Schedule 16 Annex A - Design of the Common 500MW Network Model

CONTENTS

SECTION 1. INTRODUCTION

The gross asset value outputs from the Common 500MW Network Model (previously referred to as the *500MW Network Model*) comprise key inputs into the Common Distribution Charging Methodology (CDCM) and Extra-High Voltage Distribution Charging Methodology (EDCM). Both 'use-of-system' tariff methodologies allocate negotiated revenue allowances to different customer groups according to a number of cost drivers. The gross asset values for the following distribution network levels are used within the revenue allocation mechanisms:

- 132kV circuit
- 132kV/EHV transformation
- EHV circuit
- EHV/HV transformation
- 132kV/HV transformation
- HV circuit
- HV/LV transformation
- LV circuit

The guidance contained within this document presents a structured approach to the derivation of the network level gross asset values. This harmonised approach is reflected across those factors necessary for the derivation of the gross asset values such as the derivation of asset unit costs, data sources, network configuration and design principles, and network components. The document consists of the following sections:

- Glossary
- Design Philosophy and Considerations
- Coincidence Factors
- 'Installed' and 'Firm' Capacities of GSP Substations and substations on the 132kV and EHV Networks
- Derivation of Transformation Network Level Asset Quantities
- Derivation of Circuit Network Level Asset Quantities
- Derivation of Asset Values of Substations
- Derivation of Asset Values of Circuits
- Derivation of the Gross Asset Values of Network Levels

SECTION 2. GLOSSARY

The meanings of the terms below are applicable throughout the remainder of the document unless otherwise stated.

Term	Definition
Charging year	The financial year (12 month period ending on a 31st March) for which charges and credits are being calculated.
Circuit Network Level	A type of Network Level that excludes transformation assets (see "Network Level").
Coincidence Factor	A scaling factor calculated as the ratio of the maximum demand observed at a given location on the network and the aggregate of the individual maximum demands observed at multiple locations connected downstream (i.e. further from source) of the given location, taking account of losses. Such factors provide a means of recognising that the maximum demands observed at individual locations (e.g. substations at a given voltage level) on a section of network may not be coincident.
Common 500MW Network Model	Common 500MW Network Model. A costed design for an extension to the licensee's Distribution Assets at all relevant Network Levels.
Common Distribution Charging Methodology (CDCM)	The charging methodology used for setting 'Use-of-System' charges for high voltage and low voltage connections as described in Condition 50 of the Electricity Distribution Licence.
DNO	Each person that holds an Electricity Distribution Licence in which section B of the standard licence conditions has effect.
EHV Distribution Charging Methodology (EDCM)	The charging methodology to be used for setting 'Use-of-System' charges for relevant connections as described in Condition 50A of the Electricity Distribution Licence.
Electricity Distribution Licence	A licence granted, or treated as granted, pursuant to section 6(1)(c) of the Electricity Act 1989.
Existing Firm Capacity	The firm capacity of an existing substation as declared in the Long Term Development Statement
Existing Installed Capacity	The total capacity of an existing substation
Extra-High Voltage (EHV)	Nominal voltage greater than or equal to 22kV
Firm Capacity	The capacity at a substation that can be relied upon in the event of an outage (MVA). • For a single transformer substation, its firm capacity is taken to be the 'natural' cooling rating of the transformer (this assumes that available lower voltage network interconnection or transfer capacity will be no greater than the natural cooling rating of the transformer). • For a multi-transformer group, its firm capacity is taken to be the sum of the 'forced' cooling rating of all except the largest transformer within the group.
Grid Supply Point (GSP)	A point of supply from the National Electricity Transmission System to the DNO Party's Distribution System. Three types are considered: • TR/132 – a connection point that provides direct transformation from the Transmission network to the

	132kV network. • TR/EHV – a connection point that provides direct transformation from the Transmission network to the EHV network. • TR/HV – a connection point that provides direct transformation from the Transmission network to the HV network.
Gross Asset Value	The total value of all assets allocated to a Network Level.
High Voltage (HV)	Nominal voltage of at least 1kV and less than 22kV
Installed Capacity	Sum of 'enhanced forced cooling' rating of transformers associated with a particular substation configuration (MVA).
Long Term Development Statement (LTDS)	The Long Term Development Statement as detailed by Licence Condition 25 of the Distribution Licences.
Low Voltage (LV)	Nominal voltage of less than 1kV
Maximum Import Capacity (MIC)	Maximum amount of electricity which is permitted to flow from the Distribution System through the Connection Point (or the Connection Points collectively) at a customer site. (MVA)
Megavolt ampere (MVA)	A unit of network capacity
Megavolt ampere reactive (MVAr)	A unit of reactive power flow
Megawatt (MW)	A unit of power flow
Merchant Generator	A merchant generator is a generator whose primary business activity is the generation of electricity.
Modelled Asset Value	The total value of assets associated with a specified transformation allocated to a particular Network Level or the total value or assets of circuits at a specified voltage allocated to a particular Circuit Network Level.
Modelled Firm Capacity	Total firm capacity at each Transformation Network Level derived from the numbers of the substation configurations considered at the Transformation Network Level.
Modelled Installed Capacity	Total installed capacity at each Transformation Network Level derived from the numbers of the substation configurations considered at the Transformation Network Level.
Modelled Maximum Demand	The maximum demand that must be satisfied at each Transformation Network Level
Network Level	A network level is modelled as a stack of circuit or transformation levels between supplies at LV and transmission network.
Power factor	The ratio of real power (MW) to apparent power (MVA)
Regulatory Reporting Pack (RRP)	A dataset produced each year by each DNO for OFGEM.
Transformation Network Level	A type of Network Level that includes transformation assets (see "Network Level").

SECTION 3. DESIGN PHILOSOPHY AND CONSIDERATIONS

3.1. Design Philosophy

The Common 500MW Network Model is considered to be a minimum specification demand-dominated extension of the existing distribution network at all relevant Network Levels that is fully utilised under N-1 conditions at the 132kV and EHV networks and partially utilised under N-1 conditions at the HV network. The extension is designed to satisfy a specified level of simultaneous demand at the boundary between the distribution network and the GB transmission system and the equivalent demand at each relevant Network Level. It is assumed the network extension is constructed on greenfield land. Future load growth should not be taken into account.

The overall design philosophy of the Common 500MW Network Model has been guided by the desire to maintain consistency with the fact that both tariff-setting methodologies in which the outputs are used serve as revenue recovery tools. This approach renders the reliance of the derivation of asset quantities on existing distribution asset profiles permissible. For example, existing circuit lengths are used to inform the quantities required within the Common 500MW Network Model.

It is recognised that the interpretation of ‘minimum specification’ can be subjective depending on current DNO and industry practice such as network operation and procurement – these considerations are embedded where possible. For example, the costs associated with oil-insulated switchgear are excluded since current practice involves these assets being phased out over time. Further, different design philosophies such as radial and interconnected network topologies can be accommodated within the Common 500MW Network Model.

The vagaries of network design along with historic and current considerations can also contribute to the subjectivity of the interpretation of ‘minimum specification’. In the context of this document, ‘minimum specification’ is interpreted to be any specification which:

- may or may not result in the ‘minimum cost’ network,
- allows DNOs to comply with national and international design standards,
- allows DNOs to comply with company-specific design and protection principles, philosophies and standards,
- allows DNOs to fulfil licence obligations, and
- may be inferred from costs allowed for in recent negotiated price control settlements.

An example of this difference in interpretation relates to the quantities of switchgear and protection devices on the HV network allowed for within the Common 500MW Network Model. DNOs have sought to maximise network performance by way of the installation of varying levels of switchgear and protection devices in order to minimise the impact of outages. Other than the minimum amount necessary to meet statutory obligations, the installation of additional devices is not strictly required for the operation of distribution networks but some allowances have been made because this is now perceived to be 'business-as-usual' practice.

It is advised that any data related to the network physical parameters, which are used to derive the Common 500MW Network Model, are reviewed within a 3 to 5 year interval considering the low volatility of network structures.

3.2. Asset Unit Costing Principles

Asset unit costs are required for the derivation of the Modelled Asset Values of substations and circuits. The costs applied within the Common 500MW Network Model must reflect current DNO practice and policy and must also account for the following:

- costs of purchase and installation of the assets including building and civil works in unmade ground must be reflected since it is assumed the network extension is constructed on greenfield land,
- unit costs included should align with business plan submissions assuming costs for new build and unit costs associated with asset replacement must not be used because the Common 500MW Network Model is based on network extension rather than asset replacement,
- the unit costs for circuits should be based on the cost of those taken to be the lowest relevant standard size that will deliver the required capacity.

Further, the costs associated with the following must be excluded:

- indirect costs,
- land or easement purchase value and land damage,
- legal and administrative costs incurred in establishing wayleaves,
- wayleave rental payments,
- preparation and submission of planning permission applications, and
- participation in public inquiries.

It is advised that asset unit cost data are reviewed annually considering higher volatility of asset costs.

3.3. Data Sources

To ensure a common approach across all DNOs there should be commonality in the data sources used for the purposes of the derivation of the Gross Asset Values of all Network Levels in the Common 500MW Network Model.

The common data sources that should be used are listed below, most of which are already published in the public domain.

Data Type	Data Source
Forecast maximum demands at Grid Supply Point substations	Long Term Development Statement Standard Planning Data and the Detailed Planning Data (typically referred to as the "Week 24 Returns")
Firm capacities at Grid Supply Point substations	NGT Data e.g. P26 Analysis
Forecast maximum demands at 132/EHV substations, 132/HV and EHV/HV substations	Long Term Development Statement
Forecast reactive power at 132/EHV substations, 132/HV and EHV/HV substations	Long Term Development Statement
Power factors at 132/EHV substations, 132/HV and EHV/HV substations	Long Term Development Statement
Firm capacities at 132/EHV substations, 132/HV and EHV/HV substations	Long Term Development Statement
Maximum Import Capacities for 132kV-connected and EHV-connected demand sites	Customer connection agreements or billing data
Transformer capacities and asset profiles of HV/LV substations	DNO-specific asset database
132kV, EHV and LV circuit data	Regulatory Reporting Pack Table (it is assumed this data source contains circuit lengths and not circuit 'route' lengths)
HV circuit data	Network Disaggregation Workbook

SECTION 4. COINCIDENCE FACTORS

When considering a group of substations, the overall maximum demand is usually smaller than the sum of the non-simultaneous maximum demands. This may be mathematically expressed by coincidence factors. Coincidence factors may then be used to estimate the maximum demand to be satisfied at each transformation level that corresponds to the Modelled Maximum Demand as measured at the boundary of the distribution system and the GB transmission system (i.e. the ‘entry point’ to the Common 500MW Network Model). A simple schematic of a typical primary system on a distribution network (Figure 1) is presented to illustrate the calculation of the relevant coincidence factors.

The schematic illustrates typical assets on a distribution system between the boundary of the distribution system and the GB transmission system and the HV network boundary. Various Grid Supply Point (GSP) configurations are included: TR/132, TR/EHV and TR/HV where ‘TR’ denotes typical transmission system voltages such as 400kV and 275kV (and 132kV in Scotland). The flows through the network may be summarised as:

- all flows that exit the 132kV network (at the points denoted as 132/EHV transformation, 132/HV transformation and 132kV-connected site) are supplied through the TR/132 transformation.
- all flows that exit the EHV network (at the points denoted as EHV/HV transformation and EHV-connected site) are supplied through the TR/EHV and 132/EHV transformations.
- all flows that enter the HV network are supplied through the TR/HV, 132/HV and EHV/HV transformations.
- for the purpose of the Common 500MW Network Model, the point of common coupling (POCC) with other system users is used to determine the network level of large customers; for example a customer connected to a DNO owned HV switchboard which connected to the lower voltage side of a 132kV/HV BSP with no other customers connected at HV would be classed as a 132kV Connected Site as the POCC is at 132kV.

The following forecast coincidence factors are required:

- coincidence between the DNO system maximum demand and GSPs,
- combined coincidence between the GSPs and the 132/EHV and 132/HV substations, and
- coincidence between the 132/EHV substations and EHV/HV substations.

Coincidence between the EHV/HV substations and HV/LV substations are not calculated because of the difficulties associated with obtaining maximum demand data for HV/LV substations. Instead, a composite coincidence/utilisation factor is used to estimate the Modelled Firm Capacity required at the HV/LV Transformation Network Level.

Where a GSP is shared among parties (e.g. another DNO or large customer), the forecast maximum demand should be apportioned between users in proportion to their maximum demands.

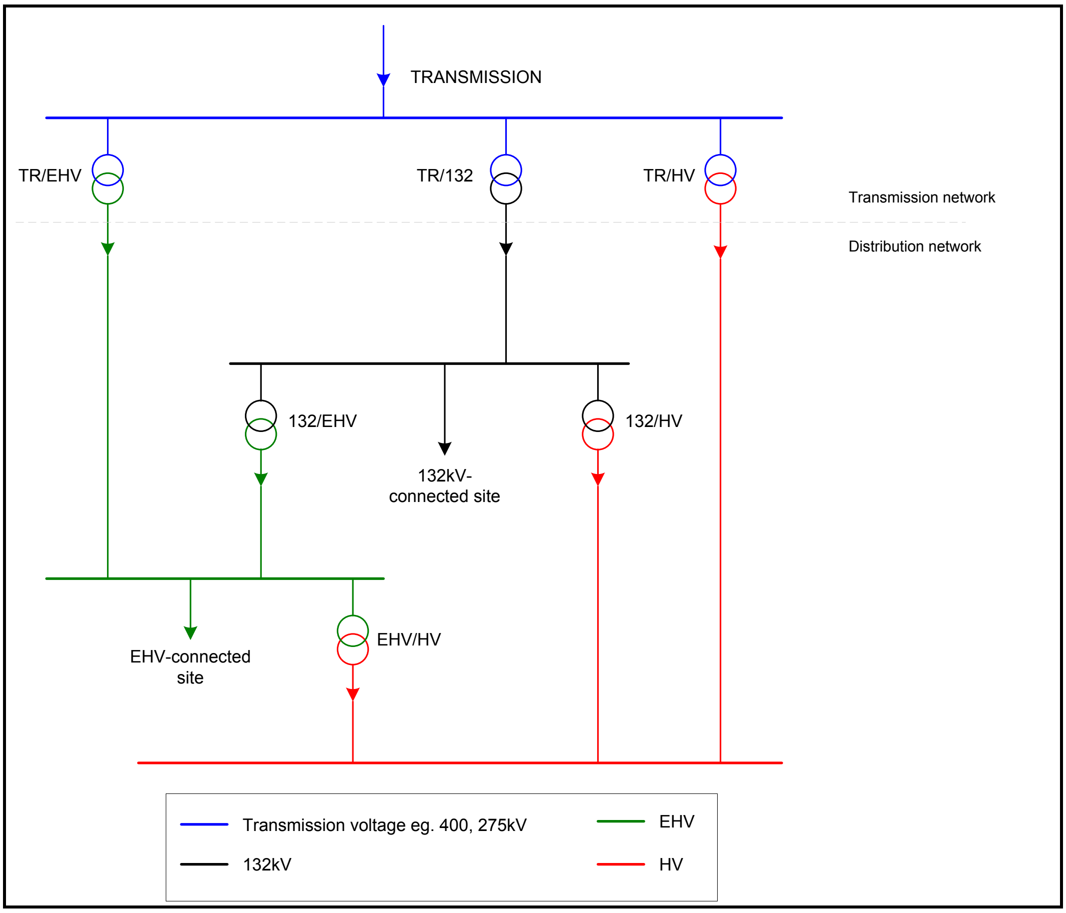

Figure 1 - Example of Typical Distribution Primary Network

SECTION 5. 'INSTALLED' AND 'FIRM' CAPACITIES OF GSP SUBSTATIONS AND SUBSTATIONS ON THE 132KV AND EHV NETWORKS

It is expected that DNOs currently install a selection of standard substation configurations with respect to the number and capacity of transformers on primary distribution networks that would be suitable for installation on future network extensions. No limit is placed on the number of configurations that may be included in the Common 500MW Network Model other than the limits of the spread sheet model and 'modern equivalents' for existing substation configurations may be used. The derivation of the 'installed' and 'firm' capacity of each configuration is presented below.

5.1. Multi-Transformer Groups

The following types of multi-transformer groups at GSP substations and on the 132kV and EHV networks are defined:

- a group in which all transformers are co-located at a single site, and
- a group in which some or all are located remotely from each other but are electrically connected via interconnecting circuits and can be treated as single entity.

The installed capacity of each considered multi-transformer group is given by:

$$IC\_MTX\_SUB_j = \sum_{1}^{v} FRAT\_TX \qquad \textbf{...Equ. 1}$$

where:

$IC\_MTX\_SUB_j$	=	Installed capacity of multi-transformer group configuration *j* (MVA). These may be TR/132, TR/EHV, TR/HV, 132/EHV, 132/HV or EHV/HV transformer groups (MVA).
FRAT_TX	=	'Enhanced Forced cooling' rating of transformer associated with multi-transformer group configuration *j* (MVA). The subscript '*j*' is not shown for simplicity.
V	=	number of transformers associated with the multi-transformer group configuration *j.*

The firm capacity of each considered multi-transformer group configuration is then:

$$FC\_MTX\_SUB_j = \sum_{1}^{v} FRAT\_TX - LIM\_FAC_{largest} \qquad \textbf{...Equ. 2}$$

where:

$FC\_MTX\_SUB_j$	=	firm capacity of multi-transformer group configuration *j* (MVA). These may be TR/132, TR/EHV, TR/HV, 132/EHV, 132/HV or EHV/HV transformer groups (MVA).
FRAT_TX	=	'Enhanced forced cooling' rating used by DNO of transformer associated with multi-transformer group configuration *j.* (MVA). The subscript '*j*' is not shown for simplicity.

V = Number of transformers associated with multi-transformer group configuration *j*.

$LIM\_FAC_{largest}$ = Reduction in firm capacity due to the largest limiting constraint.

- For a multi-transformer group in which all transformers are co-located at a single site, this factor is set to the 'enhanced forced cooling' rating of the largest transformer within the group.
- For multi-transformer group in which some or all transformers are located remotely from each other, this factor is set to the 'enhanced forced cooling' rating of the largest transformer within the group or the largest assumed capacity limitation associated with any of the interconnecting circuits.

In contrast to a group of transformers co-located at a single site, the firm capacity of this type of multi-transformer group can be limited by multiple factors such as the loss of the largest transformer within the group or capacity limitations on the interconnecting circuits.

5.2. Single-Transformer Substations

The installed capacity of each single-transformer substation configuration on the primary network is:

$$IC\_STX\_SUB_k = FRAT\_TX$$

…Equ. 3

where:

$IC\_STX\_SUB_k$ = Installed capacity of single-transformer substation configuration *k* (MVA). These may be TR/132, TR/EHV, TR/HV, 132/EHV, 132/HV or EHV/HV substations (MVA).

FRAT_TX = 'Enhanced forced cooling' rating of the transformer in the substation configuration *k* (MVA).

The firm capacity of each considered single-substation configuration on the primary network is then:

$$FC\_STX\_SUB_k = NRAT\_TX$$

…Equ. 4

where:

$FC\_STX\_SUB_k$ = Firm capacity of single-transformer substation configuration *k* (MVA). These may be TR/132, TR/EHV, TR/HV, 132/EHV, 132/HV or EHV/HV substations (MVA).

NRAT_TX = 'Natural' cooling rating of transformer (MVA). The 'natural cooling' rating is used since the firm capacity of single transformer substations is sometimes limited by a number of factors such as available transfer capacity, interconnection capacity and possible DNO standby generation (see Figure 2).

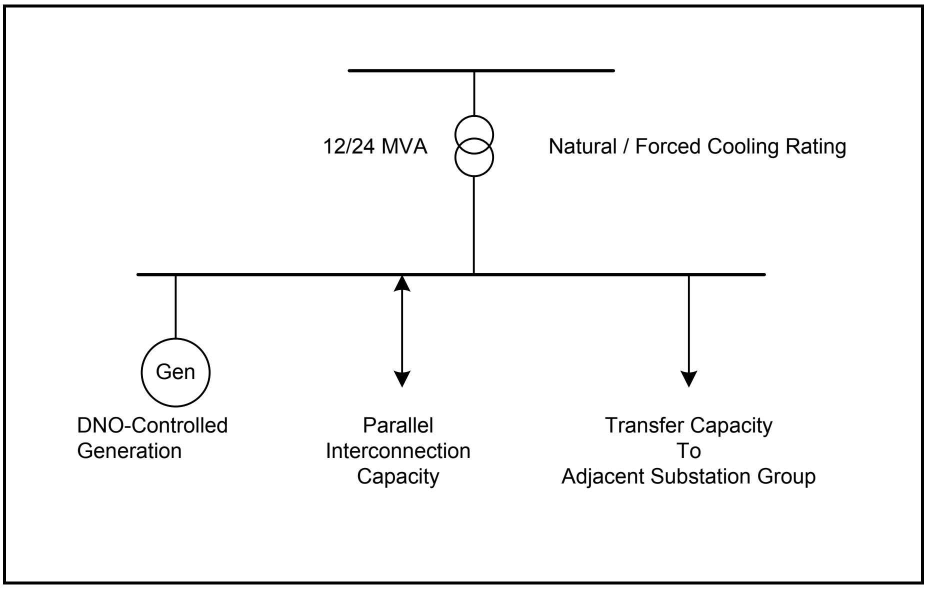

Figure 2 - Examples of Considerations that Limit Firm Capacity at Single-Transformer Substations

5.3. Shared GSPs

Where a GSP is shared with another party (e.g. another DNO or large customer), firm capacity of the GSP should be apportioned amongst parties in proportion to their maximum demand.

