E/F 80 Ohms</td>
<td>79A</td>
<td>76A</td>
<td>73A</td>
<td>70A</td>
<td>67A</td>
<td>65A</td>
<td>62A</td>
<td>60A</td>
<td>58A</td>
</tr>
</tbody>
</table>

Table 2: Fault Currents on OHL Circuits

From Table 2, it can be shown that the 3-phase fault figures show that the standard overcurrent setting of 225 Amps will not detect phase-phase faults beyond 30km of main line and with a 50% safety margin this will reduce to 20km. SEF provides adequate network coverage for all network lengths.
12.2.2 Calculating the “Effective” Length of Overhead Line Circuits

It is necessary to calculate the protection “reach” in terms of main line kilometres to include abnormal feeding arrangements. This must take account of the different conductor sizes for main lines (50mm$^2$ AAAC) and spurs (25mm$^2$ ACSR) by using an equivalence factor of 1.73 for the spurs in terms of main line length. E.g. 10km main line + 10km spur equates to 27.3km main line $[10 + (10 \times 1.73)]$

From a calculation of the maximum effective length of a circuit, including abnormal feeding arrangements and spurs near the extremities, the overcurrent protection setting can be calculated and guidance for this is given in the following table. The table includes the range of PMAR settings.

<table>
<thead>
<tr>
<th>Effective circuit length</th>
<th>&lt;19km</th>
<th>&lt;20km</th>
<th>&lt;27km</th>
<th>&lt;33km</th>
<th>&lt;42km</th>
<th>&lt;51km</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAD or ESR</td>
<td>225A O/C</td>
<td>150A O/C</td>
<td>120A O/C</td>
<td>100A O/C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PMR3</td>
<td>240A O/C</td>
<td>180A O/C</td>
<td>120A O/C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GVR</td>
<td>240A O/C</td>
<td>180A O/C</td>
<td>120A O/C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. Circuit loading</td>
<td>160A</td>
<td>150A</td>
<td>120A</td>
<td>100A</td>
<td>80A</td>
<td>65A</td>
</tr>
</tbody>
</table>

Table 3: Overcurrent Setting Selection

Where circuit loading presents a problem for source protection settings then consideration should be given to an additional PMAR on the circuit beyond the load centre. This can be set to a lower overcurrent setting to “see” through to the source of the adjacent circuit beyond the Normal Open Point (NOP).
13. LOCATION OF EQUIPMENT

Fuse holders and smart link equipment should, where practicable, be mounted at the tee-off pole.

Jumper connections should be positioned to avoid the risk of arc transfer from ejected gases or fuse tails, and they should approach the terminals slightly from the rear. The lower side of the fuse/smart link unit should be connected to the protected line.

13.1 Smart Links

The location of smart links on an overhead circuit selected for auto-reclosing shall comply with the following guidelines but, when applying them, consideration must be given to local conditions affecting access.

i) New fuse holders shall be a C-type design rated at 150MVA minimum.
ii) Spurs more than 5 spans long shall be group protected with smart links.
iii) Due to network design and application of the "five spans" rule, some circuit designs have shown few smart links to be fitted making the circuit almost entirely solidly connected. In this circumstance only, the "five spans" rule will be relaxed to an extent that permits 40% of the spurs (not including main-line transformers) to be fitted with smart links.
iv) If a spur supplies more than 30% of the customers controlled by the associated recloser then the spur shall be solidly connected to the main line and the sub-spurs protected by smart links.
v) Spurs less than 5 spans long shall be solidly connected to the main line except where the spur contains a section of cable or has environmental risks e.g. trees. In this case the spur should be protected with smart links (<500m cable) or auto sectionalising disconnector (>500m cable).
vi) Smart links will only operate in series where the “count” of the device, NOT the current rating, is used as a means of discrimination. This is clarified in Scheme AR8 of this document.

13.2 Expulsion Fuses

The preferred method of protecting overhead circuits is by the use of multi-shot reclosers and smart links.

