

# **THE DISTRIBUTION SYSTEM SECURITY AND PLANNING STANDARDS.**

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# Contents

<b>1.0</b>	<b>Introduction.....</b>	<b>3</b>
1.1	Definitions.....	3
1.2	Aim of Planning.....	5
<b>2.0</b>	<b>Distribution System.....</b>	<b>5</b>
2.1	Voltage Levels.....	6
2.2	Effects of Disturbing Loads.....	6
<b>3.0</b>	<b>Assessment of New Load.....</b>	<b>7</b>
3.1	Information Required from Customers.....	7
3.1.1	Geographical location.....	7
3.1.2	Maximum Import Capacity (MIC).....	7
3.1.3	Disturbing Loads.....	7
3.1.5	Specific Requirements.....	7
3.1.6	Diversity.....	8
3.2	Requirements for a Terminal Station Building.....	8
3.2.1	Requirement for a HV Terminal Station.....	8
3.2.2	Requirements for a HV/MV Terminal Station.....	8
3.2.3	Requirements for a MV Terminal Station.....	9
3.2.4	Requirements for a MV/LV Terminal Station.....	9
<b>4.0</b>	<b>Determining the Least Cost Technically Acceptable Solution.....</b>	<b>Error!</b>
	Bookmark not defined.	
4.1	Location of Load.....	10
4.2	Network Examination.....	10
4.3	Short Circuit Capacity.....	11
4.4	Voltage Drop.....	11
4.5	Substation Capacity.....	12
4.6	Other Reinforcements.....	12
4.7	Network Configuration (how the load is connected).....	12
4.8	Treatment of Electrical Losses.....	12
4.9	Economic Analysis.....	13
<b>5.0</b>	<b>Specific Requirements for Generators.....</b>	<b>13</b>
5.1	Voltage Rise.....	13
5.2	Flicker.....	14
5.3	Harmonics.....	
5.4	Network Protection.....	14
<b>6.0</b>	<b>System Planning Issues.....</b>	<b>14</b>
6.1	Security of connection.....	
6.2	Continuity.....	15

**Appendix 1 Examples of Disturbing Loads**

**Appendix 2 Volt drop Allocation**

## 1.0 Introduction.

The Distribution System Operator (DSO) licence requires ESB as licensee to:

*‘operate and ensure the maintenance of and develop, as necessary, a safe, secure, reliable, economical and efficient electricity distribution system...’*

To this end, condition 11 calls for DSO to prepare this document: “The Distribution System Security and Planning Standards”

This document outlines the DSO’s approach to the development of network. The document gives details of how we assess the connection of new loads and embedded generators to the Distribution System. It is intended as a guide to Users of the Distribution System and is referred to in the Distribution Code (Item 13). While this guide refers to customers’ loads the same factors will apply, in general, to generators also. There are however, some specific requirements relating to generators and these are included under a separate heading. (Section 5)

## 1.1 Definitions

In general the terms used in this document have the meanings intended in the Distribution Code. As a brief guide, the terms used in this document are defined below:

Term	Definition
Connection Asset	The network erected to connect the connection point to the existing Distribution System. The connection asset forms part of the Distribution System and is not shared by other users.
Continuity or Continuity of Supply	This describes the quality of a supply as it relates to outages, whether caused by faults or planned work. A set of measures are required to describe continuity but, in general, the lower the incidence of outages and the shorter their duration, the higher the continuity.
Distribution System	The electric lines, plant and switch-gear used to convey electricity to final customers (excluding customers connected directly to the transmission system (grid)).
Disturbing Load	An electrical load that of its nature may affect the quality of electricity supply of other customers. Examples are welders, large electric motors etc. (See Appendix 1)
Diversity	The ratio of actual peak loading in a customer’s premises to the sum of all the individual load ratings connected within the premises.
Flicker	Voltage fluctuations, caused by a disturbing load (or rapid variations in generator output), the major effect of which is flickering of standard (incandescent) light bulbs.

