Mains Design Instruction

Method of calculating voltage drop in low voltage mains

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1.0 PURPOSE

To set out in detail the method to be used to calculate voltage drop on Endeavour Energy's low voltage distribution network.

2.0 SCOPE

This instruction shall apply to the design and construction of all new subdivisions, extensions or connections within Endeavour Energy's network franchise area.

3.0 REFERENCES

- Board Policy 9.0 – Network Asset Management
- Company Policy 9.2.1 - Network Planning
- Company Policy 9.1.4 – Network Power Quality
- Company Policy 9.2.5 – Network Asset Design
- Endeavour Energy Network Management Plan December 2013
- Mains Design Instruction MDI 0011 - Underground distribution cables - continuous current ratings
- AS/NZS 3000:2007 Electrical Installations
- AS/NZS 3008.1.1:2009:Electrical installations - Selection of cables - Cables for alternating voltages up to and including 0.6/1 kV - Typical Australian installation conditions
- AS 60038-2012 Standard voltages
- AS 61000.3.100-2011: Electromagnetic compatibility (EMC) Part 3.100 Limits – Steady state voltage limits in public electricity systems
- Service and Installation Rules of New South Wales, August 2012

4.0 DEFINITIONS AND ABBREVIATIONS

ADMD	After diversity maximum demand, the average contribution of each customer in a homogenous group (usually residential customers) towards the maximum aggregated peak demand of the group as seen at the point of supply of that group and for a specific period of time, for example, summer, winter (further explained in clause 5.1)
ASP	Accredited Service Provider/Level 3 Designer
CWO	Contestable Works Officer
CWE	Contestable Works Engineer
Fin	Correction factor for phase inequality
FLD	Correction factor for lack of diversity
Fu	Correction factor for phase unbalance
HV	High voltage
LV	Low voltage
MDI	Mains Design Instruction
Point of Supply	The point at which the consumer connects to the distribution system, also known as Connection Point (refer to figures 1.1 and 1.2 of the *Service and Installation Rules of NSW*)
Point load	Any load, except a residential load, connected to a point in the circuit whose maximum demand is assessed according to AS/NZS 3000 (refer clause 5.6)
URD	Underground residential distribution

5.0 ACTIONS

This instruction shows the accepted method of calculating voltage drop in low voltage distribution mains.

5.1 Application of After Diversity Maximum Demand (ADMD)

ADMD is the average contribution of each customer in a homogenous group towards the maximum aggregated peak demand of the group as seen at the point of supply of that group and for a specific period of time, for example, summer, winter.

$$ADMD = (\text{Total peak demand})/N$$

Where N is the number of customers connected and N is greater than 100.

For voltage drop calculation purposes, even if the customer numbers are less than 100, the group ADMD with certain correction factors is taken as the contribution of individual customers for feeder loading. The correction factors are discussed in Annexure 1.

Refer to Table 1 to determine the correct ADMD for new URD development areas and for existing dwellings (refer to CWO/CWE for more information on schedule considerations).

Table 1: After Diversity Maximum Demand (ADMD) Schedule for new URD development areas

Geographic Area	Density	Dwelling Size	ADMD	
			Gas Area	Non-gas Area
Western Sydney	Low Density Development	Small (<25 squares/230m^2)	6.5	7
		Medium (25 – 40 squares/230 - 370m^2)	7	7.5
		Large (>40 squares/370m^2)	8.5	9
	Medium/High Density Development	Villas, Townhouses, Apartments – (1-3 bedroom, <15 squares/140m^2)	6.5	7
		Townhouses, Apartments - (3 bedroom, >15 squares/140m^2)	6.5	7
South Coast	Low Density Development	Small (<25 squares/230m^2)	6.5	7
		Medium (25 – 40 squares/230 - 370m^2)	6.5	7
		Large (>40 squares/370m^2)	7.5	8
	Medium/High Density Development	Villas, Townhouses, Apartments – (1-3 bedroom, <15 squares/140m^2)	6.5	7
		Townhouses, Apartments - (3 bedroom, >15 squares/140m^2)	6.5	7
Southern Highlands/ Blue Mountains	Low Density Development	Small (<25 squares/230m^2)	6.5	7
		Medium (25 – 40 squares/230 - 370m^2)	6.5	7
		Large (>40 squares/370m^2)	7.5	8.5
	Medium/High Density Development	Villas, Townhouses, Apartments – (1-3 bedroom, <15 squares/140m^2)	6.5	7
		Townhouses, Apartments - (3 bedroom, >15 squares/140m^2)	6.5	7

Where the dwelling size is not known it shall be inferred from the lot size. The dwelling size chosen shall be the largest possible that will fit on the lot, to be conservative. For example if the dwelling size is not known a 400m2 lot shall be assumed to be a large dwelling size.

For dwellings with a special condition or for dwellings substantially larger than 40 squares ($370m^2$) in size, the ADMD shall be determined by Endeavour Energy's Contestable Works Officer/Engineer (CWO/CWE) responsible for the area concerned.