However the following guidelines shall be used for determining the location of expulsion fuses on circuits with no multi-shot auto-reclose facilities. When applying them, consideration must be given to local conditions affecting access.

i) Spurs more than 5 spans long shall be group protected with a Minimum of 25A fuses.
ii) If the spur supplies more than 30% of the customers controlled by the associated circuit breaker then the spur shall be solidly connected to the main line and the sub-spurs protected by fuses.
iii) Spurs less than 5 spans long shall be solidly connected to the main line except where the spur contains a section of cable. In this case the spur should be protected with smart links (<500m cable) or auto sectionalising disconnector (>500m cable).
iv) Single pole mounted transformers on a line shall not normally be fused.
v) On very long spurs sub group fusing may be necessary. This situation is likely to arise where the 11kV fault level is under 4MVA and in these instances 15 Amp fuses may be used.

13.3 Auto-Sectionalising Disconnectors

Auto-sectionalising disconnectors (e.g. Soule Switch) shall be fitted in order to improve fault detection for low-level earth fault currents on heavily loaded spurs, normally requiring 63 or 100 Amp smart links. These units will be set to detect 20A earth fault currents. See 10.1.4 for further details.

Auto-sectionalising disconnectors (e.g. Soule Switch) shall be installed on spurs with more than 600kVA of aggregate transformer capacity or more than 500m of cable.
14. SYMBOLS

The location of auto-reclosers, smart links and auto-sectionalising disconnectors shall be clearly marked on PowerOn.

Overhead line equipment shall be identified on PowerOn using the following symbols:
15. APPENDIX 1 – AUTO-RECLOSE SCHEMES

SCHEME AR1: Predominantly Overhead Circuit
Multi-Shot Auto-recloser at Source

**Trip Sequence**
- 3I : 240A O/C
- 3I : 30A E/F
- 3 x 3sec SEF (20A)

**Reclose Time**
10 seconds

**Reclaim Time**
15 seconds

**Notes:**
No fuses on overhead system.

If existing single shot auto-recloser at source, change protection relay to provide multi-shot scheme as above. [see 10.1.1].

If relay change is not practical (e.g. spring charge time too slow) see SCHEME AR2 and AR3.

If grading with switchgear fuses is required, e.g. RMU, then PMAR instantaneous protection shall be set to “delayed”, see 11.1(h).

Due to network design and applying the “five spans” rule, some circuit designs have shown few smart links to be fitted making the circuit almost entirely solidly connected. In this circumstance only, the “five spans” rule will be relaxed to an extent which permits 40% of the spurs (not including main-line transformers) to have smart links fitted.

Where:
- I - Instantaneous
- Id - “delayed” Instantaneous
- D - Delayed (IDMT)
SCHEME AR2: Predominantly Overhead Circuit
No suitable spring charging mechanism on source C.B.
[O/H Line Fault Level <230 MVA]

**PMAR Trip Sequence**

- 3I : 240A O/C
- 3I : 30A E/F
- 3 x 3sec SEF (20A)

**Reclose Time**
10 seconds

**Reclaim Time**
15 seconds

Notes:
No fuses on overhead system.

Convert source single shot auto-recloser to “Non-Auto; Delayed” operation.

Install PMAR on first suitable pole.

If grading with switchgear fuses is required, e.g. RMU, then PMAR instantaneous protection shall be set to “delayed”, see 11.1(h).

In applying the “five spans” rule, some circuit designs have shown few smart links to be installed. In this circumstance only, the “five spans” rule will be relaxed to an extent which permits 40% of the spurs (not including main-line transformers) to have smart links fitted.

Where:
I - Instantaneous
Id - “delayed” Instantaneous
D - Delayed (IDMT)
SCHEME AR3: Predominantly Overhead Circuit
Single Shot Auto-recloser at Source
Multi-shot Auto-recloser on Line

Trip Sequence

<table>
<thead>
<tr>
<th>Trip Sequence</th>
<th>R</th>
<th>PMAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1I + 1D</td>
<td>3I : 240A</td>
</tr>
<tr>
<td></td>
<td>3I : 30 A</td>
<td>O/C</td>
</tr>
<tr>
<td></td>
<td>1 x 5sec</td>
<td>3 x 3sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SEF (20A)</td>
</tr>
</tbody>
</table>

Reclose Time

| Reclose Time | 10 seconds |
|             | 10 seconds |

Reclaim Time

| Reclaim Time | 15 seconds |
|             | 15 seconds |

Notes:

No fuses on overhead system.