SECTION 6. DERIVATION OF TRANSFORMATION NETWORK LEVEL ASSET QUANTITIES

The derivation of the quantities of the main asset types at each Transformation Network Level is described in this section.

6.1. Modelled Maximum Demand calculation

6.1.1 Modelled Maximum Demands at the TR/ 132, TR/EHV and TR/HV Transformation Network Levels

For simplicity, only the Modelled Maximum Demand in the Common 500MW Network Model at the TR/132 Transformation Network Level is shown as below:

$$MMD\_TR/132 = MMD\_\text{GSP} * \left(\frac{EFC\_TR/132}{(EFC\_TR/132 + EFC\_TR/EHV + EFC\_TR/HV)}\right) \quad \textbf{...Equ. 5}$$

where:

MMD_GSP	=	Modelled Maximum Demand in the Common 500MW Network Model at the GSP Transformation Network Level (MW).
MMD_TR/132	=	Modelled Maximum Demand in the Common 500MW Network Model at the TR/132 Transformation Network Level (MW).
EFC_TR/132	=	Total Existing Firm Capacity of TR/132 substations in the licence area (MVA).
EFC_TR/EHV	=	Total Existing Firm Capacity of TR/EHV substations in the licence area (MVA).
EFC_TR/HV	=	Total Existing Firm Capacity of TR/HV substations in the licence area (MVA).

For other GSP transformation voltage levels the above calculation must be repeated using appropriate numerator in equation 5.

6.1.2 Modelled Maximum Demands at the 132/EHV and 132/HV Transformation Network Levels

The Coincidence between the TR/132 and downstream 132/EHV and 132/HV substations is (see Figure 3):

$$COI\_TR/132\_132/COMB = \left(\sum_{1}^{a} MD\_GSP - \sum_{1}^{b} MD\_TR/EHV - \sum_{1}^{c} MD\_TR/HV\right) / \left(\sum_{1}^{d} MD\_132/EHV + \sum_{1}^{e} MD\_132/HV + \sum_{1}^{f} MD\_132SITE\right)$$

…Equ. 6

If:

$$\sum_{1}^{d} MD\_132/EHV + \sum_{1}^{e} MD\_132/HV + \sum_{1}^{f} MD\_132SITE = 0$$

$$COI\_TR/132\_132/COMB = 1$$

where:

COI_TR/132_132/COMB	=	combined coincidence between the TR/132 and the downstream 132/EHV and 132/HV substations
MD_GSP	=	Forecast maximum demand at each GSP in the licence area in the charging year for which 'use-of-system' charges are being calculated (MW), where GSPs are TR/EHV, TR/132 and TR/HV.
a	=	Number of GSPs in the licence area.
MD_TR/EHV	=	Forecast maximum demand at each TR/EHV substation in the licence area in the charging year for which 'use-of-system' charges are being calculated (MW).
b	=	Number of TR/EHV substations in the licence area.
MD_TR/HV	=	Forecast maximum demand at each TR/HV substation in the licence area in the charging year for which 'use-of-system' charges are being calculated (MW).
c	=	Number of TR/HV substations in the licence area.
MD_132/EHV	=	Forecast maximum demand at each 132/EHV substation in the licence area in the charging year for which 'use-of-system' charges are being calculated (MW).
d	=	number of 132/EHV substations in the licence area
MD_132/HV	=	Forecast maximum demand at each 132/HV substation in the licence area in the charging year for which 'use-of-system' charges are being calculated (MW).
e	=	Number of 132/HV substations in the licence area.
MD_132SITE	=	Forecast maximum demand at 132kV-connected demand site in the charging year for which 'use-of-system' charges are being calculated (MW). The import connections of Merchant Generators are ignored.
f	=	Number of 132kV-connected demand sites in the licence area. The import connections of Merchant Generators are ignored.

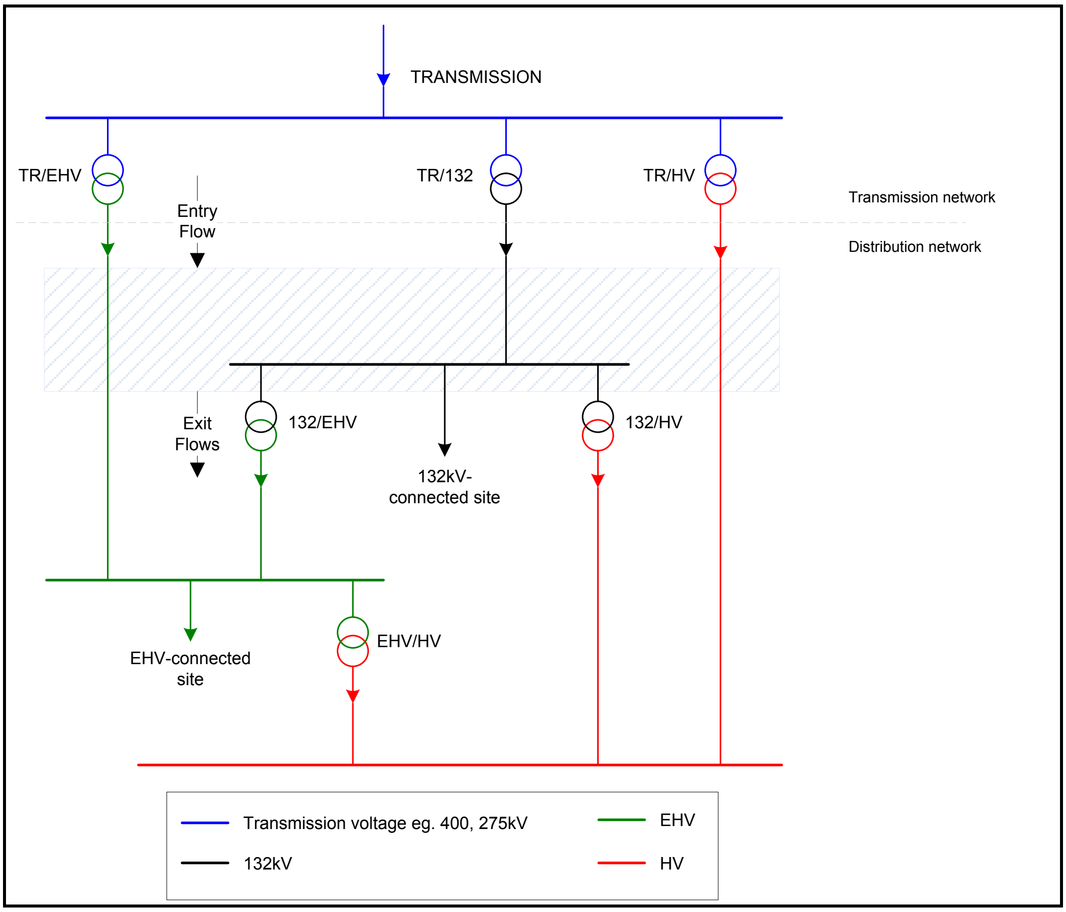

Figure 3 - GSP: combined 132/EHV and 132/HV Coincidence

The combined Modelled Maximum Demand in the Common 500MW Network Model at the 132/EHV and 132/HV Transformation Network Levels is equal to:

$$MMD\_132/COMB = \frac{MMD\_TR/132}{COI\_TR/132\_132/COMB}$$ **…Equ. 7**

where:

MMD_132/COMB = Combined Modelled Maximum Demand in the Common 500MW Network Model at the 132/EHV and 132/HV Transformation Network Levels (MW).

MMD_TR/132 = Modelled Maximum Demand in the Common 500MW Network Model at the TR/132kV Transformation Network Level (MW).

COI_TR/132_132/COMB = Combined coincidence between the TR/132 and the downstream 132/EHV and 132/HV substations.

The combined maximum demand at the 132/EHV and 132/HV Transformation Network Levels must be allocated to each Transformation Network Level. The Modelled Maximum Demand in the Common 500MW Network Model at the 132/EHV Transformation Network Level is:

$$MMD\_132/EHV = MMD\_132/COMB * \left(\frac{EFC\_132/EHV}{(EFC\_132/EHV + EFC\_132/HV)}\right)$$ **…Equ. 8**

where:

MMD_132/EHV	=	Modelled Maximum Demand in the Common 500MW Network Model at the 132/EHV Transformation Network Level (MW).
MMD_132/COMB	=	Combined Modelled Maximum Demand in the Common 500MW Network Model at the 132/EHV and 132/HV Transformation Network Levels (MW).
EFC_132/EHV	=	Total Existing Firm Capacity of 132/EHV substations in the licence area (MVA).
EFC_132/HV	=	Total Existing Firm Capacity of 132/HV substations in the licence area (MVA).

If:

$EFC\_132/EHV + EFC\_132/HV = 0$, then MMD_132/EHV = 0

The Modelled Maximum Demand in the Common 500MW Network Model at the 132/HV Transformation Network Level is the remaining portion of the combined maximum demand:

$$MMD\_132/HV = MMD\_132/COMB * \left(\frac{EFC\_132/HV}{(EFC\_132/EHV + EFC\_132/HV)}\right) \quad \text{...Equ. 9}$$

where:

MMD_132/HV	=	Modelled Maximum Demand in the Common 500MW Network Model at the 132/HV Transformation Network Level (MW).
MMD_132/COMB	=	Combined Modelled Maximum Demand in the Common 500MW Network Model at the 132/EHV and 132/HV Transformation Network Levels (MW).
EFC_132/HV	=	Total Existing Firm Capacity of 132/HV substations in the licence area (MVA).
EFC_132/EHV	=	Total Existing Firm Capacity of 132/EHV substations in the licence area (MVA).

If:

$EFC\_132/EHV + EFC\_132/HV = 0$, then MMD_132/HV = 0

6.1.3 Modelled Maximum Demand at the EHV/HV Transformation Network Level

Coincidence between the TR/EHV, 132/EHV and the downstream EHV/HV substations is calculated as (see Figure 4) is:

$$COI\_TR/EHV\&132/EHV\_EHV/HV = \left(\sum_{1}^{e} MD\_TR/EHV + \sum_{1}^{b} MD\_132/EHV\right) \Big/ \left(\sum_{1}^{g} MD\_EHV/HV + \sum_{1}^{h} MD\_EHVSITE\right) \quad \text{...Equ. 10}$$

where:

COI_TR/EHV&132/EHV _EHV/HV	=	Coincidence between the TR/EHV, 132/EHV and the downstream EHV/HV substations.
MD_TR/EHV	=	Forecast maximum demand at each TR/EHV substation in the licence area in the charging year for which ‘use-of-system’ charges are being calculated (MW).
e	=	Number of TR/EHV substations in the licence area.
MD_132/EHV	=	Forecast maximum demand at each 132/EHV substation in the licence area in

the charging year for which 'use-of-system' charges are being calculated (MW).

b	=	Number of 132/EHV substations in the licence area.
MD_EHV/HV	=	Forecast maximum demand at each EHV/HV substation in the licence area in the charging year for which 'use-of-system' charges are being calculated (MW).
g	=	Number of EHV/HV substations in the licence area.
MD_EHVSITE	=	Forecast maximum demand at each EHV-connected demand site demand in the year for which 'use-of-system' charges are being calculated (MW). The import connections of Merchant Generators are ignored.
h	=	Number of EHV-connected demand sites in the licence area. The import connections of Merchant Generators are ignored.

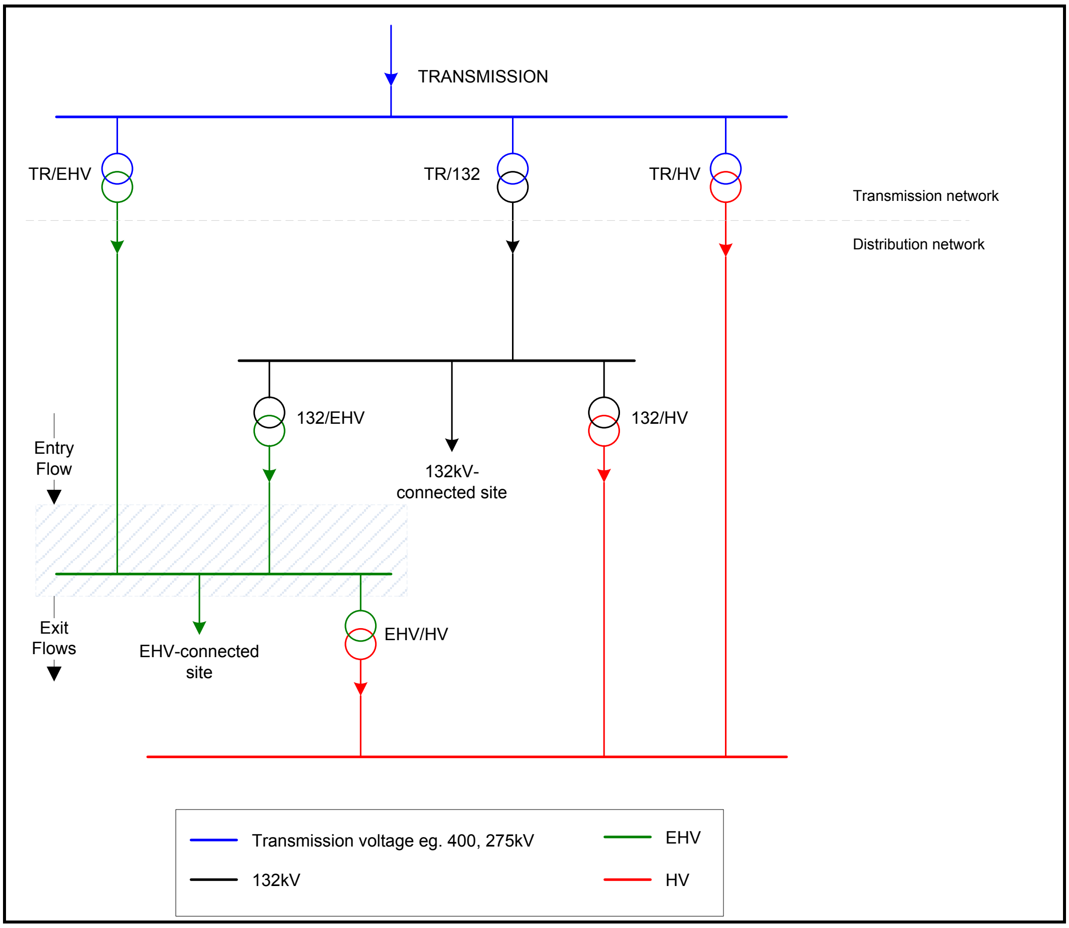

Figure 4 - 132/EHV: EHV/HV Coincidence

The Modelled Maximum Demand in the Common 500MW Network Model at the EHV/HV Transformation Network Level is:

$$MMD\_EHV/HV = \frac{MMD\_132/EHV + MMD\_TR/EHV}{COI\_TR/EHV\&132/EHV\_EHV/HV} \qquad \text{...Equ. 11}$$

where:

MMD_EHV/HV	=	Modelled Maximum Demand in the Common 500MW Network Model at the EHV/HV Transformation Network Level (MW).
MMD_132/EHV	=	Modelled Maximum Demand in the Common 500MW Network Model at the 132/EHV Transformation Network Level (MW).

COI_TR/EHV&132/EHV _EHV/HV	=	Coincidence between TR/EHV, 132/EHV and the downstream EHV/HV substations.
MMD_TR/EHV	=	Modelled Maximum Demand in the Common 500MW Network Model at the TR/EHV Transformation Network Level (MW)

6.2. Adjusted Modelled Maximum Demand Calculation

To reflect current network design practice and experience, the modelled maximum demand calculated at the voltage transformation levels in above section may be adjusted.

6.2.1 Adjusted Maximum Demand at GSPs

If modelled maximum demand needs to be adjusted at the GSP level:

- the adjusted maximum demand AMMD_TR/132 shall replace the MMD_TR/132,
- the adjusted maximum demand AMMD_TR/EHV shall replace the MMD_TR/EHV,
- the adjusted maximum demand AMMD_TR/HV shall replace the MMD_TR/HV.

where the following equality must be maintained:

$$AMMD\_\mathrm{TR}/132 + AMMD\_\mathrm{TR}/\mathrm{EHV} + AMMD\_\mathrm{TR}/\mathrm{HV} = MMD\_\mathrm{GSP} \quad \text{...Equ. 12}$$

The MMD_GSP is currently set to 500MW.

6.2.2 Adjusted Maximum Demand at 132kV/EHV and 132kV/HV Transformation Network Level

The modelled maximum demand of 132/COMB will be automatically adjusted if AMMD_TR/132 are used. In such a case,

- the adjusted maximum demand AMMD_132/COMB shall replace the MMD_132/COMB,

If the calculated modelled maximum demand at 132kV/EHV and 132kV/HV needs to be adjusted,

- the adjusted maximum demand AMMD_132/EHV shall replace the MMD_132/EHV,
- the adjusted maximum demand AMMD_132/HV shall replace the MMD_132/HV.

where the following equality must be maintained

$$AMMD\_132/\mathrm{E}HV + AMMD\_132/HV = AMMD\_132/COM \quad \text{...Equ. 13}$$

6.2.3 Adjusted Maximum Demand at EHV/HV Transformation Network Level

The modelled maximum demand at EHV/HV will be automatically adjusted if AMMD_132/EHV and AMMD_TR/EHV are used. In such a case

- the adjusted maximum demand AMMD_EHV/HV shall replace the MMD_EHV/HV

6.3. Transformer Capacity at GSPs

GSP (TR/132, TR/EHV and TR/HV) substations must be considered within the Common 500MW Network Model. Any appropriate configuration based on number of transformers, transformer capacity and transformations may be utilised as long as consistency with the design philosophy is maintained.

The firm and installed capacities of each substation configuration may be derived as described in SECTION 5. The firm capacities of all GSPs are required for the derivation of 'lower' Network Level asset quantities as described in this section. The considered configurations of all GSPs are required for the derivation of the quantities of components within the substation compound typically owned by DNOs and, by extension, the asset values of these substations described in SECTION 8.

For simplicity only TR/132 transformation network level is described below, for other GSP transformation levels the calculation must be repeated using the appropriate transformation level. The Modelled Maximum Demand at the TR/132 Transformation Network Level is used to calculate the required firm capacity which, in turn, is used to determine the total installed transformer capacity. The Modelled Firm Capacity at the TR/132 Transformation Network Level is equal to:

$$MFC\_TR/132 = n_1.FC\_MTX\_TR/132_1 + \cdots n_j.FC\_MTX\_TR/132_j + n_1.FC\_STX\_TR/132_1 + \cdots n_k.FC\_STX\_TR/132_k \quad \text{...Equ. 14}$$

where:

MFC_TR/132	=	Modelled Firm Capacity at the TR/132 Transformation Network Level in the Common 500MW Network Model (MVA).
n_j	=	Number of type *j* multi-transformer TR/132 substations in the Common 500MW Network Model.
$FC\_MTX\_TR/132_j$	=	Firm capacity associated with multi-transformer TR/HV substation configuration type *j* (MVA).
n_k	=	Number of type *k* single-transformer TR/132 substations in the Common 500MW Network Model.
$FC\_STX\_TR/132_k$	=	Firm capacity associated with single-transformer TR/132 substation configuration type *k* (MVA).

The number of each substation configuration included may be arrived at using any method deemed appropriate as long as consistency with current DNO-specific design policy is maintained. For example, the distribution of existing, installed substation configurations may be relied upon and reflected within the Common 500MW Network Model.

The Modelled Firm Capacity at the TR/132 Transformation Network Level must satisfy the following condition:

$$MFC\_TR/132 \geq \frac{MMD\_TR/132}{APF\_TR/132} \quad \text{...Equ. 15}$$

and generally, the following should hold through,

$$MFC\_TR/132 < 1.05 * \frac{MMD\_TR/132}{APF\_TR/132} \qquad \text{...Equ. 16}$$

where the above inequality cannot be achieved, fractions of the less common types of substation are to be used to make the inequality true.

where:

$$APF\_TR/132 = Cos\,Tan^{-1} \sum_{1}^{c} RP\_TR/132 \Big/ \sum_{1}^{c} MD\_TR/132 \qquad \text{...Equ. 17}$$

where:

MFC_TR/132	=	Modelled Firm Capacity at the TR/132 Transformation Network Level in the Common 500MW Network Model (MVA).
MMD_TR/132	=	Modelled Maximum Demand in the Common 500MW Network Model at the TR/132 Transformation Network Level (MW).
APF_TR/132	=	Average power factor for TR/132 substations.
MD_TR/132	=	Forecast maximum demand at TR/132 substation in the licence area in the charging year for which 'use-of-system' charges are being calculated (MW).
RP_TR/132	=	Forecast reactive power at TR/132 substation in the licence area in the charging year for which 'use-of-system' charges are being calculated (MVAR). For the case of leading power factor, reactive power should be entered as a negative value.
c	=	Number of TR/132 substations in the licence area

Where adjusted modelled maximum demand (AMMD) values are used, they shall replace modelled maximum demand (MMD) in the calculation.