Term	Definition
Looped Connection	A connection with both normal and standby feeds – at the connection voltage - either of which is capable of providing the full MIC within the quality of supply standards.
Losses	Electrical losses account for the difference between the power entering the distribution system and that delivered to customers. Losses can be regarded as the energy lost in the network due to the heating effect of the electricity passing through it.
Normal Feeding	The network configuration under normal conditions and when all distribution plant is in service. The normal feeding arrangement is typically designed to provide best voltage performance, to minimise network losses and to make optimum use of the capacity of feeding substations is also a factor
Security of Connection	The expectation that the connection point will remain energised.
Short Circuit Capacity	The short circuit capacity is a measure of the ‘strength’ of the network i.e. the ability to limit the impact of disturbing loads and to maintain voltage stability. The size of the customer switched load relative to the short circuit level determines whether the voltage quality will be maintained within standard.
Standby Feeding	The feeding arrangement when one or more items of network plant is out of service. The exact feeding arrangement will depends on which items are out of service. As standby feeding is a temporary arrangement, different standards of voltage apply.
Terminal Substation	A standard structure owned and operated by the DSO containing the distribution equipment necessary to connect a customer to the distribution system. Terminal substations are operated at the connection voltage of the customer i.e. transformation is not required.
Transformer Substation	A standard structure owned and operated by the DSO containing one or more transformers, to convert electricity at one standard distribution voltage to a lower standard voltage.

## 1.2 Aim of Planning

The aim of planning is to ensure that the Distribution System is developed in an orderly and cost effective manner. We need to ensure that there is capacity available to meet new loads as they arise, and to meet ongoing growth requirements. We also need to ensure that new connections are made:

- in an economic fashion
- with a view to the possible future needs of the customer
- in a way that is technically acceptable.

In summary, ESB will provide customer connections, which will deliver the required capacity to an acceptable standard as detailed in the Distribution Code. A higher standard of installation or a higher security of connection arrangement can be provided at the customer's request, however the full additional costs will be attributed to the customer.

## 2.0 Distribution System.

The standard configuration of the Distribution System is illustrated schematically in Figure 1 below.

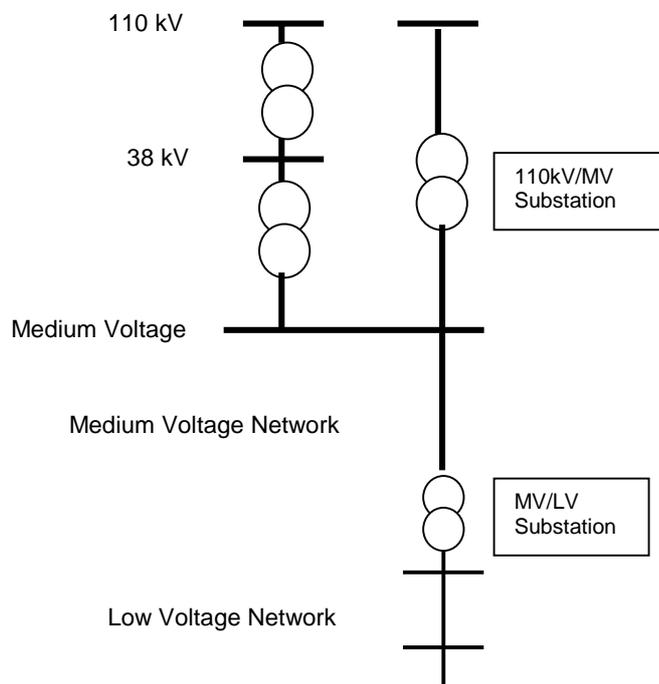


Figure 1. Representation of the Distribution System

## 2.1 Voltage Levels.

There are a number of standard voltages in use on the Distribution System and customers will be connected at one of these levels. Voltage Levels at which a connection can be provided are as follows:

Voltage Level	Nominal Voltage
Low Voltage (LV)	230V (single phase)
	400V (3 phase)
Medium Voltage (MV)	10kV
	20kV
High Voltage (HV)	38kV
	110kV <sup>1</sup>

ESB is currently in the process of upgrading its medium voltage Distribution networks. This involves converting the more heavily loaded rural overhead 10kV networks to 20kV operation and feeding directly from the 110kV networks i.e. 110kV/MV stations. Thus future developments are likely to be 110kV/MV rather than 38kV/MV. This will provide improved voltage performance and greater voltage stability. While large customers may be offered a 38kV connection depending on location and other factors the trend will be towards connection at MV voltage ranges.