No Sectionalisers between R and PMAR.

May require fuses on overhead system between R and PMAR, if any connected spur >5 spans in length. In this situation, source SEF protection should be set to 15 seconds.

If switchgear fuses are required beyond the PMAR then there will be no discrimination with the PMAR.

The source circuit breaker may also trip for a fault beyond the PMAR due to lack of grading with instantaneous protection.

In applying the “five spans” rule, some circuit designs have shown few smart links to be installed. In this circumstance only, the “five spans” rule will be relaxed to an extent which permits 40% of the spurs (not including main-line transformers) to have smart links fitted.

Where:

I - Instantaneous
Id - “delayed” Instantaneous
D - Delayed (IDMT)
SCHEME AR4: Predominantly Overhead Circuit
2 Auto-reclosers in Series
Multi-Shot Auto-recloser at Source

<table>
<thead>
<tr>
<th>Trip Sequence</th>
<th>R</th>
<th>PMAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3Id1</td>
<td>3I : 240A</td>
</tr>
<tr>
<td></td>
<td>3Id1</td>
<td>3I : 30 A</td>
</tr>
<tr>
<td></td>
<td>3 x 5sec</td>
<td>3 x 3sec</td>
</tr>
<tr>
<td>Reclose Time</td>
<td>10</td>
<td>10 seconds</td>
</tr>
<tr>
<td>Reclaim Time</td>
<td>15</td>
<td>15 seconds</td>
</tr>
</tbody>
</table>

Notes:
No fuses on overhead system.

Instantaneous protection on R shall be set to “delayed”, see 11.1(h), to ensure coordination with PMAR.

If grading with switchgear fuses is required, e.g. RMU, then PMAR instantaneous protection shall be set to “delayed”, see 11.1(h).

For Single Shot Auto-recloser at source see SCHEME AR3.

In applying the “five spans” rule, some circuit designs have shown few smart links to be installed. In this circumstance only, the “five spans” rule will be relaxed to an extent which permits 40% of the spurs (not including main-line transformers) to have smart links fitted.

Where:
I - Instantaneous       Id - “delayed” Instantaneous       D - Delayed (IDMT)
SCHEME AR5 : Predominantly Overhead Circuit  
3 Auto-Reclosers in Series  
Multi-Shot Auto-recloser at Source

<table>
<thead>
<tr>
<th>Trip Sequence</th>
<th>R</th>
<th>PMAR 1</th>
<th>PMAR 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3Id2</td>
<td>3Id1 : 240A</td>
<td>3I : 240A</td>
</tr>
<tr>
<td></td>
<td>3 x 7sec</td>
<td>3 x 5sec</td>
<td>3 x 3sec</td>
</tr>
<tr>
<td>Reclose Time</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Reclaim Time</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

Notes: No fuses on overhead system.

Instantaneous protection on R shall be set to “delayed”, see 11.1(h), to ensure coordination with PMAR1.

PMAR1 instantaneous protection shall be set to “delayed”, see 11.1(h), to ensure coordination with PMAR2.

There will be no discrimination with RMU fuses beyond PMAR2.

For Single Shot Auto-recloser at source see SCHEME AR3.

In applying the “five spans” rule, some circuit designs have shown few smart links to be installed. In this circumstance only, the “five spans” rule will be relaxed to an extent which permits 40% of the spurs (not including main-line transformers) to have smart links fitted.

Where:
I - Instantaneous  
Id - “delayed” Instantaneous  
D - Delayed (IDMT)
SCHEME AR6 : Mixed Urban / Rural Circuit
Multi-Shot Pole Mounted Auto-Recloser

<table>
<thead>
<tr>
<th>Trip Sequence</th>
<th>PMAR</th>
<th>O/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>3ID1 : 240A</td>
<td>3I : 30A</td>
<td>E/F</td>
</tr>
<tr>
<td>3 x 3sec</td>
<td>SEF (20A)</td>
<td></td>
</tr>
</tbody>
</table>

Reclose Time: 10 seconds
Reclaim Time: 15 seconds

Notes:
No fuses on overhead system.