6.4. Transformer Capacity at the 132/EHV and 132/HV Transformation Network Levels

6.4.1 Aggregate Transformer Capacities at the 132/EHV Transformation Network Level

The Modelled Maximum Demand at the 132/EHV Transformation Network Level is used to calculate the required firm capacity which, in turn, is used to determine the total installed transformer capacity. The Modelled Firm Capacity at the 132/EHV Transformation Network Level is equal to:

$$MFC\_132/EHV = n_1.FC\_MTX\_132/EHV_1 + \cdots n_j.FC\_MTX\_132/EHV_j + n_1.FC\_STX\_132/EHV_1 + \cdots n_k.FC\_STX\_132/EHV_k \qquad \text{...Equ. 18}$$

where:

MFC_132/EHV	=	Modelled Firm Capacity at the 132/EHV Transformation Network Level in the Common 500MW Network Model (MVA).
n_j	=	Number of type *j* multi-transformer 132/EHV substations in the Common 500MW Network Model.
FC_MTX_132/EHV_j	=	Firm capacity associated with multi-transformer 132/EHV substation configuration

		type *j* (MVA).
n_k	=	Number of type *k* single-transformer 132/EHV substations in the Common 500MW Network Model.
FC_STX_132/EHV_k	=	Firm capacity associated with single-transformer 132/EHV substation configuration type *j* (MVA).

The number of each substation configuration included may be arrived at using any method deemed appropriate as long as consistency with current DNO-specific design policy is maintained. For example, the distribution of existing, installed substation configurations may be relied upon and reflected within the Common 500MW Network Model.

The Modelled Firm Capacity at the 132/EHV Transformation Network Level must satisfy the following condition:

$$MFC\_132/EHV \geq \frac{MMD\_132/EHV}{APF\_132/EHV}$$ **…Equ. 19**

and

$$MFC\_132/EHV < 1.05 * \frac{MMD\_132/EHV}{APF\_132/EHV}$$ **…Equ. 20**

where the above inequality cannot be achieved, fractions of the less common types of substation are to be used to make the inequality true.

where:

$$APF\_132/EHV = Cos\,Tan^{-1} \sum_{1}^{b} RP\_132/EHV \Big/ \sum_{1}^{b} MD\_132/EHV$$ **…Equ. 21**

where:

MFC_132/EHV	=	Modelled Firm Capacity at the 132/EHV Transformation Network Level in the Common 500MW Network Model (MVA).
MMD_132/EHV	=	Modelled Maximum Demand in the Common 500MW Network Model at the 132/EHV Transformation Network Level (MW).
APF_132/EHV	=	Average power factor for 132/EHV substations.
MD_132/EHV	=	Forecast maximum demand at 132/EHV substation in the licence area in the charging year for which 'use-of-system' charges are being calculated (MW).
RP_132/EHV	=	Forecast reactive power at 132/EHV substation in the licence area in the charging year for which 'use-of-system' charges are being calculated (MVAR). For the case of leading power factor, reactive power should be entered as a negative value.
b	=	Number of 132/EHV substations in the licence area

When the Modelled Firm Capacity at the 132/EHV Transformation Network Level is determined to satisfy the above inequality, the Modelled Installed Capacity in the Common 500MW Network Model at the 132/EHV Transformation Network Level is:

$$MIC\_132/EHV = n_1.IC\_MTX\_132/EHV_1 + \cdots n_j.IC\_MTX\_132/EHV_j + n_1.IC\_STX\_132/EHV_1 + \cdots n_k.IC\_STX\_132/EHV_k$$ **…Equ. 22**

where:

MIC_132/EHV	=	Modelled Installed Capacity at the 132/EHV Transformation Network Level (MVA).
IC_MTX_132/EHV_j	=	Installed capacity of multi-transformer substation configuration *j* (MVA).
n_j	=	Number of type *j* multi-transformer 132/EHV substations in the Common 500MW Network Model.
IC_STX_132/EHV_k	=	Installed capacity of single-transformer substation configuration *k* (MVA).
n_k	=	Number of type *k* single-transformer 132/EHV substations in the Common 500MW Network Model.

Where adjusted modelled maximum demand (AMMD) values are used, they shall replace modelled maximum demand (MMD) in the calculation.

6.4.2 Aggregate Transformer Capacities at the 132/HV Transformation Network Level

The Modelled Maximum Demand at the 132/HV Transformation Network Level is used to calculate the required firm capacity which, in turn, is used to determine the total installed transformer capacity. The Modelled Firm Capacity at the 132/HV Transformation Network Level is equal to:

$$MFC\_132/HV = n_1.FC\_MTX\_132/HV_1 + \cdots n_j.FC\_MTX\_132/HV_j + n_1.FC\_STX\_132/HV_1 + \cdots n_k.FC\_STX\_132/HV_k$$ **…Equ. 23**

where:

MFC_132/HV	=	Modelled Firm Capacity at the 132/HV Transformation Network Level in the Common 500MW Network Model (MVA).
n_j	=	Number of type *j* multi-transformer 132/HV substations in the Common 500MW Network Model.
FC_MTX_132/HV_j	=	Firm capacity associated with multi-transformer 132/HV substation configuration type *j* (MVA).
n_k	=	Number of type *k* single-transformer 132/HV substations in the Common 500MW Network Model.
FC_STX_132/HV_k	=	Firm capacity associated with single-transformer 132/HV substation configuration type *k* (MVA).

The number of each substation configuration included may be arrived at using any method deemed appropriate as long as consistency with current DNO-specific design policy is maintained. For example, the distribution of existing, installed substation configurations may be relied upon and reflected within the Common 500MW Network Model.

The Modelled Firm Capacity at the 132/HV Transformation Network Level must satisfy the following condition:

$$MFC\_132/HV \geq \frac{MMD\_132/HV}{APF\_132/HV}$$ **…Equ. 24**

and

$$MFC\_132/HV < 1.05 * \frac{MMD\_132/HV}{APF\_132/HV}$$ **…Equ. 25**

where the above inequality cannot be achieved, fractions of the less common types of substation are to be used to make the inequality true.

where:

$$APF\_132/HV = Cos\, Tan^{-1} \sum_{1}^{c} RP\_132/HV \Big/ \sum_{1}^{c} MD\_132/HV$$ **…Equ. 26**

where:

MFC_132/HV	=	Modelled Firm Capacity at the 132/HV Transformation Network Level in the Common 500MW Network Model (MVA).
MMD_132/HV	=	Modelled Maximum Demand in the Common 500MW Network Model at the 132/HV Transformation Network Level (MW).
APF_132/HV	=	Average power factor for 132/HV substations.
MD_132/HV	=	Forecast maximum demand at 132/HV substation in the licence area in the charging year for which 'use-of-system' charges are being calculated (MW).
RP_132/HV	=	Forecast reactive power at 132/HV substation in the licence area in the charging year for which 'use-of-system' charges are being calculated (MVAR). For the case of leading power factor, reactive power should be entered as a negative value.
c	=	Number of 132/HV substations in the licence area

When the Modelled Firm Capacity at the 132/HV Transformation Network Level is determined to satisfy the above inequality, the Modelled Installed Capacity in the Common 500MW Network Model at the 132/HV Transformation Network Level is:

$$MIC\_132/HV = n_1.IC\_MTX\_132/HV_1 + \cdots n_j.IC\_MTX\_132/HV_j + n_1.IC\_STX\_132/HV_1 + \cdots n_k.IC\_STX\_132/HV_k$$ **…Equ. 27**

where:

MIC_132/HV	=	Modelled Installed Capacity at the 132/HV Transformation Network Level (MVA).

IC_MTX_132/HV_j	=	Installed capacity of multi-transformer substation configuration *j* (MVA).
n_j	=	Number of type *j* multi-transformer 132/HV substations in the Common 500MW Network Model.
IC_STX_132/HV_k	=	Installed capacity of single-transformer substation configuration *k* (MVA).
n_k	=	Number of type *k* single-transformer 132/HV substations in the Common 500MW Network Model.

Where adjusted modelled maximum demand (AMMD) values are used, they shall replace modelled maximum demand (MMD) in the calculation.

6.5. Transformer Capacity at the EHV/HV Transformation Network Level

The Modelled Maximum Demand at the EHV/HV Transformation Network Level is used to calculate the required firm capacity which, in turn, is used to determine the total installed transformer capacity. The Modelled Firm Capacity at the EHV/HV Transformation Network Level is equal to:

$$MFC\_EHV/HV = n_1.FC\_MTX\_EHV/HV_1 + \cdots n_j.FC\_MTX\_EHV/HV_j + n_1.FC\_STX\_EHV/HV_1 + \cdots n_k.FC\_STX\_EHV/HV_k$$ **…Equ. 28**

where:

MFC_EHV/HV	=	Modelled Firm Capacity at the EHV/HV Transformation Network Level in the Common 500MW Network Model (MVA).
n_j	=	Number of type *j* multi-transformer EHV/HV substations in the Common 500MW Network Model.
FC_MTX_EHV/HV_j	=	Firm capacity associated with multi-transformer EHV/HV substation configuration type *j* (MVA).
n_k	=	Number of type *k* single-transformer EHV/HV substations in the Common 500MW Network Model.
FC_STX_EHV/HV_k	=	Firm capacity associated with single-transformer EHV/HV substation configuration type *k* (MVA).

The number of each substation configuration included may be arrived at using any method deemed appropriate as long as consistency with current DNO-specific design policy is maintained. For example, the distribution of existing, installed substation configurations may be relied upon and reflected within the Common 500MW Network Model.

The Modelled Firm Capacity at the EHV/HV Transformation Network Level must satisfy the following condition:

$$MFC\_EHV/HV \geq \frac{MMD\_EHV/HV}{APF\_EHV/HV}$$ **…Equ. 29**

and

$$MFC\_EHV/HV < 1.05 * \frac{MMD\_EHV/HV}{APF\_EHV/HV}$$ **…Equ. 30**

where the above inequality in Equ. 28 cannot be achieved, fractions of the less common types of substation are to be used to make Equ 28 true.

where:

$$APF\_EHV/HV = Cos\,Tan^{-1} \sum_{1}^{g} RP\_EHV/HV \bigg/ \sum_{1}^{g} MD\_\mathrm{EHV}/HV$$ **…Equ. 31**

where:

MFC_EHV/HV	=	Modelled Firm Capacity at the EHV/HV Transformation Network Level in the Common 500MW Network Model (MVA).
MMD_EHV/HV	=	Modelled Maximum Demand in the Common 500MW Network Model at the EHV/HV Transformation Network Level (MW).
APF_EHV/HV	=	Average power factor for EHV/HV substations.
MD_EHV/HV	=	Forecast maximum demand at EHV/HV substation in the licence area in the charging year for which 'use-of-system' charges are being calculated (MW).
RP_EHV/HV	=	Forecast reactive power at EHV/HV substation in the licence area in the charging year for which 'use-of-system' charges are being calculated (MVAR). For the case of leading power factor, reactive power should be entered as a negative value.
g	=	Number of EHV/HV substations in the licence area.

When the Modelled Firm Capacity at the EHV/HV Transformation Network Level is determined to satisfy the above inequality, the Modelled Installed Capacity in the Common 500MW Network Model at the EHV/HV Transformation Network Level is:

$$MIC\_EHV/HV = n_1.IC\_MTX\_EHV/HV_1 + \cdots n_j.IC\_MTX\_EHV/HV_j + n_1.IC\_STX\_EHV/HV_1 + \cdots n_k.IC\_STX\_EHV/HV_k$$ **…Equ. 32**

where:

MIC_EHV/HV	=	Modelled Installed Capacity at the EHV/HV Transformation Network Level (MVA).
IC_MTX_EHV/HV_j	=	Installed capacity of multi-transformer substation configuration *j* (MVA).
n_j	=	Number of type *j* multi-transformer EHV/HV substations in the Common 500MW Network Model.
IC_STX_EHV/HV_k	=	Installed capacity of single-transformer substation configuration *k* (MVA).
n_k	=	Number of type *k* single-transformer EHV/HV substations in the Common 500MW Network Model.

Where adjusted modelled maximum demand (AMMD) values are used, they shall replace modelled maximum demand (MMD) in the calculations.

6.6. Transformer Capacity at the HV/LV Transformation Network Level

The Modelled Firm Capacity and, by extension, the Modelled Installed Capacity at the HV/LV Transformation Network Level are not derived from the Modelled Maximum Demand as is done for the 'upstream' Network Levels. The main reason for this is that the maximum demand at the HV/LV level cannot be determined with sufficient accuracy as most DNOs do not retrieve data for maximum demand indications at ground mounted distribution substations and data is generally not available for pole mounted substations.

The Modelled Firm Capacity at the HV/LV Transformation Network Level is therefore derived from the aggregate existing installed capacity of ground and pole mounted HV/LV transformers and the ratio of the Modelled Firm Capacity to Installed Firm capacity of EHV/HV, 132/HV and TR/HV substations.

The Modelled Firm Capacity of ground mounted HV/LV Transformation is calculated as:

$$MFC\_HV/LVGM = \left(\frac{(MFC\_EHV/HV + MFC\_132/HV + \mathrm{MFC}\_TR/HV)}{EFC\_EHV/HV + EFC\_132/HV + \mathrm{EFC}\_TR/HV}\right) * EIC\_HV/LVGM \quad \textbf{...Equ. 33}$$

The Modelled Firm Capacity of pole mounted HV/LV Transformation in the model is calculated as:

$$MFC\_HV/LVPM = \left(\frac{(MFC\_EHV/HV + MFC\_132/HV + \mathrm{MFC}\_TR/HV)}{EFC\_EHV/HV + EFC\_132/HV + \mathrm{EFC}\_TR/HV}\right) * EIC\_HV/LVPM \quad \textbf{...Equ. 34}$$

where:

MFC_HV/LVGM	=	Modelled Firm Capacity at the HV/LV ground mounted Transformation Network Level in the Common 500MW Network Model (MVA).
MFC_HV/LVPM	=	Modelled Firm Capacity at the HV/LV pole mounted Transformation Network Level in the Common 500MW Network Model (MVA).
MFC_132/HV	=	Modelled Firm Capacity at the 132/HV Transformation Network Level in the Common 500MW Network Model (MVA).
MFC_TR/HV	=	Modelled Firm Capacity of TR/HV substations included in the Common 500MW Network Model (MVA).
MFC_EHV/HV	=	Modelled Firm Capacity of EHV/HV substations included in the Common 500MW Network Model (MVA).
EIC_HV/LVGM	=	Total Existing Installed Capacity of ground mounted HV/LV substations in the licence area (MVA). This is the sum of the 'natural cooling' ratings of all HV/LV transformers in the licence area.
EIC_HV/LVPM	=	Total Existing Installed Capacity of pole mounted HV/LV substations in the licence area (MVA). This is the sum of the 'natural cooling' ratings of all HV/LV transformers in the licence area.

EFC_132/HV	=	Total Existing Firm Capacity of 132/HV substations in the licence area (MVA).
EFC_TR/HV	=	Total Existing Firm Capacity of TR/HV substations in the licence area (MVA).
EFC_EHV/HV	=	Total Existing Firm Capacity of EHV/HV substations in the licence area (MVA).

The population of all existing HV/LV substations installed in the DNO area together with new substations commissioned up to 5 years ago for new business reasons shall be used to determine the mix of size and quantity of transformers to be used in the Model. The percentage of existing HV/LV transformation supplied by modern equivalent size transformers should be averaged with what has been installed over recent years (up to 5 years). For example, if at present 50% of HV/LV transformation is supplied through 500 kVA transformers, but in the last 5 years only 40% of new LV load has been supplied through 500 kVA transformers, then (if 500 kVA transformers are to be used in the model) a figure 45% should be used. The intention is to reflect recent and potential future network extensions yet capture existing topography of DNO's licence area.

$$EIC\_HV/LV\_PM = EIC\_HV/LV\_PM_1 + \cdots + EIC\_HV/LV\_PM_j$$ **…Equ. 35**

$$EIC\_HV/LV\_GM = EIC\_HV/LV\_GM_1 + \cdots + EIC\_HV/LV\_GM_k$$ **…Equ. 36**

where

EIC_ HV/LV_PM	=	Total Existing installed capacity of HV/LV pole mounted substations (MVA) in the licence area.
EIC_HV/LV_PM_j	=	Total Existing installed capacity of HV/LV pole mounted substation configuration type *j* (MVA) in the licence area that was commissioned recently.
EIC_ HV/LV_GM	=	Total Existing installed capacity of HV/LV ground mounted substations (MVA) in the licence area.
EIC_HV/LV_GM_k	=	Total Existing installed capacity of HV/LV ground mounted substation configuration type *k* (MVA) in the licence area that was commissioned recently.

The Modelled Installed Capacities of HV/LV pole mounted and ground mounted Transformations are calculated as:$MIC\_HV/LV\_PM = n_1.IC\_HV/LV\_PM_1 + \cdots n_j.IC\_HV/LV\_PM_j$ **…Equ. 37**

$$MIC\_HV/LV\_GM = n_1.IC\_HV/LV\_GM_1 + \cdots n_k.IC\_HV/LV\_GM_k$$ **…Equ. 38**

and therefore the total Modelled Installed Capacity at the HV/LV Transformation Network Level is

$$MIC\_HV/LV = MIC\_HV/LV\_PM\ + MIC\_HV/LV\_GM$$ **…Equ. 39**

where:

MIC_HV/LV_PM	=	Modelled Installed Capacity of pole mounted HV/LV substations in the Common 500MW Network Model (MVA).

IC_HV/HV_PM_j	=	Installed capacity of pole mounted substation configuration *j* (MVA).
n_j	=	Number of type *j* pole mounted HV/HV substations in the Common 500MW Network Model.
MIC_HV/LV_GM	=	Modelled Installed Capacity of ground mounted HV/LV substations in the Common 500MW Network Model (MVA).
IC_HV/HV_GM_k	=	Installed capacity of ground mounted substation configuration *k* (MVA).
n_k	=	Number of type *k* ground mounted HV/HV substations in the Common 500MW Network Model.
MIC_HV/LV	=	Total Modelled Installed Capacity of HV/LV substations in the Common 500MW Network Model (MVA).

The Modelled Installed Capacity at the HV/LV Transformation (pole and ground mounted) Network Level must satisfy the following condition:

$$MIC\_HV/LV \geq MFC\_HV/LV$$ **…Equ. 40**

and

$$MIC\_HV/LV < 1.01 * MFC\_HV/LV$$ **…Equ. 41**

where:

MIC_HV/LV	=	Modelled Installed Capacity in the Common 500MW Network Model at the HV/LV Transformation Network Level (MVA).
MFC_HV/LV	=	Modelled Firm Capacity in the Common 500MW Network Model at the HV/LV Transformation Network Level in the Common 500MW Network Model (MVA).

SECTION 7. DERIVATION OF CIRCUIT NETWORK LEVEL ASSET QUANTITIES

The derivation of the quantities of the main asset types at each Circuit Network Level is described in this section. The existing circuit lengths for assets used solely for Merchant Generator connections should be excluded in the following calculations.

7.1. Circuit Lengths at the 132kV Circuit Network Level

The total 132kV circuit length in the Common 500MW Network Model is calculated in two steps. Firstly, the 132kV circuit length per unit of firm capacity at the 132/EHV and 132/HV Transformation Network Levels in the existing network is determined as:

$$LEN\_132PERFC = \frac{ELEN\_132}{EFC\_132/EHV + EFC\_132/HV + \sum_{1}^{d} MIC\_132SITE} \qquad \text{...Equ. 42}$$

where:

LEN_132PERFC	=	132kV circuit length per unit of firm capacity at the 132/EHV and 132/HV Transformation Network Levels in the existing network (km/MVA).
ELEN_132	=	Total existing 132kV circuit length in the licence area (km).
EFC_132/EHV	=	Total Existing Firm Capacity of 132/EHV substations in the licence area (MVA).
EFC_132/HV	=	Total Existing Firm Capacity of 132/HV substations in the licence area (MVA).
MIC_132SITE	=	Maximum import capacity of 132kV-connected demand site (MVA). The import connections of Merchant Generators are ignored.
d	=	Number of 132kV-connected demand sites in the licence area. The import connections of Merchant Generators are ignored.

In the second step, the modelled 132kV circuit length in the Common 500MW Network Model is calculated as:

$$MLEN\_132 = LEN\_132PERFC * (MFC\_132/EHV + MFC\_132/HV) \qquad \text{...Equ. 43}$$

where:

MLEN_132	=	Modelled 132kV circuit length in the Common 500MW Network Model (km).
LEN_132PERFC	=	132kV circuit length per unit of firm capacity at the 132/EHV and 132/HV Transformation Network Levels in the existing network (km/MVA).
MFC_132/EHV	=	Modelled Firm Capacity in the Common 500MW Network Model at the 132/EHV Transformation Network Level in the Common 500MW Network Model (MVA).
MFC_132/HV	=	Modelled Firm Capacity in the Common 500MW Network Model at the 132/HV Transformation Network Level in the Common 500MW Network Model (MVA).

7.1.1 Modelled 132kV Circuit Lengths by Conductor Type

The following conductor categories are specified for 132kV circuits in the Common 500MW Network Model:

- underground circuit,

- overhead single circuit (this is assumed to be equivalent to 132kV ‘wood pole’ construction as identified in the RRP), and
- overhead double circuit (this is assumed to be equivalent to 132kV ‘tower line’ construction as identified in the RRP).

The modelled 132kV underground cable length in the Common 500MW Network Model:

$$MLEN\_132UGC = MLEN132 * PROP\_132UGC$$ **…Equ. 44**

where:

$$PROP\_132UGC = \frac{ELEN\_132UGC}{ELEN\_132UGC + ELEN\_132WPOHL + ELEN\_132TLOHL}$$ **…Equ. 45**

where:

MLEN_132UGC	=	Modelled 132kV underground cable length in the Common 500MW Network Model (km).
MLEN_132	=	Modelled 132kV circuit length in the Common 500MW Network Model (km).
PROP_132UGC	=	Proportion of total existing 132kV circuit length in the licence area comprised of underground cable.
ELEN_132UGC	=	Total existing 132kV underground cable length in the licence area (km).
ELEN_132WPOHL	=	Total existing 132kV ‘wood pole’ (i.e. single circuit) overhead line circuit length in the licence area (km).
ELEN_132TLOHL	=	Total existing 132kV ‘tower line’ (i.e. double circuit) overhead line circuit length in the licence area (km).