Generally the voltage level at which customer connection will be made is dependent on the load range. The typical voltage level for various load ranges is shown below.

Load Range	Typical Voltage Level
Up to 500kVA	LV <sup>2</sup>
500kVA to 15MVA	MV <sup>3</sup>
Exceptionally	38kV <sup>4</sup>
>15MVA	110kV

## 2.2 Effects of Disturbing Loads.

Certain types of equipment such as motors and welders may cause fluctuations in the supply voltage, which cause disturbances to the connection of other customers. Where customers intend to install any equipment likely to cause supply disturbances, this equipment must be evaluated to assess the likely impact. The limits imposed on disturbing loads are specified in the

<sup>1</sup> While certain 110kV stations and lines (mainly in the Dublin Region) are part of the Distribution System, the 110kV system is primarily a Transmission voltage and connections at this voltage level will normally be dealt with by the Transmission System Operator (TSO).

<sup>2</sup> In some cases an LV MIC increase >500kVA and <900kVA may be possible.

<sup>3</sup> In some cases loads of up to 20MVA may be connected at 20kV,

<sup>4</sup> If redundancy or over-capacity exists on the 38kV network

Distribution Code. It may be necessary, depending on the characteristics of the equipment, for a customer connection to be made using a different network configuration via a higher voltage, a dedicated substation or other method.

### **3.0 Assessment of New Load**

The assessment of the connection for a new load requires details of the load.

#### **3.1 Information Required from Customers.**

Details of the information required from demand customers and generators seeking connections or extensions to the Distribution System are provided in the Distribution Code. Application forms for connection are available from ESB offices, and are on the ESB website. Specifically the following information may be requested, depending on the nature of the load.

##### **3.1.1 Geographical location.**

Site location maps and site layout plans in order to determine the location of the proposed load in relation to the existing network.

##### **3.1.2 Maximum Import Capacity (MIC).**

Maximum Import Capacity (MIC) required, the size and nature of the load, diversity of the load and proposed phasing of the development i.e. the pace at which the load is expected to ramp up to full demand.

##### **3.1.3 Disturbing Loads.**

Details of any disturbing elements of the load are required such as:

- Large motors - details of starting arrangements for all large motor.
- Disturbing Loads i.e. electric welding, and details of the nature and usage pattern of the disturbing load.
- Harmonics - details of any equipment likely to produce harmonics on our system and in the case of convertors and AC regulators, whether they are controlled by six-pulse or twelve-pulse rectification. The customer should also include details of any filtering arrangements they may have already in place.

Some examples of disturbing loads are given in Appendix 1.

##### **3.1.4 Business Parks versus Single Load**

Whether the application is for connections to multiple end customers within a development, or is a single customer load.

##### **3.1.5 Specific Requirements**

Details of any specific customer requirements for connection of the load.

### 3.1.6 Diversity.

Customers should note when assessing the Capacity requirements that not all of the equipment will be operating at full load at the same time. The customer should apply a diversity factor to each component of the load, as well as to the overall load in order to assess the capacity required. Diversity factors will vary depending on the nature of the load.

## 3.2 Requirements for a Terminal Station Building.

A Customer or Developer should check with the following ESB offices at the earliest stage of project design regarding a requirement for the provision of a Terminal Station Building / Site for the development.

Proposed MIC > 2000kVA – New Business Team Leader, ESB Commercial and Customer Section, Osprey House, Lower Grand Canal Street, Dublin 2

Proposed MIC < 2000kVA - local ESB Area Manager or Design Construction Manager at 15 locations around the country.

### 3.2.1 Requirement for a HV Terminal Station.

Where the connection voltage is determined to be at 38kV or 110kV then a HV Terminal Station to comply with the standard *ESB Substation Building Specification* is required in all cases. The terminal station may be either indoor or outdoor based on the least cost technically acceptable solution.