As an alternative for existing dwellings, maximum demand indicator (MDI) for the last 5 years of the relevant substation shall be obtained from company databases or the Contestable Works Officer/Engineer (CWO/CWE) responsible for the area concerned. Outliers (significant deviation from the median) from the MDI reads shall be removed prior to the calculation of ADMD. Allowance is to be made for load growth in the area. The ADMD shall be calculated using the following formula:

$$\text{ADMD} = (\text{5 Year MDI average} / N)$$

Where 5 Year MDI average is the average of the past 5 MDI reads, after the removal of outliers, and N is the current number of customers.

Where the MDI of an area is seen to be regularly increasing over the past five years, this should be taken into consideration.

5.2 Voltage drop limits

The voltage drop, when calculated using the methods outlined in this document, shall not exceed the limits specified below.

The maximum allowable voltage drop between the substation low voltage bus and any customer point of supply shall not exceed **4.35%** of the standard base voltage 400/ 230V (that is, maximum conductor voltage drop of 10V) in the following situations:

- Industrial/ commercial developments.
- Urban areas and situations in non-urban areas where the HV supply route length from the HV regulated supply source (zone substation or regulator) to the distribution transformer does not exceed a nominal value of 5km.

The maximum allowable voltage drop shall be **2.17%** of the standard base voltage 400/ 230V (that is, maximum conductor voltage drop of 5V) in non-urban areas where the HV supply route length from the HV regulated supply source to the distribution transformer exceeds a nominal value of 5km.

These limits are in compliance with the values given in Distribution Network Design Parameters Summary Table 2 of Company Policy 9.2.5.

Care shall be taken when connecting new loads to an existing system to ensure that the downstream customers are not affected. Should the calculated voltage drop exceed the limits specified above for the proposed extension/load being connected to the Endeavour network, the designer/ASP shall take appropriate action to remedy the situation.

Note: Parallel circuits for reduction of voltage drop shall **not** be permitted.

5.3 Voltage limits - customer's point of supply

The voltage at a customer's point of supply shall comply with company policy 9.1.4. These limits shall be taken into consideration along with the effects of peak and off-peak load conditions when the distribution transformer tapping is selected.

5.4 Assumptions/criteria

- Consumers may be categorised into clusters having a common ADMD.

- The continuous current rating of the conductors are based on:
  a) Ambient temperature of air is 40 deg. C and that of soil is 25 deg. C
  b) Maximum conductor temperature for aerial conductors is 75 deg. C
  c) Maximum conductor temperature for underground XLPE insulated cables is 90 deg. C (refer to MDI 0011 for other cables).
- The conductor temperature rise corresponding to any given current is calculated based on the above criteria.
- The power factor used in the voltage drop calculator spreadsheet is by default unity and should be used unless it can be shown otherwise.
- Any extension for more than two (2) customers shall be of three phase.

5.5 Computation method

5.5.1 Fundamentals of voltage drop calculation

The customer at the far end of a feeder/branch is most affected due to voltage drop. Voltage drop is calculated using Ohm's law equation **V=IZ** where:

V is the voltage drop in the conductor,

I is the current through the conductor,

Z is the impedance of the conductor at current I.

There can be a disparity between the calculated and the actual values of conductor voltage drop caused mainly by lack of diversity, phase unbalance and phase inequality. When preparing the voltage drop spreadsheet, correction factors FLD, Fu and Fin have been introduced to compensate for the disparity due to lack of diversity, phase unbalance and phase inequality respectively (refer to the detailed explanation given in Annexure 1).

5.5.2 Calculation of voltage drop

The following steps shall be taken to calculate the conductor voltage drop from the substation low voltage busbar up to any customer point of supply in a three phase, four wire system that satisfies the assumptions in clause 5.4.

- Determine the route of the LV feeder/branches, customer points of supply (poles/pillars), conductor type and length of each segment.
- The single or three phase customers having the same ADMD distributed evenly among three phases, shall be identified as one customer group (that is, irrespective of them being single or three phase customers).
- Refer to the 'Instructions' Worksheet in the MDI0030 Voltage Drop Calculator for instructions on entering data into the spreadsheet.
- The spreadsheet is then used to calculate the voltage drop at any point in the circuit.

The conductor voltage drop in a single phase spur line extended from the three phase system for supplying less than three (3) customers can be obtained by considering the one or two customer/s as single phase point loads. This consideration is for the calculation of voltage drop in the spur line only.

5.6 Point loads

When voltage drop is calculated for connecting a point load, it is advisable that the maximum demand of the point load shall be assessed under the guidelines given in AS/NZS 3000. The point load is considered to be a balanced three phase load. The voltage drop corresponding to the assessed load current shall be calculated using the voltage drop calculator spreadsheet.

Any new single phase small customer (such as a corner shop), whose consumption is comparable to the residential loads in the circuit, shall not be considered as a point load. Instead, such a customer should be accommodated in the closest ADMD group in the circuit.