The modelled 132kV single overhead line circuit length in the Common 500MW Network Model is:

$$MLEN\_132SOHL = MLEN132 * PROP\_132SOHL$$ **…Equ. 46**

where:

$$PROP\_132SOHL = \frac{ELEN\_132WPOHL}{ELEN\_132UGC + ELEN\_132WPOHL + ELEN\_132TLOHL}$$ **…Equ. 47**

where:

MLEN_132SOHL	=	Modelled 132kV single overhead line circuit length in the Common 500MW Network Model (km).
MLEN_132	=	Modelled 132kV circuit length in the Common 500MW Network Model (km).
PROP_132SOHL	=	Proportion of total existing 132kV circuit length in the licence area comprised of ‘wood pole’ (i.e. single circuit) overhead line conductor.
ELEN_132UGC	=	Total existing 132kV underground cable length in the licence area (km).
ELEN_132WPOHL	=	Total existing 132kV ‘wood pole’ (i.e. single circuit) overhead line circuit length in the licence area (km).
ELEN_132TLOHL	=	Total existing 132kV ‘tower line’ (i.e. double circuit) overhead line circuit length in the licence area (km).

The modelled 132kV double overhead line circuit length (i.e. tower route length) in the Common 500MW Network Model is calculated as:

$$MLEN\_132DOHL = \frac{MLEN132 * PROP\_132DOHL}{2}$$ **…Equ. 48**

where:

$$PROP\_132DOHL = \frac{ELEN\_132TLOHL}{ELEN\_132UGC + ELEN\_132WPOHL + ELEN\_132TLOHL}$$ **…Equ. 49**

where:

MLEN_132DOHL	=	Modelled 132kV double overhead line route length in the Common 500MW Network Model (km).
MLEN_132	=	Modelled 132kV circuit length in the Common 500MW Network Model (km).
PROP_132DOHL	=	Proportion of total existing 132kV circuit length in the licence area comprised of 'tower line' (i.e. double circuit) overhead line conductor.
ELEN_132UGC	=	Total existing 132kV underground cable length in the licence area (km).
ELEN_132WPOHL	=	Total existing 132kV 'wood pole' (i.e. single circuit) overhead line circuit length in the licence area (km).
ELEN_132TLOHL	=	Total existing 132kV 'tower line' (i.e. double circuit) overhead line circuit length in the licence area (km).

The derivation of the various types of 132kV circuit lengths above is based on the proportions obtained from the installed asset profiles. These proportions may be adjusted to reflect current practice and experience. This, for example, may be based on the preference for the construction of underground circuits in light of the difficulty sometimes associated with obtaining consent for the construction of overhead circuits. If this approach is adopted:

- the modelled MPROP_132UGC shall replace the calculated PROP_132UGC,
- the modelled MPROP_132SOHL shall replace the calculated PROP_132SOHL, and
- the modelled MPROP_132DOHL shall replace the calculated PROP_132DOHL.

In such a case, the following equality must be maintained:

$$MPROP\_132UGC + MPROP\_132SOHL + MPROP\_132DOHL = 1$$ **…Equ. 50**

where:

MPROP_132UGC	=	Modelled proportion of modelled 132kV circuit length comprised of underground cable in the Common 500MW Network Model.
MPROP_132SOHL	=	Modelled proportion of modelled 132kV circuit length comprised of single circuit overhead line in the Common 500MW Network Model.
MPROP_132DOHL	=	Modelled proportion of modelled 132kV circuit length comprised of double circuit overhead line in the Common 500MW Network Model.

7.2. Circuit Lengths at the EHV Circuit Network Level

The total EHV circuit length in the Common 500MW Network Model is calculated in two steps. Firstly, the EHV circuit length per unit of firm capacity at the EHV/HV Transformation Network Level in the existing network is determined as:

$$LEN\_EHVPERFC = \frac{ELEN\_EHV}{EFC\_EHV/HV + \sum_{1}^{h} MIC\_EHVSITE}$$ **…Equ. 51**

where:

LEN_EHVPERFC	=	EHV circuit length per unit of firm capacity at the EHV/HV Transformation Network Level in the existing network (km/MVA).
ELEN_EHV	=	Total existing EHV circuit length in the licence area (km).
EFC_EHV/HV	=	Total Existing Firm Capacity of EHV/HV substations in the licence area (MVA).
MIC_EHVSITE	=	Maximum import capacity of EHV-connected demand site (MVA). The import connections of Merchant Generators are ignored.
h	=	Number of EHV-connected demand sites in the licence area. The import connections of Merchant Generators are ignored.

In the second step, the modelled EHV circuit length in the Common 500MW Network Model is:

$$MLEN\_EHV = LEN\_EHVPERFC * MFC\_EHV/HV$$ **…Equ. 52**

where:

MLEN_EHV	=	Modelled EHV circuit length (km).
LEN_EHVPERFC	=	EHV circuit length per unit of firm capacity in the Common 500MW Network Model at the EHV/HV Transformation Network Level (km/MVA).
MFC_EHV/HV	=	Modelled Firm Capacity at the EHV/HV Transformation Network Level in the Common 500MW Network Model (MVA).

7.2.1 Modelled EHV Circuit Lengths by Conductor Type

The following conductor categories are specified for EHV circuits in the Common 500MW Network Model:

- underground circuit,
- overhead single circuit (this is assumed to be equivalent to EHV 'wood pole' construction as identified in the RRP), and
- overhead double circuit (this is assumed to be equivalent to EHV 'tower line' construction as identified in the RRP).

The modelled EHV underground cable length in the Common 500MW Network Model:

$$MLEN\_EHVUGC = MLENEHV * PROP\_EHVUGC$$ **…Equ. 53**

where:

$$PROP\_EHVUGC = \frac{ELEN\_EHVUGC}{ELEN\_EHVUGC + ELEN\_EHVWPOHL + ELEN\_EHVTLOHL} \quad \text{...Equ. 54}$$

where:

MLEN_EHVUGC	=	Modelled EHV underground cable length in the Common 500MW Network Model (km).
MLEN_EHV	=	Modelled EHV circuit length in the Common 500MW Network Model (km).
PROP_EHVUGC	=	Proportion of total existing EHV circuit length in the licence area comprised of underground cable.
ELEN_EHVUGC	=	Total existing EHV underground cable length in the licence area (km).
ELEN_EHVWPOHL	=	Total existing EHV 'wood pole' (i.e. single circuit) overhead line circuit length in the licence area (km).
ELEN_EHVTLOHL	=	Total existing EHV 'tower line' (i.e. double circuit) overhead line circuit length in the licence area (km).

The modelled EHV single overhead line circuit length in the Common 500MW Network Model is:

$$MLEN\_EHVSOHL = MLENEHV * PROP\_EHVSOHL \quad \text{...Equ. 55}$$

where:

$$PROP\_EHVSOHL = \frac{ELEN\_EHVWPOHL}{ELEN\_EHVUGC + ELEN\_EHVWPOHL + ELEN\_EHVTLOHL} \quad \text{...Equ. 56}$$

where:

MLEN_EHVSOHL	=	Modelled EHV single overhead line circuit length in the Common 500MW Network Model (km).
MLEN_EHV	=	Modelled EHV circuit length in the Common 500MW Network Model (km).
PROP_EHVSOHL	=	Proportion of total existing EHV circuit length in the licence area comprised of 'wood pole' (i.e. single circuit) overhead line conductor.
ELEN_EHVUGC	=	Total existing EHV underground cable length in the licence area (km).
ELEN_EHVWPOHL	=	Total existing EHV 'wood pole' (i.e. single circuit) overhead line circuit length in the licence area (km).
ELEN_EHVTLOHL	=	Total existing EHV 'tower line' (i.e. double circuit) overhead line circuit length in the licence area (km).

The modelled EHV double overhead line circuit length (i.e. tower route length) in the Common 500MW Network Model is calculated as:

$$MLEN\_EHVDOHL = \frac{MLENEHV * PROP\_EHVDOHL}{2} \quad \text{...Equ. 57}$$

where:

$$PROP\_EHVDOHL = \frac{ELEN\_EHVTLOHL}{ELEN\_EHVUGC + ELEN\_EHVWPOHL + ELEN\_EHVTLOHL} \quad \text{...Equ. 58}$$

where:

MLEN_EHVDOHL	=	Modelled EHV double overhead line route length in the Common 500MW Network Model (km).

MLEN_EHV	=	Modelled EHV circuit length in the Common 500MW Network Model (km).
PROP_EHVDOHL	=	Proportion of total existing EHV circuit length in the licence area comprised of 'tower line' (i.e. double circuit) overhead line conductor.
ELEN_EHVUGC	=	Total existing EHV underground cable length in the licence area (km).
ELEN_EHVWPOHL	=	Total existing EHV 'wood pole' (i.e. single circuit) overhead line circuit length in the licence area (km).
ELEN_EHVTLOHL	=	Total existing EHV 'tower line' (i.e. double circuit) overhead line circuit length in the licence area (km).

The derivation of the various types of EHV circuit lengths above is based on the proportions obtained from the installed asset profiles. These proportions may be adjusted to reflect current practice and experience. This, for example, may be based on the preference for the construction of underground circuits in light of the difficulty sometimes associated with obtaining consent for the construction of overhead circuits. If this approach is adopted:

- the modelled MPROP_EHVUGC shall replace the calculated PROP_EHVUGC,
- the modelled MPROP_EHVSOHL shall replace the calculated PROP_EHVSOHL, and
- the modelled MPROP_EHVDOHL shall replace the calculated PROP_EHVDOHL.

In such a case, the following equality must be maintained:

$$MPROP\_EHVUGC + MPROP\_EHVSOHL + MPROP\_EHVDOHL = 1$$ **…Equ. 59**

where:

MPROP_EHVUGC	=	Modelled proportion of modelled EHV circuit length comprised of underground cable in the Common 500MW Network Model.
MPROP_EHVSOHL	=	Modelled proportion of modelled EHV circuit length comprised of single circuit overhead line in the Common 500MW Network Model.
MPROP_EHVDOHL	=	Modelled proportion of modelled EHV circuit length comprised of double circuit overhead line in the Common 500MW Network Model.

7.3. Circuit Lengths at the HV Circuit Network Level

The types of HV circuits in the DNO's existing network, as defined in the "Network Disaggregation Workbook"[1] detailed in APPENDIX 1 , will be used to determine the required volumes of HV network level switchgear and automation components used in the Common 500MW Network Model. This data shall also be used to determine the total length of existing underground and overhead HV circuit in each licence area.

[1] The "Network Disaggregation Workbook" is compiled annually by all DNOs in a format prescribed by Ofgem for price control incentive assessments. These circuit types are classified according to a number of parameters such as the percentage of overhead line, number of connected customers and length. This classification is shown in APPENDIX 1

7.3.1 Proportions of HV Underground Cable Construction Types

The installation of HV underground cable for a network extension typically involves 'excavate-and-lay' and 'lay-only' construction. The distinction is made between the two since a significant proportion of all network extensions are carried out on new development sites where the excavation is normally undertaken by the developer. As DNOs do not incur trenching costs in these instances the Common 500MW Network Model must account for this as it is based on only those costs DNOs bear. The proportions of these two types of cable installation are inputs to the Common 500MW Network Model and therefore DNOs must estimate the proportion of HV cable installed by each method, for network extensions in the recent past, up to 5 years ago.

The following equality must be satisfied:

$$PROP\_HVUGCEL + PROP\_HVUGCLO = 1$$ **…Equ. 60**

where:

PROP_HVUGCEL = Average proportion of total HV underground cable installation involving 'excavate-and-lay' construction up to 5 years ago.

PROP_HVUGCLO = Average proportion of total HV underground cable installation involving 'lay-only' construction up to 5 years ago.

The derivation of the various types of HV circuit lengths above is based on the proportions obtained from the installed asset profiles. These proportions may be adjusted to reflect current practice and experience. This, for example, may be based on the preference for the construction of underground circuits in light of the difficulty sometimes associated with obtaining consent for the construction of overhead circuits. If this approach is adopted:

- the modelled MPROP_HVUGCEL shall replace the calculated PROP_HVUGCEL, and
- the modelled MPROP_HVUGCLO shall replace the calculated PROP_HVUGCLO.

In such a case, the following equality must be maintained:

$$MPROP\_HVUGCEL + MPROP\_HVUGCLO = 1$$ **…Equ. 61**

where:

MPROP_HVUGCEL = Modelled proportion of total HV underground cable installation involving 'excavate-and-lay' construction in the Common 500MW Network Model.

MPROP_HVUGCLO = Modelled proportion of total HV underground cable installation involving 'lay-only' construction in the Common 500MW Network Model.

7.3.2 Modelled HV Circuit Lengths by Circuit Type

The following conductor categories are specified for HV circuits in the Common 500MW Network Model:

- overhead circuit,
- underground circuit involving ‘excavate-and-lay’ construction, and
- underground circuit involving ‘lay-only’ construction.

The total HV circuit length in the Common 500MW Network Model is calculated in two steps. Firstly, the HV circuit length per unit of firm capacity at the TR/HV, EHV/HV and 132/HV Transformation Network Levels in the existing network is determined as:

$$LEN\_HVPERFC = \frac{ELEN\_HV}{EFC\_TR/HV + EFC\_EHV/HV + EFC\_132/HV}$$ **…Equ. 62**

where:

LEN_HVPERFC	=	HV circuit length per unit of firm capacity at the TR/HV, EHV/HV and 132/HV Transformation Network Levels in the existing network (km/MVA).
ELEN_HV	=	Total existing HV circuit length in the licence area (km).
EFC_TR/HV	=	Total Existing Firm Capacity of TR/HV substations in the licence area (MVA).
EFC_EHV/HV	=	Total Existing Firm Capacity of EHV/HV substations in the licence area (MVA).
EFC_132/HV	=	Total Existing Firm Capacity of 132/HV substations in the licence area (MVA).

In the second step, the modelled HV circuit length in the Common 500MW Network Model is calculated by:

$$MLEN\_HV = LEN\_HVPERFC * (MFC\_TR/HV + MFC\_EHV/HV + MFC\_132/HV)$$ **…Equ. 63**

where:

MLEN_HV	=	Total modelled HV circuit length in the Common 500MW Network Model (km).
LEN_HVPERFC	=	HV circuit length per unit of firm capacity at the TR/HV, EHV/HV and 132/HV Transformation Network Levels in the licence area (km/MVA).
MFC_TR/HV	=	Modelled Firm Capacity at the TR/HV Transformation Network Level in the Common 500MW Network Model (MVA).
MFC_EHV/HV	=	Modelled Firm Capacity at the EHV/HV Transformation Network Level in the Common 500MW Network Model (MVA).
MFC_132/HV	=	Modelled Firm Capacity at the 132/HV Transformation Network Level in the Common 500MW Network Model (MVA).

The modelled overhead line circuit length in the Common 500MW Network Model is:

$$MLEN\_HVOHL = MLEN\_HV * PROP\_HVOHL$$ **…Equ. 64**

where:

$$PROP\_HVOHL \quad = ELEN\_HVOHL \,/\, ELEN\_HV$$ **…Equ. 65**

and:

MLEN_HVOHL = Modelled HV overhead line length in the Common 500MW Network Model (km).

PROP_HVOHL = Proportion of total existing length of HV circuit in the licence area comprised of

		overhead line conductor
ELEN_HVOHL	=	Existing length of HV overhead line conductor in licence area (km).
ELEN_HV	=	Existing length of HV circuit in licence area (km).

The modelled underground cable length involving 'excavate-and-lay' construction in the Common 500MW Network Model is:

$$MLEN\_HVUGCEL = MLEN\_HV * PROP\_HVUGC * PROP\_HVUGCEL$$

…Equ. 66

The modelled underground cable length involving 'lay-only' construction in the Common 500MW Network Model is:

$$MLEN\_HVUGCLO = MLEN\_HV * PROP\_HVUGC * PROP\_HVUGCLO$$

…Equ. 67

where:

$$PROP\_ HVUGC = ELEN\_HVUGC / ELEN\_HV$$

…Equ. 68

The following equality must be satisfied:

$$PROP\_HVOHL + PROP\_HVUGC = 1$$

…Equ. 69

and:

MLEN_HVUGCEL	=	Modelled HV underground cable circuit length involving 'excavate-and-lay' construction in the Common 500MW Network Model (km).
MLEN_HVUGCLO		Modelled HV underground cable circuit length involving 'lay-only' construction in the Common 500MW Network Model (km).
PROP_HVUGC	=	Proportion of total existing length of HV circuit in the licence area comprised of underground cable
PROP_HVUGCEL	=	Average proportion of HV underground cable installation involving 'excavate-and-lay' construction experienced in licence area for new business schemes over past 5 years.
PROP_HVUGCLO	=	Average proportion of HV underground cable installation involving 'lay only' construction experienced in licence area for new business schemes over past 5 years.
ELEN_HVUGC	=	Existing length of HV underground cable conductor in licence area (km).
ELEN_HV	=	Existing length of HV circuit in licence area (km).

The derivation of the various types of HV circuit lengths above is based on the proportions obtained from the installed asset profiles. These proportions may be adjusted to reflect current practice and experience. This, for example, may be based on the preference for the construction of underground circuits in light of the difficulty sometimes associated with obtaining consent for the construction of overhead circuits. If this approach is adopted:

- the modelled MPROP_HVOHL shall replace the calculated PROP_HVOHL,
- the modelled MPROP_HVUGC shall replace the calculated PROP_HVUGC.

In such a case, the following equality must be maintained:

$$MPROP\_HVOHL + MPROP\_HVUGC = 1 \quad \text{...Equ. 70}$$

where:

MPROP_HVOHL	=	Modelled proportion of modelled HV circuit length comprised of overhead line in the Common 500MW Network Model.
MPROP_HVUGC	=	Modelled proportion of modelled HV circuit length comprised of underground cable in the Common 500MW Network Model.

7.4. Circuit Lengths at the LV Circuit Network Level

The total LV circuit length in the Common 500MW Network Model is calculated in two steps. Firstly, the LV circuit length per unit of installed capacity at the HV/LV Transformation Network Level in the existing network is determined as:

$$LEN\_LVPERIC = \frac{ELEN\_LV}{EIC\_HV/LV} \quad \text{...Equ. 71}$$

where:

LEN_LVPERIC	=	LV circuit length per unit of installed capacity at the HV/LV Transformation Network Level in the existing network (km/MVA).
ELEN_LV	=	Total existing LV circuit length in the licence area (km).
EIC_HV/LV	=	Total existing Installed Capacity of HV/LV substations in the licence area (MVA). This is the sum of the 'natural cooling' ratings of all HV/LV transformers in the licence area.

In the second step, the modelled LV circuit length in the Common 500MW Network Model is:

$$MLEN\_LV = LEN\_LVPERIC * MIC\_HV/LV \quad \text{...Equ. 72}$$

where:

MLEN_LV	=	Modelled LV circuit length in the Common 500MW Network Model (km).
LEN_LVPERIC	=	LV circuit length per unit of installed capacity at the HV/LV Transformation Network Level in the existing network (km/MVA).
MIC_HV/LV	=	Modelled Installed Capacity at the HV/LV Transformation Network Level in the Common 500MW Network Model (MVA).

7.4.1 Proportions of LV Underground Cable Construction Types

The installation of LV underground cable for a network extension typically involves 'excavate-and-lay' and 'lay-only' construction. The distinction is made between the two since a significant proportion of all network extensions are carried out on new development sites where the excavation is normally undertaken by the developer. As DNOs do not incur trenching costs in these instances the Common 500MW Network Model must account for this as it is based on only those costs DNOs bear. The proportions of these two types of cable installation are inputs to the Common 500MW Network Model and therefore DNOs must estimate the proportion of HV cable installed by each method, for network extensions in the recent past, up to 5 years ago.

The following equality must be satisfied:

$$PROP\_LVUGCEL + PROP\_LVUGCLO = 1$$ **…Equ. 73**

where:

PROP_LVUGCEL = Average proportion of total LV underground cable installation involving 'excavate-and-lay' construction.

PROP_LVUGCLO = Average proportion of total LV underground cable installation involving 'lay-only' construction.

The derivation of the various types of LV circuit lengths above is based on the proportions obtained from the installed asset profiles. These proportions may be adjusted to reflect current practice and experience. This, for example, may be based on the preference for the construction of underground circuits in light of the difficulty sometimes associated with obtaining consent for the construction of overhead circuits. If this approach is adopted:

- the modelled MPROP_LVUGCEL shall replace the calculated PROP_LVUGCEL, and
- the modelled MPROP_LVUGCLO shall replace the calculated PROP_LVUGCLO.

In such a case, the following equality must be maintained:

$$MPROP\_LVUGCEL + MPROP\_LVUGCLO = 1$$ **…Equ. 74**

where:

MPROP_LVUGCEL = Modelled proportion of total LV underground cable installation involving 'excavate-and-lay' construction in the Common 500MW Network Model.

MPROP_LVUGCLO = Modelled proportion of total LV underground cable installation involving 'lay-only' construction in the Common 500MW Network Model.

7.4.2 Modelled LV Circuit Lengths by Conductor Type

The following conductor categories are specified for LV circuits in the Common 500MW Network Model:

- overhead circuit,
- underground circuit involving 'excavate-and-lay' construction, and
- underground circuit involving 'lay-only' construction.