### 3.2.2 Requirements for a HV/MV Terminal Station.

In some cases where a customer is supplied at MV, but this load cannot be met by the existing network, a terminal station may be required. The general guidelines and site requirements for a Terminal Station Building under these circumstances are shown on the attached table.

Maximum Import Capacity (MIC)	Customer requirement for the provision of a Substation Building
$\geq$ (Greater than or equal to) 6MVA	HV/MV Terminal Station will probably be required for loads greater than this level.
<6MVA	A HV/MV Terminal Station may be required where this is the least cost technically acceptable solution based on : <ul style="list-style-type: none"><li>• The MIC (MVA) of the proposed load.</li><li>• Disturbing elements of customer load</li><li>• The distance from the existing substations to the proposed load.</li><li>• Any spare capacity available on existing substations and on the local MV network.</li><li>• The Customer's future expansion plans</li></ul>

### 3.2.3 Requirements for a MV Terminal Station.

MV connected customers are required to provide an MV Terminal Station Building to comply with the standard *ESB Substation Building Specification* in all cases.

### 3.2.4 Requirements for a MV/LV Terminal Station.

The general guidelines for a Terminal Station Building requirements when a customer connected at LV needs a new MV/LV Terminal Station are shown on the attached table.

Maximum Import Capacity (MIC)	Customer requirement for the provision of a Terminal Station Building
$\geq$ (Greater than or equal to) 200kVA	Customer / Developer to provide a Terminal Station Building free of charge to ESB in all cases.
Urban Areas <200kVA	In all cases in Urban Areas a Terminal Station building is required where this is the least cost technically acceptable solution based on: <ul style="list-style-type: none"><li>• The MIC (kVA) of the proposed load.</li><li>• The distance from existing substations to the proposed load.</li><li>• Any spare capacity available on existing substations and on the local LV networks.</li><li>• The Customer's future expansion plans.</li></ul>
Rural Areas <200kVA	Unless future expansion, which would raise the proposed MIC above 200kVA is <u>ruled out</u> a Terminal Station building will be required. In Rural Areas the largest pole-mounted transformer is a 200kVA unit.

## 4.0 Determining the Least cost Technically Acceptable Solution.

The following factors are taken into account when determining the method of connection and the Least Cost Technically Acceptable solution.

### 4.1 Location of Load

The position of the load relative to a **suitable** network will be a significant factor in determining the connection method. The load may be close to the network but this does not necessarily mean that a connection can be made at this point. Connections can only be made from that part of the network which has adequate capacity to feed the new load, taking into account the impact of existing and other proposed loads.

In general the least cost technically acceptable method of connection is to the adjoining network but there are several factors which may necessitate an alternative connection.

- The adjoining network may not be at the appropriate voltage level or it may not have the necessary capacity.
- System requirements for the adjoining network may mean there is not sufficient spare capacity to feed the new load.
- The capacity of the networks at the same voltage may vary considerably from one location to another. In urban areas, for example, it may be possible to connect a load at a lower voltage than would be the case in rural areas.

#### **4.2 Network Examination.**

On deciding on the method of connection it must first be established that the existing network has adequate capacity to feed the additional load. If this is not the case then it is necessary to upgrade the network or construct additional network to connect the load.

Networks are assessed to determine:

- Voltage levels
- Line/cable loading under normal feeding and standby feeding conditions.
- Station loading under normal and standby feeding conditions
- Short Circuit levels on the networks in question

Expected circuit loading is calculated for both Winter and Summer loading conditions. The network capacity limits are specified for two conditions of ambient temperature<sup>5</sup> to correspond to Winter and Summer conditions.

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<sup>5</sup> Weather conditions are: ambient temperature 5° or 25°, 2MPH cross wind, full sun radiation.