5.7 Street lamp circuits

Voltage drop due to street lamp circuits should also be calculated in a similar way. Maximum allowable voltage drop shall include the voltage drop due to street lamps.

6.0 AUTHORITIES AND RESPONSIBILITIES

The **Chief Engineer** shall have the authority and responsibility for approving this instruction.

The **Manager Primary Systems** shall have authority and the responsibility for reviewing this instruction and making recommendations to the Chief Engineer.

The **Earthing and Power Quality Manager** has the authority and responsibility for determining the maximum allowable voltage drop between the distribution substation low voltage bus and the point of supply of the customer.

The **Network Mains Manager** has the authority and responsibility for reviewing the cable/conductor parameters used in the voltage drop calculator.

Distribution Managers shall be responsible for ensuring that designs of the low voltage network by their staff comply with the requirements of this instruction.

The **Manager Network Connections** shall be responsible for ensuring that designs by Accredited Service Providers (ASPs) comply with the requirements of this instruction as well as supplying the required ADMD information for designs.

The **Contractor Operations Manager** shall be responsible for ensuring that installations are in accordance with designs.

Accredited Service Providers shall be responsible for ensuring that the voltage drop in any new development, extension of an existing LV feeder, or connection of load to an existing LV feeder, does not exceed those values shown in this instruction. Evidence of compliance with this requirement shall be provided with every application for certification.

Designers shall be responsible for ensuring that they adhere to the latest issue of any Standards, technical bulletins or drawings relevant to or referred to in this instruction.

7.0 DOCUMENT CONTROL

Documentation content coordinator: Earthing and Power Quality Manager

Documentation process coordinator: Branch Process Coordinator

Annexure 1: Correction factors

A number of correction factors have been used to calculate the conductor voltage drop. These correction factors are introduced to correct the actual line current contributed by a group of customers considered to have the same individual ADMD.

Lack of diversity factor (FLD)

F_{LD} compensates for the lack of diversity between customer loads. When the number of customers is small, the load profiles of customers are more likely to be similar. This results in customer load peaks to align with each other, increasing the estimate ADMD It has been set at 2 for 1, 2 or 3 customers.

For 4 or more customers, it is determined by the equation $F_{LD} = \left(1+\frac{2}{n}\right)$ where n is the actual number of customers.

This is an empirical formula, which tolerates a 100% deviation for individual customer maximum demand from the standard ADMD value for one customer, and converging rapidly towards unity as *n* increases.

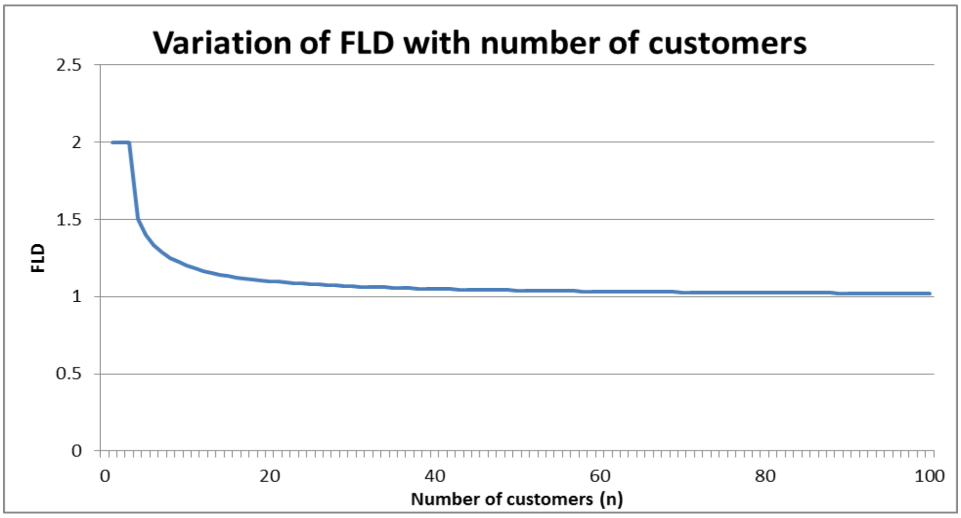

Figure 1: Variation of FLD vs number of customers

Phase inequality factor (Fin)

The phase inequality correction factor (Fin) compensates for the phase currents being unequal even when the total number of single phase connections is equal. This can be due to single phase usage of three phase connected customers. With experience it has been set at 1.15.

Phase unbalanced factor (Fu)

The phase unbalance factor (Fu) compensates for the unavoidable unbalance is either due to the total number of single phase connections not being divisible by 3 or the individual preferences of linesmen when connecting single phase loads. It has been set at 4, 2 and 1.5 for 1, 2 and 3 customers respectively. For 4 or more customers it is determined by the equation Fu = $\left(1+\frac{5}{n}\right)$ where n is the number of customers.