The modelled LV overhead line circuit length in the Common 500MW Network Model is:

$$MLEN\_LVOHL = MLEN\_LV * PROP\_LVOHL$$ **…Equ. 75**

where:

$$PROP\_LVOHL = \frac{ELEN\_LVOHL}{ELEN\_LVUGC + ELEN\_LVOHL}$$ **…Equ. 76**

where:

MLEN_LVOHL	=	Modelled LV overhead line circuit length in the Common 500MW Network Model (km).
MLEN_LV	=	Modelled LV circuit length in the Common 500MW Network Model (km).
PROP_LVOHL	=	Proportion of total existing LV circuit length in the licence area comprised of overhead line conductor.
ELEN_LVOHL	=	Total existing LV overhead line circuit length in the licence area (km).
ELEN_LVUGC	=	Total existing LV underground cable length in the licence area (km).

The proportion of total existing LV circuit length in the licence area comprised of underground cable is given by:

$$PROP\_LVUGC = \frac{ELEN\_LVUGC}{ELEN\_LVUGC + ELEN\_LVOHL}$$ **…Equ. 77**

The following equality must be satisfied:

$$PROP\_LVOHL + PROP\_LVUGC = 1$$ **…Equ. 78**

where:

PROP_LVUGC	=	Proportion of total existing LV circuit length in the licence area comprised of underground cable conductor.
PROP_LVOHL	=	Proportion of total existing LV circuit length in the licence area comprised of overhead line conductor.

The modelled LV underground cable circuit length involving ‘excavate-and-lay’ construction in the Common 500MW Network Model is:

$$MLEN\_LVUGCEL = MLEN\_LV * PROP\_LVUGC * PROP\_LVUGCEL$$ **…Equ. 79**

where:

MLEN_LVUGCEL	=	Modelled LV underground cable circuit length involving ‘excavate-and-lay’ construction in the Common 500MW Network Model (km).
MLEN_LV	=	Modelled LV circuit length in the Common 500MW Network Model (km).
PROP_LVUGC	=	Proportion of total existing LV circuit length in the licence area comprised of underground cable.
PROP_LVUGCEL	=	Average proportion of total LV underground cable installation involving ‘excavate-and-lay’ construction.

The modelled LV underground cable circuit length involving ‘lay-only’ construction in the Common 500MW Network Model is:

$$MLEN\_LVUGCLO = MLEN\_LV * PROP\_LVUGC * PROP\_LVUGCLO$$ **…Equ. 80**

where:

MLEN_LVUGCLO = Modelled LV underground cable circuit length involving 'lay-only' construction in the Common 500MW Network Model (km).
MLEN_LV = Modelled LV circuit length in the Common 500MW Network Model (km).
PROP_LVUGC = Proportion of total existing LV circuit length in the licence area comprised of underground cable.
PROP_LVUGCLO = Average proportion of total LV underground cable installation involving 'lay-only' construction.

The derivation of the various types of LV circuit lengths above is based on the proportions obtained from the installed asset profiles. These proportions may be adjusted to reflect current practice and experience. This, for example, may be based on the preference for the construction of underground circuits in light of the difficulty sometimes associated with obtaining consent for the construction of overhead circuits. If this approach is adopted:

- the modelled MPROP_LVOHL shall replace the calculated PROP_LVOHL,
- the modelled MPROP_LVUGC shall replace the calculated PROP_LVUGC.

In such a case, the following equality must be maintained:

$$MPROP\_LVOHL + MPROP\_LVUGC = 1$$ **…Equ. 81**

where:
MPROP_LVOHL = Modelled proportion of modelled LV circuit length comprised of overhead line in the Common 500MW Network Model.
MPROP_LVUGC = Modelled proportion of modelled LV circuit length comprised of underground cable in the Common 500MW Network Model.

SECTION 8. DERIVATION OF ASSET VALUES OF SUBSTATIONS

The derivation of the asset values of substations at all Transformation Network Levels in the Common 500MW Network Model is described in this section. The components that should be considered and included in the costing of each defined substation configuration or on circuits is presented in Appendix 2.

It should be noted that building/civil costs should be apportioned between the transformation and associated lower network voltage level. For example at an 11 kV primary substation which has a ten panel 11kV switchboard, possibly 70% of switchroom costs should be allocated to the 11 kV network level and 30% to the transformation level. The 30% would account for room accommodated by the two 11kV transformer circuit breakers and bus-section.

8.1. Modelled Asset Values of TR/132 (GSP) Substations

The asset value relevant to the Common 500MW Network Model of a given GSP substation configuration is composed of the values of only those assets within the substation compound typically owned by DNOs. This asset value is allocated to the 132kV Circuit Network Level and is calculated by:

$$AV\_TR/132SUB_j = AV\_TR/132_j\_AT\_TR + AV\_TR/132_j\_AT\_132 \quad \text{...Equ. 82}$$

where:

$AV\_TR/132SUB_j$	=	Asset value associated with TR/132 substation configuration j (£).
$AV\_TR/132_j\_AT\_TR$	=	Asset value associated with TR/132 substation configuration j of assets owned by the GB Transmission network operator (£). These costs are ignored in the Common 500MW Network Model.
$AV\_TR/132_j\_AT\_132$	=	Asset value associated with TR/132 substation configuration j allocated to the 132kV Circuit Network Level (£).

The allocation of asset values to Network Levels for a given TR/132 (GSP) substation is presented diagrammatically in

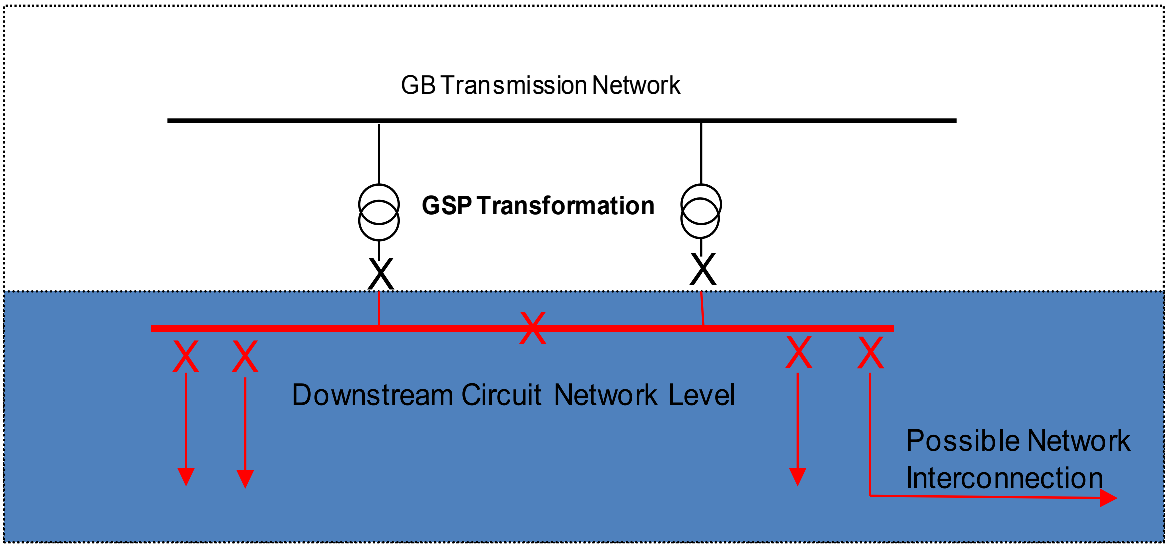

Figure 5 below. This allocation is valid for all types of GSP substations.

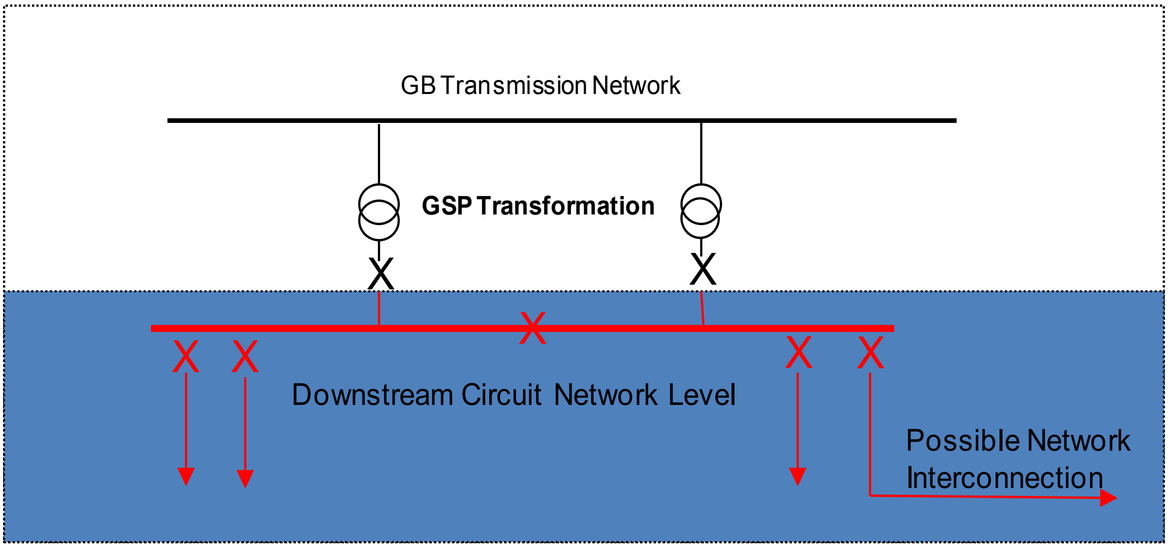

Figure 5 - Allocation of Asset Values to Network Levels at a TR/132 Substation

Since the asset value of assets owned by the GB Transmission network operator is ignored within the Common 500MW Network Model, the Modelled Asset Value of all TR/132 substations within the Common 500MW Network Model is simply:

$$MAV\_TR/132SUB = MAV\_TR/132SUB\_AT\_132 \qquad \text{...Equ. 83}$$

where:

$$MAV\_TR/132SUB\_AT\_132 = \sum_{1}^{j} n_j . AV\_TR/132_j\_AT\_132 \qquad \text{...Equ. 84}$$

where:

MAV_TR/132SUB = Modelled Asset Value of all TR/132 substations in the Common 500MW Network Model (£).

MAV _TR/132SUB_AT_132	=	Modelled Asset Value of all TR/132 substations within the Common 500MW Network Model assets allocated to the 132kV Circuit Network Level (£).
$AV\_TR/132_j\_AT\_132$	=	Asset value associated with TR/132 substation configuration *j* allocated to the 132kV Circuit Network Level (£).
n_j	=	Number of type *j* GSP substations.

8.2. Modelled Asset Values of TR/EHV (GSP) Substations

The asset value relevant to the Common 500MW Network Model of a given TR/EHV substation configuration is composed of the values of only those assets within the substation compound typically owned by DNOs. This asset value is allocated to the EHV Circuit Network Level and is calculated by:

$$AV\_TR/EHVSUB_j = AV\_TR/EHVj\_AT\_TR + AV\_TR/EHVj\_AT\_EHV \quad \textbf{...Equ. 85}$$

where:

$AV\_TR/EHVSUB_j$	=	Asset value associated with TR/EHV substation configuration *j* (£).
$AV\_TR/EHVj\_AT\_TR$	=	Asset value associated with TR/EHV substation configuration *j* of assets owned by the GB Transmission network operator (£). These costs are ignored in the Common 500MW Network Model.
$AV\_TR/EHVj\_AT\_EHV$ AV_	=	Asset value associated with TR/EHV substation configuration *j* allocated to the EHV Circuit Network Level (£).

Since the asset value of assets owned by the GB Transmission network operator is ignored within the Common 500MW Network Model, the Modelled Asset Value of all TR/EHV substations within the Common 500MW Network Model is simply:

$$MAV\_TR/EHVSUB = MAV\_TR/EHV\_AT\_EHV \quad \textbf{...Equ. 86}$$

where:

$$MAV\_TR/EHV\_AT\_EHV = \sum_{1}^{j} n_j . AV\_TR/EHVj\_AT\_EHV \quad \textbf{...Equ. 87}$$

where:

MAV_TR/EHVSUB	=	Modelled Asset Value of all TR/EHV substations in the Common 500MW Network Model (£).
MAV_TR/EHV_AT_EHVAV	=	Modelled Asset Value of all TR/EHV substations within the Common 500MW Network Model assets allocated to the EHV Circuit Network Level (£).
AV_TR/ EHVj_AT_EHVAV_EHV_AT_T R/EHV	=	Asset value associated with TR/EHV substation configuration *j* allocated to the EHV Circuit Network Level (£).
n_j	=	Number of type *j* TR/EHV substations.

8.3. Modelled Asset Values of TR/HV (GSP) Substations

The asset value relevant to the Common 500MW Network Model of a given TR/HV substation configuration is composed of the values of only those assets within the substation compound typically owned by DNOs. This asset value is allocated to the HV Circuit Network Level and is calculated by:

$$AV\_TR/HVSUB_j = \mathrm{AV\_\ TR/HVj\ \_AT\_TR} + \mathrm{AV\_\ TR/HVj\ \_AT\_HV} \quad \textbf{...Equ. 88}$$

where:

$AV\_TR/HVSUB_j$	=	Asset value associated with TR/HV substation configuration *j* (£).
$AV\_\ TR/HV_j\ \_AT\_TR$	=	Asset value associated with TR/HV substation configuration *j* of assets owned by the GB Transmission network operator (£). These costs are ignored in the Common 500MW Network Model.
$AV\_\ TR/HV_j\ \_AT\_HV$	=	Asset value associated with TR/HV substation configuration *j* allocated to the HV Circuit Network Level (£).

Since the asset value of assets owned by the GB Transmission network operator is ignored within the Common 500MW Network Model, the Modelled Asset Value of all TR/HV substations within the Common 500MW Network Model is simply:

$$MAV\_TR/HVSUB = MAV\mathrm{\_TR/HV\ \_AT\_HV} \quad \textbf{...Equ. 89}$$

where:

$$MAV\mathrm{\_TR/HV\ \_AT\_HV} = \sum_{1}^{j} n_j . \mathrm{AV\_TR/HVj\ \_AT\_HV} \quad \textbf{...Equ. 90}$$

where:

MAV_TR/HVSUB	=	Modelled Asset Value of all TR/HV substations in the Common 500MW Network Model (£).
MAV_TR/ HV _AT_HVHV_AT_TR/HVS UB	=	Modelled Asset Value of all TR/HV substations within the Common 500MW Network Model assets allocated to the HV Circuit Network Level (£).
AV_TR/ HVj _AT_HVHV_AT_TR/HV	=	Asset value associated with TR/HV substation configuration *j* allocated to the HV Circuit Network Level (£).
n_j	=	Number of type *j* TR/HV substations.

8.4. Modelled Asset Values of 132/EHV Substations

The asset value of a given 132/EHV substation configuration is composed of the values of assets that are allocated to multiple (132/EHV and EHV) Transformation Network Levels. This is represented as:

$$AV\_132/EHVSUB_j = AV\_132/EHVj\_AT\_132/EHV + AV\_132/EHVj\ \_AT\_EHV \quad \textbf{...Equ. 91}$$

where:

$AV\_132/EHVSUB_j$	=	Asset value associated with 132/EHV substation configuration *j* (£). This may be a single- or multi-transformer substation.

$AV\_132/EHV_j\_AT\_132/EHV$	=	Asset value associated with 132/EHV substation configuration j allocated to the 132/EHV Transformation Network Level (£).
$AV\_132/EHV_j\_AT\_EHV$	=	Asset value associated with 132/EHV substation configuration j allocated to the EHV Circuit Network Level (£).

The allocation of asset values to Network Levels for a given 132/EHV substation is presented diagrammatically in

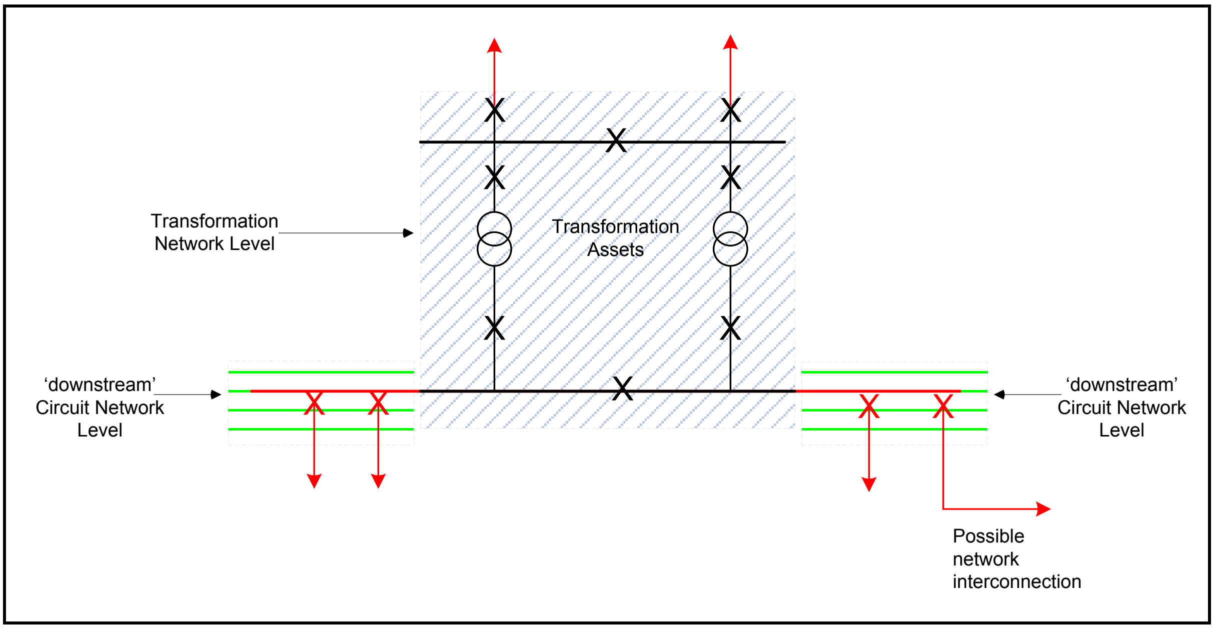

Figure 6 below. This allocation is also valid for 132/HV and EHV/HV substations.

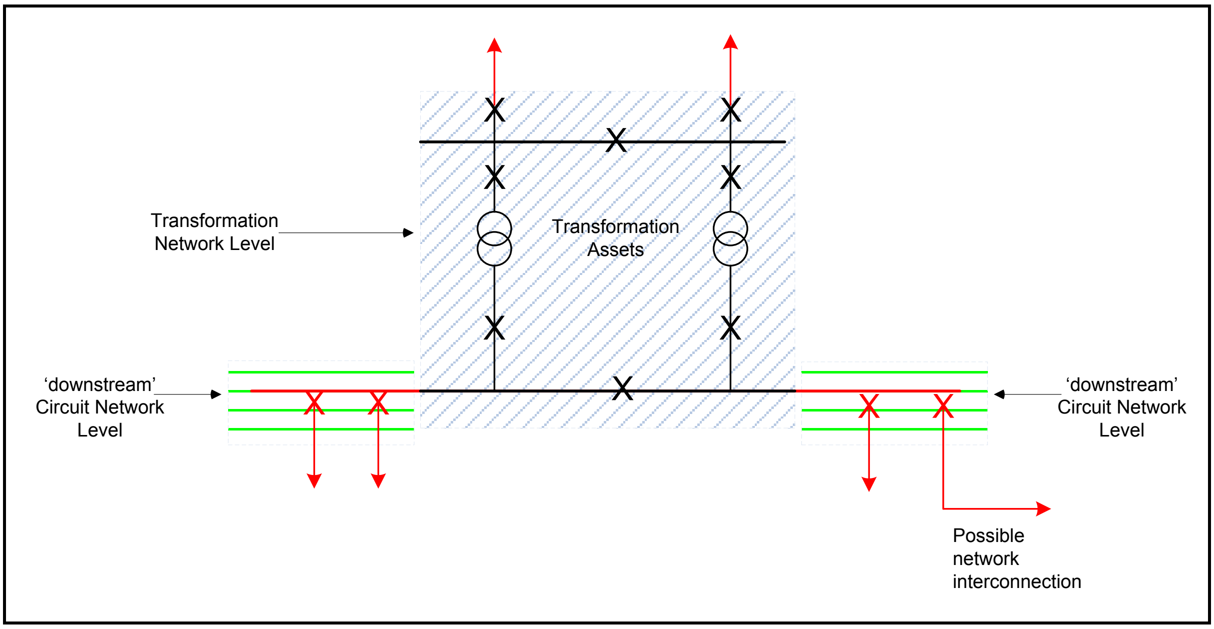

Figure 6 - Allocation of Asset Values to Network Levels at a 132/EHV Substation

The Modelled Asset Value of all 132/EHV substations within the Common 500MW Network Model is:

$$MAV\_132/EHVSUB = MAV\_132/EHV\_AT\_132/EHVSUB + MAV\_132/EHV\_AT\_EHV \quad \text{...Equ. 92}$$

where:

$$MAV\_132/EHV\_AT\_132/EHVSUB = \sum_{1}^{j} n_j . AV\_132/EHVj\_AT\_132/EHV \quad \text{...Equ. 93}$$

and:

$$MAV\_132/EHV\_AT\_EHV = \sum_{1}^{j} n_j . AV\_132/EHVj\_AT\_EHV \quad \text{...Equ. 94}$$

where:

MAV_132/EHVSUB	=	Modelled Asset Value of all 132/EHV substations in the Common 500MW Network Model (£).
MAV_132/EHV_AT_132/EHVSUB	=	Modelled Asset Value of all 132/EHV substations within the Common 500MW Network Model assets allocated to the 132/EHV Transformation Network Level (£).
MAV_132/EHV _AT_EHV	=	Modelled Asset Value of all 132/EHV substations within the Common 500MW Network Model assets allocated to the EHV Circuit Network Level (£).
AV_132/EHVj_AT_132/EHV	=	Asset value associated with 132/EHV substation configuration *j* allocated to the 132/EHV Transformation Network Level (£).
AV_132/EHV _AT_EHV	=	Asset value associated with 132/EHV substation configuration *j* allocated to the EHV Circuit Network Level (£).
n_j	=	Number of type *j* 132/EHV single- or multi-transformer substations.