### 4.3 Short Circuit Capacity.

The design short circuit levels for various connection voltages are provided in the Distribution Code and are as follows:

Connection Voltage	Short Circuit Level (RMS Symmetrical)	Short Circuit Level (RMS Symmetrical)
	Normally	Certain Designated Areas
LV (Domestic)	9.0kA	
LV (Ind/Comm)	37.0kA	
10kV	12.5kA	20kA
20kV	12.5kA	20kA
38kV	12.5kA	20kA
110kV (Dublin)	26.0kA	
110kV (outside Dublin)	25.0kA	

The short circuit rating of Customer's equipment must exceed these levels. It should be noted however, that the actual SCL at the connection point may differ from the design level.

### 4.4 Voltage Drop.

One of the factors limiting the connection of new load to a network is the level of voltage drop<sup>6</sup> incurred in carrying the current from the substation to the customer's premises. This is particularly true of rural networks where the length of network involved is often large. In order to meet the international voltage standard to which ESB is committed (EN50160) the network is designed to permit a maximum voltage drop across the various components. (See Appendix 2.)

The voltage ranges at the ESB Substation busbars using these design standards will be as follows:

Voltage Range at Busbar.					
	LV	10kV	20kV	38kV	110kV
Normal Feed	207V to 244V	10.54kV to 10.75kV	21.08kV to 21.50kV	36kV to 41kV	105kV to 120kV
Standby Feed	197V to 244V	9.68kV to 10.21kV	19.35kV to 20.42kV	35kV	85kV

<sup>6</sup> In the case of generators the problem is one of voltage rise rather than drop, and this is dealt with in Section 9.

If the voltage drop is outside standard then an alternative method of connection will be required.

#### **4.5 Substation Capacity.**

Having established that the capacity of the network is sufficient the capacity of the substation feeding this network must be considered. Where the substation capacity is not adequate to take the additional load either it must be upgraded, an alternative substation must be used or a new one constructed.

#### **4.6 Other Reinforcements.**

The addition of a new load at one voltage may result in reinforcement being carried out at the voltage level above. This could occur, for example, where a line or substation is nearing its capacity and the addition of the new load requires this to be increased. In some cases the reinforcement may not be required immediately but may have to be done sooner than previously planned as a result on the new load being connected.

#### **4.7 Network Configuration (how the load is connected)**

Major loads are connected to the system through substations on the customers' premises.

- The connection may be looped in which case two connecting lines/cables (normal and standby) are provided at the same voltage.
- The connection may be tail fed from a cubicle in a distribution station or
- The connection may be teed from the distribution network.

Except in exceptional circumstances, loads greater than 1MVA will be looped. (See below re Security of Connection.)

There is no standby connection for Tail and Teed arrangements. They may be used in cases where it is uneconomic to provide a looped connection but continuity limitations must be quantified by ESB and accepted in writing by the customer.

#### **4.8 Treatment of Electrical Losses.**

Electrical losses on the network impose a significant cost – both financial and environmental - and must be managed. Therefore losses are taken into account in determining the optimum connection method. For MV and HV circuits losses are calculated for three phase only as single phase losses are small in comparison. Losses are proportional to

$$I^2 R$$

where 'I' is the peak load in amps on the section of line concerned and 'R' is the DC resistance at 20°C of the conductor or equivalent conductor on that section in ohms per km per conductor.

It can be seen that if the line is heavily loaded then a small load increase will dramatically increase the cost of losses.

The setting of overall design parameters for the network takes account of the economic loading of conductors so that the long-term effect of losses is minimised.

#### **4.9 Economic Analysis.**

A number of options may be available to provide new or increased capacity to a customer. In evaluating the cost/savings involved in each option, the time at which these will be incurred is relevant. Therefore, to compare different options economically all cash flows are evaluated in terms of the current value of money. All future cash flows are converted to present value by discounting. The time span of the analysis should extend to the point when options have attained equivalent stages of development. This does not always happen and in such cases a time span of not more than 10 years is taken, and residual values are used.

Costs to be included in the analysis are:

- Gross cost of networks and stations and reinforcements;
- Retirements – (Present Stores Value minus the cost of dismantling);
- Losses.

In assessing the various options the detailed planning criteria must be considered. Thus factors such as network configuration, operation and protection policy on looped and radial circuits and limitations on station types (looped, tail, or teed) are addressed.

The cost of the feeding arrangement to provide the capacity required will be the most economic solution based on the above calculations.