Source circuit breakers controlling extensive underground networks shall be non-reclosing.

If grading with switchgear fuses is required, e.g. RMU, then PMAR instantaneous protection shall be set to “delayed”, see 11.1(h).

In applying the “five spans” rule, some circuit designs have shown few smart links to be installed. In this circumstance only, the “five spans” rule will be relaxed to an extent which permits 40% of the spurs (not including main-line transformers) to have smart links fitted.

Where:
I - Instantaneous
Id - “delayed” Instantaneous
D - Delayed (IDMT)
SCHEME AR7 : Mixed / Urban Rural Circuit  
Auto-Reclosers in Series

<table>
<thead>
<tr>
<th></th>
<th>PMAR 1</th>
<th>PMAR 2</th>
<th>PMAR 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trip Sequence</td>
<td>3Id2 : 240A</td>
<td>3Id1 : 240A</td>
<td>3I : 120A</td>
</tr>
<tr>
<td></td>
<td>3Id : 30A</td>
<td>3Id : 30A</td>
<td>3I : 30A</td>
</tr>
<tr>
<td></td>
<td>3 x 7sec</td>
<td>3 x 5sec</td>
<td>3 x 3sec</td>
</tr>
<tr>
<td>Reclose Time</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Reclaim Time</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Seconds</td>
<td>Seconds</td>
<td>Seconds</td>
</tr>
</tbody>
</table>

Notes:  
No fuses on overhead system.

Overcurrent setting on mainline PMARs is typically 240A and spur PMARs is 120A.

PMAR1 instantaneous protection shall be set to “delayed”, see 11.1(h), to ensure co-

ordination with PMAR2 and PMAR3. PMAR2 shall be graded with switchgear fuses,
e.g. RMU, then PMAR instantaneous protection shall be set to “delayed”, see 11.1(h).

In applying the “five spans” rule, some circuit designs have shown few smart links to
be installed. In this circumstance only, the “five spans” rule will be relaxed to an
extent which permits 40% of the spurs (not including main-line transformers) to have
smart links fitted.

Where:
I - Instantaneous  
Id - “delayed” Instantaneous  
D - Delayed (IDMT)
SCHEME AR8 : Spurs previously requiring 63 or 100A Smart Links

Where the design of a spur necessitates the use of 63 or 100 Amp smart links, an auto-sectionalising disconnector shall be installed where practicable. If the network lends itself to further treatment then consideration should be given to the use of additional 20A 2-shot smart links for sub-spur sectionalising with alternatives available for spur sectionalisers at the tapping point.

All auto-reclosers upstream of this tapping must then be set to 4 trips to lockout. **Note that this also applies to the SEF protection on the PMAR.**

Sub-spurs comprising only cable may be protected by S1 smart links (minimum 40A) where the transformer is not in the vicinity of the cable tee-off/terminal pole.
16. **APPENDIX 2 – GUIDANCE FOR SELECTION OF OVERHEAD DEVICES**

<table>
<thead>
<tr>
<th>Table 4: Location of Overhead Line Equipment - Main Line Length</th>
<th>POSITION OF R2/R3 (PMAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KM</td>
<td>2</td>
</tr>
<tr>
<td>30</td>
<td>87</td>
</tr>
<tr>
<td>28</td>
<td>94</td>
</tr>
<tr>
<td>26</td>
<td>101</td>
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<td>24</td>
<td>110</td>
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<td>122</td>
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<td>18</td>
<td>153</td>
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<td>16</td>
<td>173</td>
</tr>
<tr>
<td>14</td>
<td>202</td>
</tr>
<tr>
<td>12</td>
<td>243</td>
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<tr>
<td>10</td>
<td>303</td>
</tr>
<tr>
<td>8</td>
<td>404</td>
</tr>
<tr>
<td>6</td>
<td>607</td>
</tr>
<tr>
<td>4</td>
<td>1212</td>
</tr>
</tbody>
</table>

Number of customers on Live side of PMAR

As an example of application of Table 4, on a 24km line, a PMAR can be justified at 12km distance if there are 202 customers on the Live side.