8.5. Modelled Asset Values of 132/HV Substations

The asset value of a given 132/HV substation configuration is composed of the values of assets that are allocated to multiple (132/HV and HV) Transformation Network Levels. This is represented as:

$$AV\_132/HVSUB_j = AV\_132/HVSUBj\_AT\_132/HV + AV\_132/HVSUBj\_AT\_HV \quad \text{...Equ. 95}$$

where:

$AV\_132/HVSUB_j$	=	Asset value associated with 132/HV substation configuration *j* (£). This may be a single- or multi-transformer substation.
$AV\_132/\ HV_j\ \_AT\_132/HV$	=	Asset value associated with 132/HV substation configuration *j* allocated to the 132/HV Transformation Network Level (£).
$AV\_132/HV_j\_AT\_HV$	=	Asset value associated with 132/HV substation configuration *j* allocated to the HV Circuit Network Level (£).

The Modelled Asset Value of all 132/HV substations within the Common 500MW Network Model is:

$$MAV\_132/HVSUB = MAV\_132/HV\_AT\_132/HVSUB + MAV\_132/HV\_AT\_HV \quad \text{...Equ. 96}$$

where:

$$MAV\_132/HV\_AT\_132/HVSUB = \sum_{1}^{j} n_j.AV\_132/HVj\_AT\_132/HV$$ **…Equ. 97**

and:

$$MAV\_132/HV\_AT\_HV = \sum_{1}^{j} n_j.AV\_132/HVj\_AT\_HV$$ **…Equ. 98**

where:

MAV_132/HVSUB	=	Modelled Asset Value of all 132/HV substations in the Common 500MW Network Model (£).
MAV_132/HV_AT_132/HVSUB	=	Modelled Asset Value of all 132/HV substations within the Common 500MW Network Model assets allocated to the 132/HV Transformation Network Level (£).
MAV_132/HV_AT_HV	=	Modelled Asset Value of all 132/HV substations within the Common 500MW Network Model assets allocated to the HV Circuit Network Level (£) excluding HV source circuit breakers.
AV_132/HVj_AT_132/HVSUB	=	Asset value associated with 132/HV substation configuration *j* allocated to the 132/HV Transformation Network Level (£).
AV_132/HVj_AT_HV	=	Asset value associated with 132/HV substation configuration *j* allocated to the HV Circuit Network Level (£).
n_j	=	Number of type *j* 132/HV single- or multi-transformer substations.

8.6. Modelled Asset Values of EHV/HV Substations

The asset value of a given EHV/HV substation configuration is composed of the values of assets that are allocated to multiple (EHV/HV and HV) Transformation Network Levels. This is represented as:

$$AV\_EHV/HVSUB_j = AV\_EHV/HVj\_AT\_EHV/HV + AV\_EHV/HVj\_AT\_HV$$ **…Equ. 99**

where:

$AV\_EHV/HVSUB_j$	=	Asset value associated with EHV/HV substation configuration *j* (£). This may be a single- or multi-transformer substation.
AV_EHV/HVj_AT_EHV/HV	=	Asset value associated with EHV/HV substation configuration *j* allocated to the EHV/HV Transformation Network Level (£).
AV_EHV/HVj_AT_HV	=	Asset value associated with EHV/HV substation configuration *j* allocated to the HV Circuit Network Level (£).

The Modelled Asset Value of all EHV/HV substations within the Common 500MW Network Model is:

$$MAV\_EHV/HVSUB = MAV\_EHV/HVj\_AT\_EHV/HVSUB + MAV\_EHV/HVj\_AT\_HV$$ **…Equ. 100**

where:

$$MAV\_EHV/HV\_AT\_EHV/HVSUB = \sum_{1}^{j} n_j.AV\_EHV/HVj\_AT\_EHV/HV$$ **…Equ. 101**

and:

$$MAV\_EHV/HVj\_AT\_HV = \sum_{1}^{j} n_j . AV\_EHV/HVj\_AT\_HV$$ **…Equ. 102**

where:

MAV_EHV/HVSUB	=	Modelled Asset Value of all EHV/HV substations in the Common 500MW Network Model (£).
MAV_EHV/HV_AT_EHV/EHVSUB	=	Modelled Asset Value of all EHV/HV substations within the Common 500MW Network Model assets allocated to the EHV/HV Transformation Network Level (£).
MAV_EHV/HV_AT_HV	=	Modelled Asset Value of all EHV/HV substations within the Common 500MW Network Model assets allocated to the HV Circuit Network Level (£) excluding HV source circuit breakers.
AV_EHV/HVj_AT_EHV/HV	=	Asset value associated with EHV/HV substation configuration *j* allocated to the EHV/HV Transformation Network Level (£).
AV_EHV/HVj_AT_HV	=	Asset value associated with EHV/HV substation configuration *j* allocated to the HV Circuit Network Level (£).
n_j	=	Number of type *j* EHV/HV single- or multi-transformer substations.

8.7. Modelled Asset Values of HV/LV Substations

The asset value of a given HV/LV substation configuration is composed of the values of assets that are allocated to multiple (HV/LV and LV) Transformation Network Levels.

For ground mounted HV/LV transformers, this is represented as:

$$AV\_HV/LVGMSUB_j = AV\_HV/LVGMj\_AT\_HV/LV + AV\_\mathrm{HV}/LVGMj\_AT\_LV$$ **…Equ. 103**

where:

$AV\_HV/LVGMSUB_j$	=	Asset value associated with HV/LV ground mounted substation configuration *j* (£).
AV_HV/LVGMj_AT_HV/LV	=	Asset value associated with HV/LV ground mounted substation configuration *j* allocated to the HV/LV Transformation Network Level (£).
AV_HV/LVGMj_AT_LV	=	Asset value associated with HV/LV ground mounted substation configuration *j* allocated to the LV Circuit Network Level (£).

For pole mounted HV/LV transformers, this is represented as:

$$AV\_HV/LVPMSUB_j = AV\_HV/LVPMj\_AT\_HV/LV + AV\_\mathrm{HV}/LVPMj\_AT\_LV$$ **…Equ. 104**

where:

$AV\_HV/LVPMSUB_j$	=	Asset value associated with HV/LV pole mounted substation configuration *j* (£).
AV_HV/LVPMj_AT_HV/LV	=	Asset value associated with HV/LV pole mounted substation configuration *j* allocated to the HV/LV Transformation Network Level (£).
AV_HV/LVPMj_AT_ LV	=	Asset value associated with HV/LV pole mounted substation configuration *j* allocated to the LV Circuit Network Level (£).

The allocation of asset values to Network Levels for given HV/LV ground mounted and pole mounded substations are presented diagrammatically in

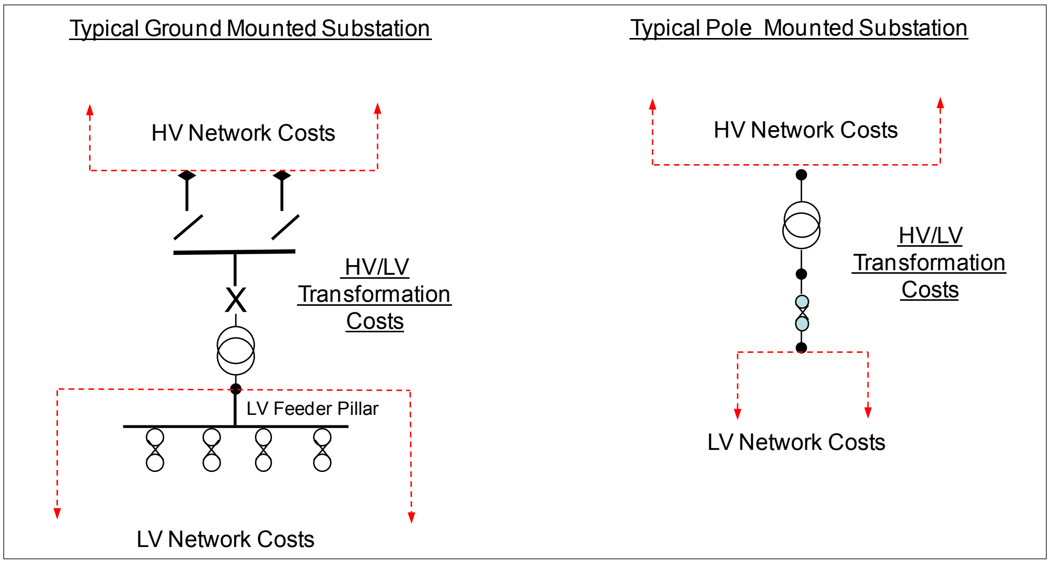

Figure 7 below.

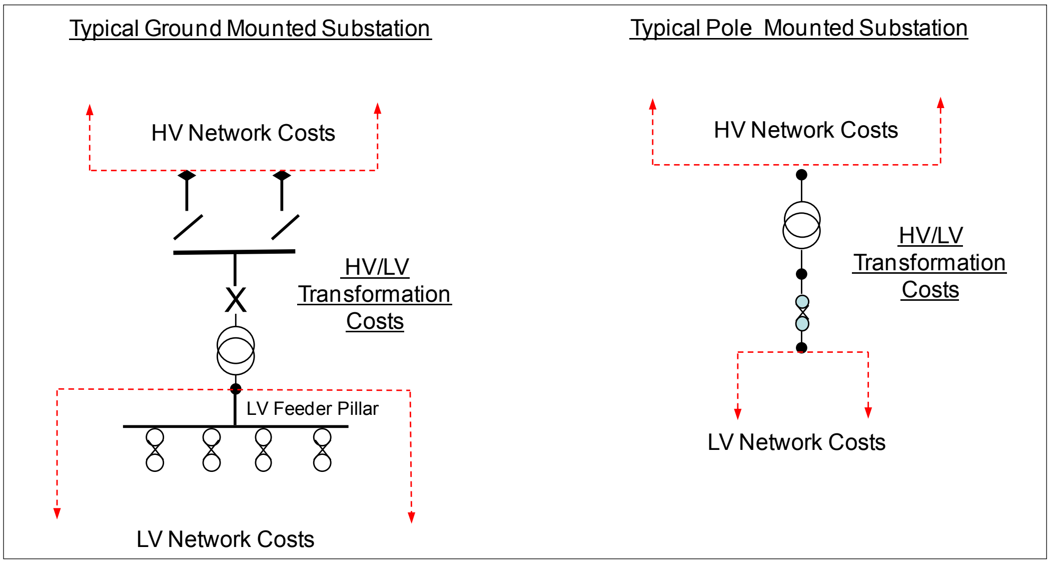

Figure 7 - Allocation of Asset Values to Network Levels at a HV/LV Substation

The Modelled Asset Value of all HV/LV ground mounted substations within the Common 500MW Network Model is:

$$MAV\_HV/LVSUB\_GM = MAV\_HV/LV\_AT\_HV/LVSUB\_GM + MAV\_LV\_AT\_HV/LVSUB\_GM \quad \text{...Equ. 105}$$

where:

$$MAV\_HV/LV\_AT\_HV/LVSUB\_GM = \sum_{1}^{j} n_j . AV\_HV/LVGMj\_AT\_HV/LV \quad \text{...Equ. 106}$$

and:

$$MAV\_LV\_AT\_HV/LVSUB\_GM = \sum_{1}^{j} n_j . AV\_\mathrm{HV}/LVGMj\_AT\_LV$$ **…Equ. 107**

where:

MAV_HV/LVSUB_GM	=	Modelled Asset Value of all HV/LV ground mounted substations in the Common 500MW Network Model (£).
MAV_HV/LV_AT_HV/LVSUB_GM	=	Modelled Asset Value of all HV/LV ground mounted substations within the Common 500MW Network Model assets allocated to the HV/LV Transformation Network Level (£).
MAV_LV_AT_HV/LVSUB_GM	=	Modelled Asset Value of all HV/LV ground mounted substations within the Common 500MW Network Model assets allocated to the LV Circuit Network Level (£).
AV_HV/LVGMj_AT_HV/LV	=	Asset value associated with HV/LV ground mounted substation configuration *j* allocated to the HV/LV Transformation Network Level (£).
AV_HV/LVGMj_AT_ LV	=	Asset value associated with HV/LV ground mounted substation configuration *j* allocated to the LV Circuit Network Level (£).
n_j	=	Number of type *j* HV/LV ground mounted substations.

The Modelled Asset Value of all HV/LV pole mounted substations within the Common 500MW Network Model is:

$$MAV\_HV/LVSUB\_PM = MAV\_HV/LV\_AT\_HV/LVSUB\_PM + MAV\_LV\_AT\_HV/LVSUB\_PM$$ **…Equ. 108**

where:

$$MAV\_HV/LV\_AT\_HV/LVSUB\_PM = \sum_{1}^{j} n_j . AV\_HV/LVPMj\_AT\_HV/LV$$ **…Equ. 109**

and:

$$MAV\_LV\_AT\_HV/LVSUB\_PM = \sum_{1}^{j} n_j . AV\_\mathrm{HV}/LVPMj\_AT\_LV$$ **…Equ. 110**

where:

MAV_HV/LVSUB_PM	=	Modelled Asset Value of all HV/LV pole mounted substations in the Common 500MW Network Model (£).
MAV_HV/LV_AT_HV/LVSUB_PM	=	Modelled Asset Value of all HV/LV pole mounted substations within the Common 500MW Network Model assets allocated to the HV/LV Transformation Network Level (£).
MAV_LV_AT_HV/LVSUB_PM	=	Modelled Asset Value of all HV/LV pole mounted substations within the Common 500MW Network Model assets allocated to the LV Circuit Network Level (£).
AV_HV/LVPMj_AT_HV/LV	=	Asset value associated with HV/LV pole mounted substation configuration *j* allocated to the HV/LV Transformation Network Level (£).
AV_HV/LVPMj_AT_ LV	=	Asset value associated with HV/LV pole mounted substation configuration *j* allocated to the LV Circuit Network Level (£).
n_j	=	Number of type *j* HV/LV pole mounted substations.

Therefore

$$MAV\_HV/LV\_AT\_HV/LVSUB$$
$$= MAV\_HV/LV\_AT\_HV/LVSUB\_GM$$
$$+ MAV\_HV/LV\_AT\_HV/LVSUB\_PM \quad \text{...Equ. 111}$$

$$MAV\_LV\_AT\_HV/LVSUB$$
$$= MAV\_LV\_AT\_HV/LVSUB\_GM + MAV\_LV\_AT\_HV/LVSUB\_PM$$

and

$$MAV\_HV/LVSUB = MAV\_HV/LV\_AT\_HV/LVSUB + MAV\_LV\_AT\_HV/LVSUB$$

where:

MAV_HV/LV_AT_HV/LVSUB	=	Modelled Asset Value of all HV/LV substations within the Common 500MW Network Model assets allocated to the HV/LV Transformation Network Level (£).
MAV_LV_AT_HV/LVSUB	=	Modelled Asset Value of all HV/LV substations within the Common 500MW Network Model assets allocated to the LV Circuit Network Level (£).
MAV_HV/LVSUB	=	Modelled Asset Value of all HV/LV substations in the Common 500MW Network Model (£).

SECTION 9. DERIVATION OF ASSET VALUES OF CIRCUITS

The derivation of the asset values of circuits at all Circuit Network Levels in the Common 500MW Network Model is described in this section. The components that should be considered and included in the costing of each defined substation configuration or on circuits is presented in Appendix 2.

9.1. Modelled Asset Values of 132kV Circuits

The Modelled Asset Value of the modelled lengths of all 132kV circuit types in the Common 500MW Network Model is derived from the asset value of the modelled length of each circuit type:

- underground circuit,
- overhead line single circuit, and
- overhead line double circuit.

The circuit components considered for the derivation of the Modelled Asset Value of 132kV circuits is presented diagrammatically in Figure 8 below. This is also valid for EHV circuits.

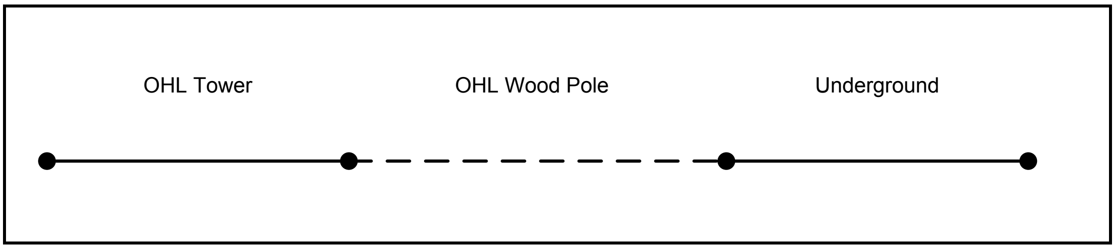

Figure 8 - 132kV Circuit Types

9.1.1 Asset Values of 132kV Circuit Components

The asset value of the modelled length of 132kV underground cable in the Common 500MW Network Model is:

$$AV\_132UGC = MLEN\_132UGC * UC\_132UGC$$ **…Equ. 112**

where:

AV_132UGC = Asset value of the modelled length of 132kV underground cable in the Common 500MW Network Model (£).

MLEN_132UGC = Modelled 132kV underground cable length in the Common 500MW Network Model (km).

UC_132UGC = Unit cost of the installation of 132kV underground cable (£/km).

The asset value of the modelled length of 132kV single overhead line circuit in the Common 500MW Network Model is:

$$AV\_132SOHL = MLEN\_132SOHL * UC\_132SOHL$$ **…Equ. 113**

where:

AV_132SOHL	=	Asset value of the modelled length of 132kV single overhead line circuit in the Common 500MW Network Model (£).
MLEN_132SOHL	=	Modelled 132kV single overhead line circuit length in the Common 500MW Network Model (km).
UC_132SOHL	=	Unit cost of the installation of 132kV single overhead line circuit (£/km).

The asset value of the modelled length of 132kV double overhead line circuit in the Common 500MW Network Model is:

$$AV\_132DOHL = MLEN\_132DOHL * UC\_132DOHL$$ **…Equ. 114**

where:

AV_132DOHL	=	Asset value of the modelled length of 132kV double overhead line circuit in the Common 500MW Network Model (£).
MLEN_132DOHL	=	Modelled 132kV double overhead line route length in the Common 500MW Network Model (km).
UC_132DOHL	=	Unit cost of the installation of 132kV double overhead line circuit (£/route km).

9.1.2 Modelled Asset Value of 132kV Circuits

The Modelled Asset Value of the modelled lengths of all types of 132kV circuits in the Common 500MW Network Model is:

$$MAV\_132CIRC = AV\_132UGC + AV\_132SOHL + AV\_132DOHL$$ **…Equ. 115**

where:

MAV_132CIRC	=	Modelled Asset Value of the modelled lengths of all types of 132kV circuits in the Common 500MW Network Model (£).
AV_132UGC	=	Asset value of the modelled length of 132kV underground cable in the Common 500MW Network Model (£).
AV_132SOHL	=	Asset value of the modelled length of 132kV single overhead line circuit in the Common 500MW Network Model (£).
AV_132DOHL	=	Asset value of the modelled length of 132kV double overhead line circuit in the Common 500MW Network Model (£).

9.2. Modelled Asset Values of EHV Circuits

The Modelled Asset Value of the modelled lengths of all EHV circuit types in the Common 500MW Network Model is derived from the asset value of the modelled length of each circuit type:

- underground circuit,

- overhead line single circuit, and
- overhead line double circuit.

9.2.1 Asset Values of EHV Circuit Components

The asset value of the modelled length of EHV underground cable in the Common 500MW Network Model is:

$$AV\_EHVUGC = MLEN\_EHVUGC * UC\_EHVUGC$$ **…Equ. 116**

where:

AV_EHVUGC	=	Asset value of the modelled length of EHV underground cable in the Common 500MW Network Model (£).
MLEN_EHVUGC	=	Modelled EHV underground cable length in the Common 500MW Network Model (km).
UC_EHVUGC	=	Unit cost of the installation of EHV underground cable (£/km).

The asset value of the modelled length of EHV single overhead line circuit in the Common 500MW Network Model is:

$$AV\_EHVSOHL = MLEN\_EHVSOHL * UC\_EHVSOHL$$ **…Equ. 117**

where:

AV_EHVSOHL	=	asset value of the modelled length of EHV single overhead line circuit in the Common 500MW Network Model (£).
MLEN_EHVSOHL	=	modelled EHV single overhead line circuit length in the Common 500MW Network Model (km).
UC_EHVSOHL	=	unit cost of the installation of EHV single overhead line circuit (£/km).

The asset value of the modelled length of EHV double overhead line circuit in the Common 500MW Network Model is:

$$AV\_EHVDOHL = MLEN\_EHVDOHL * UC\_EHVDOHL$$ **…Equ. 118**

where:

AV_EHVDOHL	=	Asset value of the modelled length of EHV double overhead line circuit in the Common 500MW Network Model (£).
MLEN_EHVDOHL	=	Modelled EHV double overhead line route length in the Common 500MW Network Model (km).
UC_EHVDOHL	=	Unit cost of the installation of EHV double overhead line circuit (£/route km).