The principles of the charges for connection are contained in the “Charges for Connection to the Distribution System”

#### **5.0 Specific Requirements for Generators.**

In addition to the aspects considered above there are some factors which apply specifically to Generators connecting to the Distribution system. These include:

##### **5.1 Voltage Rise**

When a generator is connected to the Distribution system the voltage at the point on the Distribution network will rise above its ‘normal’ level. In order to keep the voltage within standard for other customers connected to this network it is necessary to limit the level of this voltage rise. Depending on the size of the generator and the short-circuit level on the network this will often require a dedicated connection to be made to a substation to limit the impact of the voltage rise.

## **5.2 Flicker**

While flicker is an issue which is considered in assessing new loads it is a particularly important issue for generators as the output from certain generators can vary rapidly. This can translate into voltage fluctuations, the major effect of which is flickering of standard light bulbs. All generators are evaluated to assess the likelihood of this and, depending on the characteristics of the equipment, a connection to a stronger point on the network may be necessary.

## **5.3 Harmonics**

Some generators produce harmonics which can distort the connection voltage to such an extent that electrical equipment may not operate correctly. Generators are assessed to determine the likelihood of this and in certain cases an alternative connection method may be required.

## **5.4 Network Protection**

Protection on the distribution system is designed to isolate faults automatically so that the minimum number of customers is disconnected for the shortest possible time necessary to clear the fault. The correct operation of these devices can be compromised by the presence of generation. To ensure that the security of connection of existing customers is not adversely affected by the introduction of generation it may be necessary to upgrade existing protection devices.

Details of the permitted emission levels and the protection requirements are detailed in the Distribution Code.

## **6.0 System Planning Issues**

Some more general issues which are considered as part of planning for the whole system are as follows:

### **6.1 Security of Connection**

Security of Connection is an important consideration in the planning of the Distribution System. Policies relating to security of connection include the following:

- Under normal feed conditions, protection / automatic switching arrangements shall be such that a single fault will not result in loss of supply to a 38kV line length /station load product of greater than 200MW Kms;
- Under normal or standby feeding conditions protection / automatic switching arrangements shall be such that a single fault will not isolate more than two looped stations;
- Unless full standby is available at MV, a tail fed 38kV station with a normal load in excess of 5MVA shall be looped;

- The minimum re-energisation standard of connection to loads in excess of 15MVA shall be such that the connection may be re-energised automatically within 10 seconds for a single fault;
- Except in exceptional circumstances, standby will be available for single loads greater than or equal to 1MVA.

## 6.2 Continuity

The nature of continuity and how it is measured is such that the following are system standards, and are not applicable to a particular customer.

Continuity performance standards distinguish between customers connected from:

- Urban distribution networks,
- Rural systems,

and also distinguish between outages that arise due to faults or voluntary switching. The primary continuity standards are as follows:

Annual Outage Duration (Minutes Per Customer)		
Network	Fault	Planned
Urban	60	30
Rural	210	150

These values are average annual targets. They do not represent the maximum duration that may be experienced by a single customer, but rather the average outage duration over our total customer base. Major work programmes are being undertaken at present to improve continuity performance, with a view to meeting targets agreed with the CER.

When a fault occurs ESB will endeavour to re-energise customer connections as soon as practicable. The target restoration time when manual re-energisation is necessary is that 95% of the load will be restored within 4 hours.

## Appendix 1: Examples of Disturbing Loads

Table A3.1: Examples of Disturbing Loads

No.	Load Type	Impact	Factors	Mitigation
1.	Welders	Flicker	Number and Rating	Restriction on Operation
2.			Usage Pattern	
3.			Welder Type	
4.	Large Motor or Generator	Flicker	Rating (kVA)	Restriction on starts per day
5.			Machine characteristics	
6.			Starting arrangements	
7.	Rectifiers & Inverters	Harmonics	Control method (e.g. 6 or 12 pulse)	Harmonic Filter
8.			Filtering Arrangements	

**Appendix 2: Volt Drop Allocation**  
(next page)

**38kV  
Station**

### Volt-Drop Allocation