9.2.2 Modelled Asset Value of EHV Circuits

The Modelled Asset Value of the modelled lengths of all types of EHV circuits in the Common 500MW Network Model is:

$$MAV\_EHVCIRC = AV\_EHVUGC + AV\_EHVSOHL + AV\_EHVDOHL$$ **…Equ. 119**

where:

MAV_EHVCIRC	=	Modelled Asset Value of the modelled lengths of all types of EHV circuits in the Common 500MW Network Model (£).
AV_EHVUGC	=	Gross Asset Value of the modelled length of EHV underground cable in the Common 500MW Network Model (£).
AV_EHVSOHL	=	Gross Asset Value of the modelled length of EHV single overhead line circuit in the Common 500MW Network Model (£).
AV_EHVDOHL	=	Gross Asset Value of the modelled length of EHV double overhead line circuit in the Common 500MW Network Model (£).

9.3. Modelled Asset Values of HV Network

The Modelled Asset Value of the modelled HV network in the Common 500MW Network Model is derived from the unit cost of HV conductor types and HV network protection, control and automation devices installed per HV circuit.

9.3.1 Asset Values of HV Conductor Types

The proportions used to determine the average unit cost for each type of circuit installation is calculated using a weighted average based upon the sizes and quantities of each circuit type installed for network extensions completed by these methods up to 5 years ago.

The asset value of the modelled HV overhead line circuit length in the Common 500MW Network Model is:

$$AV\_HVOHL = MLEN\_HVOHL * UC\_HVOHL$$ **…Equ. 120**

where:

AV_HVOHL	=	Asset value of the modelled overhead line circuit length in the Common 500MW Network Model (£).
MLEN_HVOHL	=	Modelled overhead line circuit length in the Common 500MW Network Model (km).
UC_HVOHL	=	Average unit cost of the installation of HV overhead line (£/km).

The asset value of the modelled HV underground cable circuit length involving ‘excavate-and-lay’ in the Common 500MW Network Model is:

$$AV\_HVUGCEL = MLEN\_HVUGCEL * UC\_HVUGCEL$$ **…Equ. 121**

where:

AV_HVUGCEL	=	Asset value of the modelled underground cable circuit length involving ‘excavate-and-lay’ construction in the Common 500MW Network Model (£).
MLEN_HVUGCEL	=	Modelled underground cable circuit length involving ‘excavate-and-lay’ construction t (km).

UC_HVUGCEL = Average unit cost of the installation of HV underground cable involving 'excavate-and-lay' construction (£/km).

The asset value of the modelled HV underground cable circuit length involving 'lay-only' construction in the Common 500MW Network Model is:

$$AV\_HVUGCLO = MLEN\_HVUGCLO * UC\_HVUGCLO$$ **…Equ. 122**

where:

AV_HVUGCLO = Asset value of the modelled underground cable circuit length involving 'lay-only' construction in the Common 500MW Network Model (£).

MLEN_HVUGCLO = Modelled underground cable circuit length involving 'lay-only' construction (km).

UC_HVUGCLO = Average unit cost of the installation of HV underground cable involving 'lay-only' construction (£/km).

9.3.2 Asset Value of HV Network Protection Control and Automation Devices

Various items of HV switchgear are used to protect and control HV networks. For the purposes of the Common 500MW Network Model these have been split into 3 different input categories to be summated under the heading of HV switchgear asset value, as described below:

- Volume of HV network level switchgear and automation per circuit to comply with P2/6
- Volume of incremental HV network level switchgear and automation per circuit to meets Industry Benchmarks for the IIS (Interruptions Incentive Scheme)
- Asset value of further additional HV network level switchgear and automation per circuit to meeting specific DNO design standards

To determine the volume of switchgear it is necessary to calculate the number of each circuit type to be modelled in the Common 500MW Network Model. The circuit types modelled in the Common 500MW Network Model are defined in APPENDIX 1 and are calculated as follows:

$$\boldsymbol{MNUM\_HVi} = \left(\frac{(\boldsymbol{MFC\_HV/LV\_GM} + \boldsymbol{MFC\_HV/LV\_PM})}{(\boldsymbol{EIC\_HV/LV\_GM} + \boldsymbol{EIC\_HV/LV\_PM})}\right) * \boldsymbol{ENUM\_HVi}$$ **…Equ. 123**

$$\boldsymbol{MNUM\_HV} = \sum_{i=1}^{j} \boldsymbol{MNUM\_HV_i}$$ **…Equ. 124**

where:

MNUM_HVi = Modelled number of type i HV circuits.

MFC_HV/LVPM = Modelled Firm Capacity in the Common 500MW Network Model at the HV/LV pole mounted Transformation Network Level in the Common 500MW Network Model (MVA).

MFC_HV/LVGM = Modelled Firm Capacity in the Common 500MW Network Model at the HV/LV ground mounted Transformation Network Level in the Common 500MW Network Model (MVA).

EIC_HV/LVGM	=	Total Existing Installed Capacity of ground mounted HV/LV substations in the licence area (MVA). This is the sum of the 'natural cooling' ratings of all HV/LV transformers in the licence area.
EIC_HV/LVPM	=	Total Existing Installed Capacity of pole mounted HV/LV substations in the licence area (MVA). This is the sum of the 'natural cooling' ratings of all HV/LV transformers in the licence area.
ENUM_HVi	=	Total existing numbers of type i HV circuits.
MNUM_HV	=	Total modelled number of all types of HV circuits.
j	=	Number of HV circuits' types in the Common 500MW Network Model.

9.3.3 HV switchgear and protective devices related to the number of circuits in the Common 500MW Network Model

In order to comply with the requirements of each DNO's licence regarding minimum security of supply criteria (i.e. ER P2/6), HV circuits must be arranged such that circuit sections connected to loads of less than 1MW[2]of Group Demand can be isolated from the rest of the circuit to allow for fault repairs. On most underground circuits this will be achieved by using the source circuit breaker and transformer ring main units and pole mounted switches on the overhead networks. Transformer ring main units are already allocated to the HV/LV transformation level in the Common 500MW Network Model so can be ignored. On overhead line networks, circuits are split into 1MW of Group Demand sections assuming the use of pole mounted switches. These are allocated to HV circuits in the Common 500MW Network Model as follows.

$$SG\_P2/6\_HV = MNUM\_PMS\_HV + MNUM\_SCB\_HV$$

…Equ. 125

where

$$MNUM\_PMS\_HV = \left(\frac{\left(MIC^{[3]}\_HV/LV\_PM\right)}{(1MVA)}\right)$$

…Equ. 126

$$MNUM\_SCB\_HV = MNUM\_HV$$

…Equ. 127

where

SG_P 2/6_HV	=	Modelled items of switchgear to comply with P2/6 on HV circuits.
MNUM_SCB_HV	=	Modelled number of source circuit breakers on HV circuits.
MNUM_HV	=	Modelled number of HV circuits.
MNUM_PMS_HV	=	Modelled number of pole mounted switches on HV circuits.
MIC_HV/LV_PM	=	Modelled Installed Capacity at the HV/LV pole mounted Transformation Network Level in the Common 500MW Network Model (MVA).

[2] To simplify for the purpose of these calculations it is assumed 1 MW equals 1 MVA

[3] It is recognised that it is not strictly correct to summate the installed capacity of PMTs to determine the Group Demand for a P2/6 assessment. It is used however as a proxy to determine the likely number of isolatable sections required on an overhead line network for capturing costs for pole mounted switching device in the HIDAM.

Therefore the total asset value of all HV Network Switchgear to meet minimum security of supply criteria P2/6 for HV circuit network level in the Common 500MW Network Model is

$$AV\_SG\_P2/6\_HV = MNUM\_PMS\_HV * UC\_PMS\_HV + MNUM\_SCB\_HV * UC\_SCB\_HV$$

…Equ. 128

where

AV_SG_ P2/6_HV	=	Total asset value of HV switchgear to meet P2/6 for all HV circuits in the Common 500MW Network Model.
MNUM_PMS_HV	=	Modelled number of pole mounted switches on HV circuits.
UC_PMS_HV	=	Unit cost of pole mounted switchgear on HV circuits.
MNUM_SCB_HV	=	Modelled number of source circuit breakers on HV circuits.
UC_SCB_HV	=	Unit cost of source circuit breakers on HV circuits.

The unit cost of these source circuit breakers should be calculated using data from assets installed in the recent past, up to 5 years ago. These costs will be a weighted average and include the costs of remote control and automation schemes normally employed on these circuit breakers on the DNO's network .

In addition to the standards of security of supply stated in ER P2/6, each DNO is incentivised to out perform these standards through the Interruptions Incentive Scheme (IIS) provided for in the charge restriction conditions of its Electricity Distribution Licence. OFGEM collates annual data and calculates an industry benchmark for number of customers interrupted per fault (CI/Flt). DNOs are rewarded or penalised depending on their performance against this benchmark. As a result network investment decisions are made for each circuit type to improve performance measured for the IIS scheme. To enable DNOs to achieve the industry benchmark for numbers of customers interrupted per fault, additional control, automaton and protection zone schemes are required to sectionalise each HV circuit following the initial fault which interrupts supply to customers. If supplies can be restored within 3 minutes of fault inception then the interruption in supply is not counted for regulatory reporting purposes as a customer interruption. In this document the expression 'customers interrupted' shall have the same meaning as when used in the charge restriction conditions of the Electricity Distribution Licences (and 'customer interruption' is to be interpreted accordingly).

An input for each HV circuit type, referred to as MNUM_CAPZ_HV, is included in the Common 500MW Network Model to account for this incremental cost per circuit as these form the minimum requirements for any DNO network design required to be able to achieve the industry benchmark of CIs/Flt. For example for HV circuit type j if the industry benchmark was 350 CIs/Fault and the DNO average amount of customers for that type of circuit was 900 then that would need to have at least 900/350 = 2.57 circuit sections that could be switched within 3 minutes. This precludes manual operations for circuit restoration and therefore requires the installation of an automation or remote control scheme. In this example at least 3 circuit section zones would be required and an allowance for 3 remote control and or automation zones should be added to the circuit type. One of these zones has been accounted for with the source circuit breaker, therefore, only 2 additional remote control and /or automation zones are required to sectionalise the circuit. However, to restore supplies remote control will need to be fitted to normally open split points, therefore, three remote control devices will be required. It is accepted this would increase remote control costs for normally open split points on simple ring circuits but these additional costs will cover more economic designs such as interconnected circuits which have more than one normally open split point. The most recent DNO figures for average customer numbers per circuit type should be used, and the Ofgem figure for average performance of CIs/Fault per circuit type over past 5 years should be used.

The MNUM_CAPZ_HV is calculated as

$$MNUM_{CAPZ_{HVi}} = [int\left(\frac{(AV\_ENUMC\_HVi)}{EIB\_CI/F\_HVi}\right)] * MNUM\_HVi$$

…Equ. 129

where

MNUM_CAPZ_HVi	=	Total modelled number of control, automation and protection zones per type i HV circuits.
AV_ENUMC_HVi	=	Average existing number of customers connected to type i HV circuits in the licence area.
EIB_CI/F_HVi	=	Existing industry benchmark for the number of customers interrupted per fault on HV circuit type i source from data collated by Ofgem for IIS.
MNUM_HVi	=	Modelled number of type i HV circuits in the Common 500MW Network Model.
Int(.)	=	Rounding up to a whole number

and

Asset Values of HV Network Switchgear to meet IIS benchmark for HV Circuit type i

$$AV\_CAPZ\_SG\_HV_i = MNUM\_CAPZ\_HV_i * UC\_CAPZ\_HVi$$ **…Equ. 130**

where

$AV\_CAPZ\_SG\_HV_i$	=	Asset value of HV switchgear per circuit type i to meet IIS benchmark for circuit type i in the Common 500MW Network Model
$MNUM\_CAPZ\_HV_i$	=	Modelled number of items of switchgear per circuit type i to meet IIS benchmark for that type of circuits in the Common 500MW Network Model.
UC_CAPZ_HVi	=	Unit cost of items of switchgear per zone based on installations up to 5 years ago.

Total asset value of all additional HV Network Switchgear to meet IIS benchmark for HV circuit network level in the Common 500MW Network Model

$$AV\_CAPZ\_SG\_HV = AV\_CAPZ\_SG\_HV_1 + \cdots AV\_SG\_IIS\_HV_j$$ **…Equ. 131**

where

AV_CAPZ_SG_HV	=	Total asset value of additional HV switchgear in the Common 500MW Network Model to meet IIS benchmark.
AV_SG_ ISS_HVj	=	Asset value of HV switchgear per zone per circuit to meet IIS benchmark for circuit type j in the Common 500MW Network Model

It is envisaged that to implement a remote control scheme on an underground network would require fitting motor actuators to a ring main unit. This switchgear is already covered elsewhere in the Common 500MW Network Model so the remote control scheme cost will exclude switchgear cost. However, the fitting of remote control schemes to the overhead network may require the inclusion of incremental switchgear cost (e.g. GVS over ABI).

A further input is used to capture any additional asset cost that arise from DNO present specific design specifications for example secondary ground mounted circuit breakers or pole mounted protective devices.

Asset values of all additional HV Network Switchgear to meet DNO design standards for Circuit type i

$$AV\_SG\_DS\_HV_i \ = \ MNUM\_HV_i * \ UC\_SG\_DS\_HVi$$

…Equ. 132

where

$AV\_SG\_DS\_HV_i$	=	Asset value of additional HV switchgear to meet DNO design standards for circuit type i in the Common 500MW Network Model
MNUM_HVi	=	Modelled number of type i HV circuits in the Common 500MW Network Model.
UC_SG_DS_HVi	=	Unit cost of additional HV switchgear to meet DNO design standards for circuit type i in the Common 500MW Network Model based on installations up to 5 years ago.

Total asset value of all additional HV Network Switchgear to meet DNO design standards for HV circuit network level in the Common 500MW Network Model

$$AV\_SG\_DS\_HV = AV\_SG \quad \_DS\_HV_1 + \cdots AV\_SG\_DS\_HV_j$$ **…Equ. 133**

where

AV_SG_DS_HV	=	Total asset value of additional HV switchgear in the Common 500MW Network Model to meet DNO design standards.
$AV\_SG\_DS\_HV_j$	=	Asset value of HV switchgear per circuit to meet DNO design standards for circuit type j in the Common 500MW Network Model

The units cost of these additional automation, control and protective devices should be calculated using data from assets installed in the recent past, up to 5 years ago on the DNO's network.

9.3.4 Total HV network level switchgear in the Common 500MW Network Model

The total Modelled Asset Value of all HV network level switchgear in the Common 500MW Network Model is:

$$AV\_HV\_SG = \mathrm{AV\_SG\_P2/6\_HV} + \mathrm{AV\_SG\_IIS\_HV} + \mathrm{AV}\_SG\_DS\_HV \quad \text{...Equ. 134}$$

where:

MAV_ HV_SG	=	Asset value HV switchgear in the Common 500MW Network Model
AV_SG_P2/6_HV	=	Asset value HV switchgear to meet p2/6
AV_SG_IIS_HV	=	Asset value HV switchgear to meet IIS
AV_SG_DS_HV	=	Asset value HV switchgear to meet DNO Design Standards

9.3.5 Modelled Asset Value of HV Circuits

The Modelled Asset Value of the modelled length and automation device s associated with each pre-specified circuit type is:

$$MAV\_HVCIRC = AV\_HVOHL + AV\_HVUGCEL + AV\_HVUGCLO + AV\_HVSG \quad \text{...Equ. 135}$$

where:

MAV_HVCIRC	=	Modelled Asset Value HV network in the Common 500MW Network Model (£).
AV_HVOHL	=	Asset value of the modelled overhead line circuit length in the Common 500MW Network Model (£).
AV_HVUGCEL	=	Asset value of the modelled underground cable circuit length involving 'excavate-and-lay' construction in the Common 500MW Network Model (£).
AV_HVUGCLO	=	Asset value of the modelled underground cable circuit length involving 'lay-only' construction in the Common 500MW Network Model (£).
AV_HVSG	=	Asset value of the total HV network switchgear in the Common 500MW Network Model (£).

9.4. Modelled Asset Values of LV Circuits

The Modelled Asset Value of the modelled lengths of all LV circuit types in the Common 500MW Network Model is derived from the asset value of the modelled length of each circuit type:

- overhead line circuit,
- underground circuit involving 'excavate-and-lay' construction,
- underground circuit involving 'lay-only' construction, and

The circuit components considered for the derivation of the Modelled Asset Value of LV circuits is presented diagrammatically in Figure 9 below.

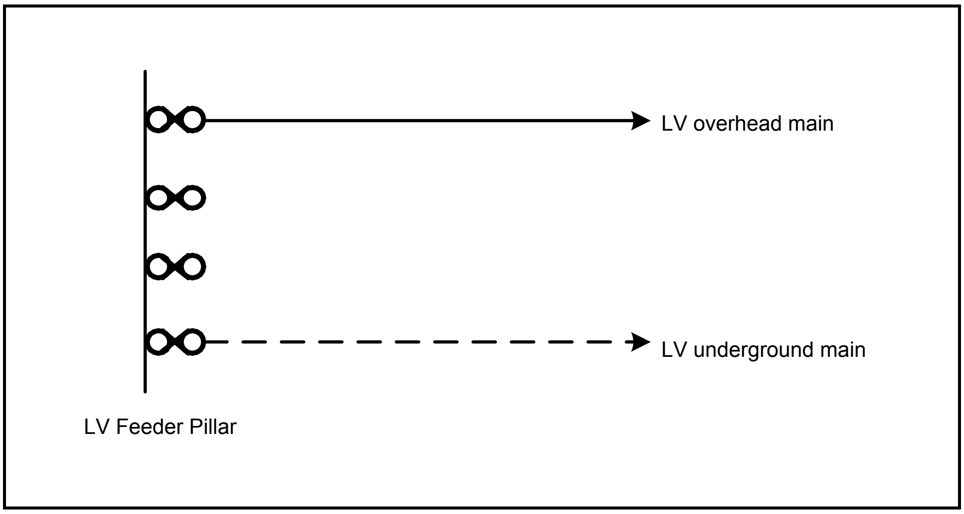

Figure 9 - LV Circuit Types

9.4.1 Asset Values of LV Circuit Components

The asset value of the modelled length of LV overhead line circuit length in the Common 500MW Network Model is:

$$AV\_LVOHL = MLEN\_LVOHL * UC\_LVOHL \qquad \text{...Equ. 136}$$

where:

AV_LVOHL	=	Asset value of the modelled length of LV overhead line circuit length in the Common 500MW Network Model (£).
MLEN_LVOHL	=	Modelled LV overhead line circuit length in the Common 500MW Network Model (km).
UC_LVOHL	=	Unit cost of the installation of LV overhead line circuit (£/km).

The asset value of the modelled length of LV underground cable length involving ‘excavate-and-lay’ construction in the Common 500MW Network Model is:

$$AV\_LVUCGEL = MLEN\_LVUGCEL * UC\_LVUGCEL \qquad \text{...Equ. 137}$$

where:

AV_LVUGCEL	=	Asset value of the modelled length of LV underground cable length involving ‘excavate-and-lay’ construction in the Common 500MW Network Model (£).
MLEN_LVUGCEL	=	Modelled LV underground cable circuit length involving ‘excavate-and-lay’ construction in the Common 500MW Network Model (km).
UC_LVUGCEL	=	Unit cost of the installation of LV underground cable involving ‘excavate-and-lay’ construction (£/km).

The asset value of the modelled length of LV underground cable length involving 'lay-only' construction in the Common 500MW Network Model is:

$$AV\_LVUCGLO = MLEN\_LVUGCLO * UC\_LVUGCLO$$ **…Equ. 138**

where:

AV_LVUGCLO	=	asset value of the modelled length of LV underground cable length involving 'lay-only' construction in the Common 500MW Network Model (£).
MLEN_LVUGCLO	=	modelled LV underground cable circuit length involving 'lay-only' construction in the Common 500MW Network Model (km).
UC_LVUGCLO	=	unit cost of the installation of EHV underground cable involving 'lay-only' construction (£/km).

9.4.2 Modelled Asset Value of LV Circuits

The Modelled Asset Value of all LV circuits in the Common 500MW Network Model is:

$$MAV\_LVCIRC = AV\_LVOHL + AV\_LVUCGEL + AV\_LVUCGLO$$ **…Equ. 139**

where:

MAV_LVCIRC	=	Modelled Asset Value of LV circuits in the Common 500MW Network Model (£).
AV_LVOHL	=	asset value of the modelled length of LV overhead line circuit length in the Common 500MW Network Model (£).
AV_LVUGCEL	=	asset value of the modelled length of LV underground cable length involving 'excavate-and-lay' construction in the Common 500MW Network Model (£).
AV_LVUGCLO	=	asset value of the modelled length of LV underground cable length involving 'lay-only' construction in the Common 500MW Network Model (£).

SECTION 10. DERIVATION OF THE GROSS ASSET VALUES OF NETWORK LEVELS

The derivation of the Gross Asset Values of each Network Level is described in this section. These form the output from the Common 500MW Network Model required for the CDCM and EDCM charging methodologies.

10.1. Gross Asset Value of the 132kV Circuit Network Level

The Gross Asset Value of the 132kV Circuit Network Level is comprised of:

- the Modelled Asset Value of all TR/132 substations allocated to the 132kV Circuit Network Level, and
- the Modelled Asset Value of the modelled lengths of all types of 132kV circuits.

This is given by:

$$GAV\_132 = MAV\_132\_AT\_TR/132SUB + MAV\_132CIRC$$ **…Equ. 140**

where:

GAV_132	=	Gross Asset Value of the 132kV Circuit Network Level (£).
MAV_132_AT_TR/132SUB	=	Modelled Asset Value of all TR/132 substations within the Common 500MW Network Model allocated to the 132kV Circuit Network Level (£).
MAV_132CIRC	=	Modelled Asset Value of the modelled lengths of all types of 132kV circuits in the Common 500MW Network Model (£).

10.2. Gross Asset Value of the 132/EHV Transformation Network Level

The Gross Asset Value of the 132/EHV Transformation Network Level is comprised of:

- the Modelled Asset Value of all 132/EHV substations allocated to the 132/EHV Transformation Network Level.

This is given by:

$$GAV\_132/EHV = MAV\_132/EHV\_AT\_132/EHVSUB$$ **…Equ. 141**

where:

GAV_132/EHV	=	Gross Asset Value of the 132/EHV Transformation Network Level (£).
MAV_132/EHV_AT_132/EHVSUB	=	Modelled Asset Value of all 132/EHV substations within the

Common 500MW Network Model allocated to the 132/EHV Transformation Network Level (£).

10.3. Gross Asset Value of the 132/HV Transformation Network Level

The Gross Asset Value of the 132/HV Transformation Network Level is comprised of:

- the Modelled Asset Value of all 132/EHV substations allocated to the 132/HV Transformation Network Level.

This is given by:

$$GAV\_132/HV = MAV\_132/HV\_AT\_132/HVSUB$$ **…Equ. 142**

where:

GAV_132/HV	=	Gross Asset Value of the 132/HV Transformation Network Level (£).
MAV_132/HV_AT_132/HVSUB	=	Modelled Asset Value of all 132/HV substations within the Common 500MW Network Model allocated to the 132/HV Transformation Network Level (£).

10.4. Gross Asset Value of the EHV Circuit Network Level

The Gross Asset Value of the EHV Circuit Network Level is comprised of:

- the Modelled Asset Value of all TR/EHV substations allocated to the EHV Circuit Network Level,
- the Modelled Asset Value of all 132/EHV substations allocated to the EHV Circuit Network Level, and
- the Modelled Asset Value of the modelled lengths of all types of EHV circuits.

This is given by:

$$GAV\_EHV = MAV\_EHV\_AT\_TR/EHVSUB + MAV\_EHV\_AT\_132/EHVSUB + MAV\_EHVCIRC$$ **…Equ. 143**

where:

GAV_EHV	=	Gross Asset Value of the EHV Circuit Network Level (£).
MAV_EHV_AT_TR/EHVSUB	=	Modelled Asset Value of all TR/EHV substations within the Common 500MW Network Model allocated to the EHV Circuit Network Level (£).
MAV_EHV_AT_132/EHVSUB	=	Modelled Asset Value of all 132/EHV substations within the Common 500MW Network Model allocated to the EHV Circuit Network Level (£).
MAV_EHVCIRC	=	Modelled Asset Value of the modelled lengths of all types of EHV

circuits in the Common 500MW Network Model (£).

10.5. Gross Asset Values of the EHV/HV Transformation Network Level

The Gross Asset Value of the EHV/HV Transformation Network Level is comprised of:

- the Modelled Asset Value of all EHV/HV substations allocated to the EHV/HV Transformation Network Level.

This is given by:

$$GAV\_EHV/HV = MAV\_EHV/HV\_AT\_EHV/HVSUB$$ **…Equ. 144**

where:

GAV_EHV/HV	=	Gross Asset Value of the EHV/HV Transformation Network Level (£).
MAV_EHV/HV_AT_EHV/HVSUB	=	Modelled Asset Value of all EHV/HV substations within the Common 500MW Network Model allocated to the EHV/HV Transformation Network Level (£).

10.6. Gross Asset Values of the HV Circuit Network Level

The Gross Asset Value of the HV Circuit Network Level is comprised of:

- the Modelled Asset Value of all TR/HV substations allocated to the HV Circuit Network Level,
- the Modelled Asset Value of all 132/HV substations allocated to the HV Circuit Network Level,
- the Modelled Asset Value of all EHV/HV substations allocated to the HV Circuit Network Level, and
- the Modelled Asset Value of the modelled lengths of all types of HV circuits.

This is given by:

$$GAV\_HV = MAV\_HV\_AT\_TR/HVSUB + MAV\_HV\_AT\_132/HVSUB + MAV\_HV\_AT\_EHV/HVSUB + MAV\_HVCIRC$$ **…Equ. 145**

where:

GAV_HV	=	Gross Asset Value of the HV Circuit Network Level (£).
MAV_HV_AT_TR/HVSUB	=	Modelled Asset Value of all TR/HV substations within the Common 500MW Network Model allocated to the HV Circuit Network Level (£).
MAV_HV_AT_132/HVSUB	=	Modelled Asset Value of all 132/HV substations within the Common

		500MW Network Model allocated to the HV Circuit Network Level (£).
MAV_HV_AT_EHV/HVSUB	=	Modelled Asset Value of all EHV/HV substations within the Common 500MW Network Model allocated to the HV Circuit Network Level (£).
MAV_HVCIRC	=	Modelled Asset Value of all types of HV circuits in the Common 500MW Network Model (£).

10.7. Gross Asset Values of the HV/LV Transformation Network Level

The Gross Asset Value of the HV/LV Transformation Network Level is comprised of:

- the Modelled Asset Value of all HV/LV substations allocated to the HV/LV Transformation Network Level.

This is given by:

$$GAV\_HV/LV = MAV\_HV/LV\_AT\_HV/LVSUB$$

…Equ. 146

where:

GAV_HV/LV	=	Gross Asset Value of the HV/LV Transformation Network Level (£).
MAV_HV/LV_AT_HV/LVSUB	=	Modelled Asset Value of all HV/LV substations within the Common 500MW Network Model allocated to the HV/LV Transformation Network Level (£).

10.8. Gross Asset Values of the LV Circuit Network Level

The Gross Asset Value of the HV Circuit Network Level is comprised of:

- the Modelled Asset Value of all HV/LV substations allocated to the LV Circuit Network Level, and
- the Modelled Asset Value of the modelled lengths of all types of LV circuits.

This is given by:

$$GAV\_LV = MAV\_LV\_AT\_HV/LVSUB + MAV\_LVCIRC$$

…Equ. 147

where:

GAV_HV	=	Gross Asset Value of the LV Circuit Network Level (£).
MAV_LV_AT_HV/LVSUB	=	Modelled Asset Value of all HV/LV substations within the Common 500MW Network Model allocated to the LV Circuit Network Level (£).
MAV_LVCIRC	=	Modelled Asset Value of the modelled lengths of all types of LV circuits in the Common 500MW Network Model (£).

10.9. Other output values for CDCM model

The Diversity Allowances between various levels are calculated also as the inputs for CDCM model.

DIV_132 = 1/ COI_TR/132_132/COMB -1 ...**Equ. 148**

DIV_EHV = 1/COI_TR/EHV&132/EHV_EHV/HV-1 ...**Equ. 149**

DIV_HV = MFC_HV/LV/(MFC_TR/HV + MFC_132kV/HV +MFC_EHV/HV) -1 ...**Equ. 150**

Coincidence factors between the EHV/HV substations and HV/LV substations are not calculated using maximum demand because of the difficulties associated with obtaining maximum demand data for HV/LV substations.

The proportion of load going through 132kV/HV direct transformation to total load supplied via 132/HV and EHV/HV substations is calculated as

PRPL_132/HV= MMD_132/HV/(MMD_TR/HV+MMD_132/HV+MMD_EHV/HV) ...**Equ.151**

Where

COI_TR/132_132/COMB	=	combined coincidence between the TR/132 and the downstream 132/EHV and 132/HV substations
COI_TR/EHV&132/EHV_EHV/HV	=	Coincidence between the TR/EHV, 132/EHV and the downstream EHV/HV substations.
MMD_TR/HV	=	Modelled maximum demand at TR/HV level
MMD_132/HV	=	Modelled maximum demand at 132/HV
MMD_EHV/HV	=	Modelled maximum demand at EHV/HV
DIV_132	=	Diversity allowance between TR/132 and downstream 132/EHV and 132/HV substations
DIV_EHV	=	Diversity allowance between TR/EHV, 132/EHV and the downstream EHV/HV substations
DIV_HV	=	Diversity allowance between TR/HV,132/HV, EHV/HV and the downstream HV/LV substations
PRPL_132/HV	=	The proportion of load going through 132kV/HV direction transformation

APPENDIX 1. HV CIRCUIT TYPES CURRENTLY DEFINED IN THE "NETWORK DISAGGREGATION WORKBOOK"

Circuit Type	% Overhead Line		Circuit Length (km)		Number of Connected Customers
UG1A	0		< 4		< 1000
UG1B	0		< 4		> 1000
UG2A	0		> 4		< 2000
UG2B	0		> 4		> 2000
MA1A	> 0	< 20	< 8		< 1000
MA1B	> 0	< 20	< 8		> 1000
MA2A	> 0	< 20	> 8		< 2500
MA2B	> 0	< 20	> 8		> 2500
MB1A	> 20	< 50	< 11		< 1000
MB1B	> 20	< 50	< 11		> 1000
MB2A	> 20	< 50	> 11		< 2200
MB2B	> 20	< 50	> 11		> 2200
MC1A	> 50	< 80	< 19		< 500
MC1B	> 50	< 80	< 19		> 500
MC2A	> 50	< 80	> 19		< 1700
MC2B	> 50	< 80	> 19		> 1700
OH1A	> 80		< 40		< 400
OH1B	> 80		< 40		> 400
OH2A	> 80		> 40	< 55	< 700
OH2B	> 80		> 40	< 55	>700
OH3A	> 80		> 55		< 700
OH3B	> 80		> 55		> 700

APPENDIX 2. ASSET COST ALLOCATION AT EACH NETWORK LEVEL

The components that should be considered and included in the costing of each defined substation configuration or on circuits is presented in this section. The Network Level to which the cost of each component must be assigned is identified.

Table 1 - Assets typically located within a Transmission/132 Substation Compound

Works/ Asset / Component	*Network Level cost assigned to*	*Comments*
Compound and Building		
ground materials and remediation	132kV	optional - if separate from substation compound
drainage	132kV	optional - if separate from substation compound
security and fencing	132kV	optional - if separate from substation compound
earth grid	132kV	optional - if separate from substation compound
control/switch room	132kV	
telecommunications connection	132kV	
telecontrol/SCADA	132kV	
AC supply	132kV	
battery	132kV	
water supply	132kV	optional - if separate from substation compound
welfare facilities	132kV	optional
Substation Components		
132kV bus coupler and section breaker	132kV	
132kV busbar and protection	132kV	
132kV disconnector/ isolator	132kV	
132kV earthing switch	132kV	
132kV tower/indoor cable/outdoor cable termination	132kV	
132kV gantry and insulator	132kV	
132kV feeder circuit breaker	132kV	
voltage/current transformer for 132kV feeder	132kV	
132kV feeder analogue metering	132kV	
132kV feeder protection	132kV	
surge arrestor	132kV	
multi-core and auxiliary cable	132kV	
event recorder panel	132kV	optional

Table 2 - Assets typically located within a Transmission/EHV Substation Compound

Works/ Asset / Component	*Network Level cost assigned to*	*Comments*
Compound and Building		
ground materials and remediation	EHV	optional - if separate from substation compound
drainage	EHV	optional - if separate from substation compound
security and fencing	EHV	optional - if separate from substation compound
earth grid	EHV	optional - if separate from substation compound
control/switch room	EHV	
telecommunications connection	EHV	
telecontrol/SCADA	EHV	
AC supply	EHV	
battery	EHV	
water supply	EHV	optional - if separate from substation compound
welfare facilities	EHV	optional
Substation Components		
EHV bus coupler and section breaker	EHV	
EHV busbar and protection	EHV	
EHV disconnector/ isolator	EHV	
EHV earthing switch	EHV	
EHV tower/indoor cable/outdoor cable termination	EHV	
EHV gantry and insulator	EHV	
EHV feeder circuit breaker	EHV	
voltage/current transformer for EHV feeder	EHV	
EHV feeder analogue metering	EHV	
EHV feeder protection	EHV	
surge arrestor	EHV	
multi-core and auxiliary cable	EHV	
event recorder panel	EHV	optional

Table 3 - Assets typically located within a Transmission/HV Substation Compound

Assets typically located within a Transmission/HV substation compound		
Works/ Asset / Component	*Network Level cost assigned to*	*Comments*
Compound and Building		
ground materials and remediation	HV	optional - if separate from substation compound
drainage	HV	optional - if separate from substation compound
security and fencing	HV	optional - if separate from substation compound
earth grid	HV	optional - if separate from substation compound
control/switch room	HV	
telecommunications connection	HV	
telecontrol/SCADA	HV	
AC supply	HV	
battery	HV	
water supply	HV	optional - if separate from substation compound

welfare facilities	HV	optional
Substation Components		
HV bus coupler and section breaker	HV	
HV busbar and protection	HV	
HV disconnector/ isolator	HV	
HV earthing switch	HV	
HV tower/indoor cable/outdoor cable termination	HV	
HV gantry and insulator	HV	
HV feeder circuit breaker	HV	
voltage/current transformer for HV feeder	HV	
HV feeder analogue metering	HV	
HV feeder protection	HV	
surge arrestor	HV	
multi-core and auxiliary cable	HV	
event recorder panel	HV	optional

Table 4 - Assets typically located on the 132kV Network

Works/ Asset / Component	*Network Level cost assigned to*	*Comments*
Network Components		
132kV conductor- overhead line, underground cable	132kV	
intermediate tower / pole	132kV	
pilot cable (protection)	132kV	
ancillary cable equipment	132kV	
132kV joints	132kV	
other remote intertripping	132kV	

Table 5 - Assets typically located within a 132/EHV Substation Compound

Works/ Asset / Component	*Network Level cost assigned to*	*Comments*
Compound and Building		
ground materials and remediation	132/EHV	
drainage	132/EHV	
security and fencing	132/EHV	
earth grid	132/EHV	
control/switch room	132/EHV	
telecommunications connection	132/EHV	
telecontrol/SCADA	132/EHV	
AC supply	132/EHV	
battery	132/EHV	
water supply	132/EHV	optional
welfare facilities	132/EHV	optional
Substation Components		
132kV tower/indoor cable/outdoor cable termination	132/EHV	
132kV gantry and insulator	132/EHV	
132kV surge arrestor	132/EHV	
132kV feeder circuit breaker	132/EHV	optional
132kV feeder protection	132/EHV	optional

132kV disconnector/isolator	132/EHV	
132kV earthing switch	132/EHV	optional
voltage/current transformer for 132kV feeder	132/EHV	optional
analogue metering for 132kV feeder	132/EHV	optional – dependent on substation configuration
132kV bus coupler and section breaker	132/EHV	optional – dependent on substation configuration
132kV busbar and protection	132/EHV	optional – dependent on substation configuration
voltage/current transformer for transformer - 132kV	132/EHV	optional
132kV analogue metering for transformer	132/EHV	optional
132kV transformer circuit breaker	132/EHV	optional
132/EHV transformer and civil works	132/EHV	
transformer protection	132/EHV	
interplant connection - 132kV and EHV	132/EHV	
neutral earthing resistor/reactor/transformer	132/EHV	
EHV transformer circuit breaker	132/EHV	
automatic voltage control panel	132/EHV	
voltage/current transformer for transformer - EHV	132/EHV	
analogue metering for transformer - EHV	132/EHV	
EHV bus coupler and section breaker	132/EHV	
EHV busbar and protection	132/EHV	
multi-core and auxiliary cable	132/EHV	
event recorder panel	132/EHV	optional
EHV feeder circuit breaker	EHV	
EHV feeder protection	EHV	
EHV tower/indoor cable/outdoor cable termination	EHV	
EHV gantry and insulator	EHV	
EHV disconnector / isolator	EHV	
EHV earthing switch	EHV	
voltage/current transformer for EHV feeder	EHV	
analogue metering for EHV feeder	EHV	
surge arrestor	EHV	

Table 6 - Assets typically located within a 132/HV Substation Compound

Works/ Asset / Component	*Network Level cost assigned to*	*Comments*
Compound and Building		
ground materials and remediation	132/HV	
drainage	132/HV	
security and fencing	132/HV	
earth grid	132/HV	
control/switch room	132/HV	
telecommunications connection	132/HV	
telecontrol/SCADA	132/HV	
AC supply	132/HV	
battery	132/HV	
water supply	132/HV	optional
welfare facilities	132/HV	optional
Substation Components		
132kV tower/indoor cable/outdoor cable termination	132/HV	
132kV gantry and insulator	132/HV	

132kV surge arrestor	132/HV	
132kV feeder circuit breaker	132/HV	optional
132kV feeder protection	132/HV	optional
132kV disconnector/isolator	132/HV	
132kV earthing switch	132/HV	optional
voltage/current transformer for 132kV feeder	132/HV	optional
analogue metering for 132kV feeder	132/HV	optional – dependent on substation configuration
132kV bus coupler and section breaker	132/HV	optional – dependent on substation configuration
132kV busbar and protection	132/HV	optional – dependent on substation configuration
voltage/current transformer for transformer - 132kV	132/HV	optional
132kV analogue metering for transformer	132/HV	optional
132kV transformer circuit breaker	132/HV	optional
132/HV transformer and civil works	132/HV	
transformer protection	132/HV	
interplant connection - 132kV and EHV	132/HV	
neutral earthing resistor/reactor/transformer	132/HV	
HV transformer circuit breaker	132/HV	
automatic voltage control panel	132/HV	
voltage/current transformer for transformer - HV	132/HV	
analogue metering for transformer - HV	132/HV	
HV bus coupler and section breaker	132/HV	
HV busbar and protection	132/HV	
multi-core and auxiliary cable	132/HV	
event recorder panel	132/HV	optional
HV feeder circuit breaker	HV	
HV feeder protection	HV	
HV tower/indoor cable/outdoor cable termination	HV	
HV gantry and insulator	HV	
HV disconnector / isolator	HV	
HV earthing switch	HV	
voltage/current transformer for HV feeder	HV	
analogue metering for HV feeder	HV	
surge arrestor	HV	

Table 7 - Assets typically located on the EHV Network

Works/ Asset / Component	*Network Level cost assigned to*	*Comments*
Network Components		
EHV conductor- overhead line, underground cable	EHV	
intermediate tower / pole	EHV	
pilot cable (protection)	EHV	
ancillary cable equipment	EHV	
EHV joints	EHV	
other remote intertripping	EHV	

Table 8 - Assets typically located within an EHV/HV Substation Compound

Works/ Asset / Component	*Network Level cost assigned to*	*Comments*

Compound and Building		
ground materials and remediation	EHV/HV	
drainage	EHV/HV	
security and fencing	EHV/HV	
earth grid	EHV/HV	
control/switch room	EHV/HV	
telecommunications connection	EHV/HV	
telecontrol/SCADA	EHV/HV	
AC supply	EHV/HV	
battery	EHV/HV	
water supply	EHV/HV	optional
welfare facilities	EHV/HV	optional
Substation Components		
EHV tower/indoor cable/outdoor cable termination	EHV/HV	
EHV gantry and insulator	EHV/HV	
EHV surge arrestor	EHV/HV	
EHV feeder circuit breaker	EHV/HV	optional
EHV feeder protection	EHV/HV	optional
EHV disconnector/isolator	EHV/HV	
EHV earthing switch	EHV/HV	optional
voltage/current transformer for EHV feeder	EHV/HV	optional
analogue metering for EHV feeder	EHV/HV	optional – dependent on substation configuration
EHV bus coupler and section breaker	EHV/HV	optional – dependent on substation configuration
EHV busbar and protection	EHV/HV	optional – dependent on substation configuration
voltage/current transformer for transformer - EHV	EHV/HV	optional
EHV analogue metering for transformer	EHV/HV	optional
EHV transformer circuit breaker	EHV/HV	optional
EHV/HV transformer and civil works	EHV/HV	
transformer protection	EHV/HV	
interplant connection - EHV and HV	EHV/HV	
neutral earthing resistor/reactor/transformer	EHV/HV	
HV transformer circuit breaker	EHV/HV	
automatic voltage control panel	EHV/HV	
voltage/current transformer for transformer - HV	EHV/HV	
analogue metering for transformer - HV	EHV/HV	
HV bus coupler and section breaker	EHV/HV	
HV busbar and protection	EHV/HV	
multi-core and auxiliary cable	EHV/HV	
event recorder panel	EHV/HV	optional
HV feeder circuit breaker	HV	
HV feeder protection	HV	
HV tower/indoor cable/outdoor cable termination	HV	
HV gantry and insulator	HV	
HV disconnector / isolator	HV	
HV earthing switch	HV	
voltage/current transformer for HV feeder	HV	
analogue metering for HV feeder	HV	
surge arrestor	HV	

Table 9 - Assets typically located on the HV Network

Assets typically located on the HV network		
Works/ Asset / Component	*Network Level cost assigned to*	*Comments*
Network Components		
HV conductor- overhead line, underground cable	HV	
intermediate tower/pole	HV	
pole-mounted auto recloser	HV	
air break isolator	HV	
fuse/auto-section link	HV	
switchgear and protection devices	HV	
remote circuit breaker/switchboard	HV	
surge arrestor	HV	
HV joints	HV	
ancillary cable equipment	HV	

Table 10 - Assets typically located within a HV/LV Substation

Works/ Asset / Component	*Network Level cost assigned to*	*Comments*
Substation Components		
substation enclosure	HV/LV	
HV/LV transformer including civil works	HV/LV	
HV transformer switch	HV/LV	
HV ring main unit with automation upgrade capability	HV/LV	
Pole-mounted transformer LV fuse	HV/LV	
LV feeder pillar for pole/ground-mounted substation	LV	
LV termination to LV board	LV	

Table 11 - Assets typically located on the LV Network

Works/ Asset / Component	*Network Level cost assigned to*	*Comments*
Network Components		
LV conductor- overhead line, underground cable	LV	
LV mains joint	LV	