New Concepts for Steady State Voltage Standards

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***Abstract*—the new Australian steady state voltage standard AS 61000.3.100 "Limits – Steady State voltage limits in public electricity systems" is introduced. Several innovative features of the standard are described including a preferred median voltage ($V_{50\%}$) range that is designed to provide for greater customer equipment end use efficiency, increased equipment life and the continuing installation of distributed small scale embedded photovoltaic generation.**

Also described is the concept of voltage spread ($V_{99\%}$ - $V_{1\%}$) which is used to place limits on steady state voltage variations in medium voltage networks.

***Index Terms*-- distribution systems, steady state voltage, standards, voltage spread.**

I. Introduction

The Australian Standards committee EL034 has recently developed and published a new standard [1] AS 61000.3.100 "Limits – Steady State voltage limits in public electricity systems". Embodied in this standard are important new concepts for establishing limits for steady state voltage for both low voltage and medium voltage customer supplies. The new standard also recommends thresholds of voltage dips and voltage swells. It is planned to promote this standard in the international domain for adoption over time to a wider audience.

II. Drivers for Change - Embedded Generation and Long Term National Power Quality Survey Results

Like many other countries, Australia has seen a remarkable influx of small scale photovoltaic embedded generation in recent years. This influx has been driven by generous subsidies and a desire to build greener generation. The result has been reverse power flows in many parts of the LV network that were never planned or designed for. In many locations, the resulting voltage rises have stressed networks and exposed many electricity customers to voltage levels higher than normal. For Australian networks that are historically designed for a 240V system, the added voltage rise effects need careful management by electricity distribution companies.

The results of the Australian Long Term National Power Quality Survey [2] has also been a driver for change. Results from the survey show that steady state voltage levels in the LV network tend to be higher than desired at many sites and greater levels of attention are required.

In Australia, the catalyst for the creation of a new steady state voltage standard has been the combination of photovoltaic generation and the results of the Australian Long Term National Power Quality Survey.

III. Steady State Voltage as a Key Measure of Power Quality

While harmonics, flicker, unbalance and voltage dips are considered mainstream power quality measures, steady state voltage is often overlooked because of its perceived simplicity. Despite its simplicity, steady state voltage levels are amongst the most important power quality parameters for customers. Keeping steady state voltage levels within limits is important for:

- providing long life for end use customer equipment.
- providing for end use customer equipment performance and efficiency.
- safety, in particular due to overheating/fire caused by voltage or current stresses.

IV. Steady State Voltage Measurement

The new AS 61000.3.100 calls up AS/NZ 61000.4.30 [3] for the measurement of steady state voltage. The standard specifies the use of 10 minute RMS average voltages measured over a minimum of one week. The combination of low voltage phase to phase and phase to neutral measurement requirements is shown in table I.

The 230V±10% range from AS 60038 [4] and IEC 60038 [5] (total 20%) of steady state voltage at the customer connection point was considered too wide for all existing customer equipment to operate effectively and efficiently. While many items of customer equipment operate effectively and efficiently over the wide steady state voltage range, some items of customer equipment are sensitive to steady state

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TABLE I
VOLTAGE MEASUREMENT DATA REQUIREMENTS

Site configuration	Phase-to-neutral quantities	Phase-to-phase quantities	Total assessed quantities
1 phase – 2 wire	1	0	1
2 phase – 2 wire	0	1	1
2 phase – 3 wire	2	1	3
3 phase – 3 wire	0	3	3
3 phase – 4 wire	3	3 (see Notes 1 and 2)	6
1 phase – centre neutral 3 wire	2	1	3

NOTES:

1 Phase-to-phase voltage measurements required to cater for unbalance in LV systems.

2 Phase-to-phase voltage measurements may be determined from phase-to-neutral voltage measurement values by calculation from waveforms.

V. BACKGROUND TO THE SELECTION OF LOW VOLTAGE STEADY STATE VOLTAGE LIMITS

voltage levels including:

- Incandescent lighting.
- Discharge lighting incorporating fixed impedance ballasts (as distinct from electronic ballasts).
- Resistive devices that are required to provide instantaneous heating including electric toasters, electric radiators, instantaneous electric water heaters, clothes dryers, hair dryers and many electric cooking appliances.
- Electric motors (non VSD types).

Other devices are also known to be sensitive to voltage levels.

A total supply steady state voltage range of 16% and a preferred sub-range of 8% was considered appropriate and achievable (albeit with cost implication) by network service providers. This smaller range was considered desirable in keeping distribution network losses at reasonable levels.

The preferred 8% sub-range encourages network service providers to provide steady voltage that is closer to the 230V nominal level where manufacturers tend to optimize the performance of their equipment to meet Australian ‘Mandatory Energy Performance Standards’ test requirements. The preferred 8% subrange is also aimed to cater for short duration voltage rise effects of distributed embedded generation, especially small scale photovoltaics.

VI. BACKGROUND TO THE SELECTION OF STEADY STATE VOLTAGE PERCENTILES

The new steady state voltage standard has set limits on $V_{1\%}$ and $V_{99\%}$ percentile values in preference to $V_{0\%}$ and $V_{100\%}$ values due to the following reasons:

- to filter out erroneous and non-representative steady state measurements that sometimes occur during the power quality monitoring process. These sometimes occur when instruments are connected/disconnected and during short duration network disturbances.
- to accommodate the impacts of short duration power system switching events.
- to alert equipment manufacturers that steady state voltages can and will move outside the $V_{1\%}$ to $V_{99\%}$ range.
- to provide consistency with many other power quality standards where limits are defined in terms of statistical quantities.
- to provide greater consistency and reproducibility when repeat measurement surveys are completed.

VII. SELECTION OF LOW VOLTAGE STEADY STATE VOLTAGE LIMITS

Table II shows steady state voltage limits to be provided at the customer’s connection point for phase-to-neutral, phase-to-phase and single phase centre neutral connections on 230/400V low voltage system:

TABLE II
230V NOMINAL STEADY STATE VOLTAGE LIMITS

Steady state voltage measure (10 minute r.m.s.)	Phase-to-neutral voltage limit		Phase-to-phase voltage limit		1 phase 3 wire centre neutral phase-to-phase voltage limit	
	Min	Max	Min	Max	Min	Max
$V_{1\%}$	216V	—	376V	—	432V	—
$V_{99\%}$	—	253V	—	440V	—	506 V

Table III shows the preferred steady state median voltage ($V_{50\%}$) at the customer’s connection point for phase-to-neutral, phase-to-phase and single phase centre neutral connections on 230V low voltage systems. This is a particularly innovative part of the standard and is designed to provide a preferred steady state voltage range lower than existing levels and provide an “upper operating range” to assist the network with the absorption of embedded generation while also providing a “lower operating range” to assist with the network supply of heavy peak loads. This concept is illustrated in figure 1.

TABLE III
230V NOMINAL STEADY STATE VOLTAGE PREFERRED PERFORMANCE

Steady state voltage measure (10 minute r.m.s.)	Phase-to-neutral voltage preferred performance		Phase-to-phase voltage preferred performance		1 phase 3 wire centre neutral phase-to-phase voltage preferred performance	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**
$V_{50\%}$	225V	244V	392V	424V	451V	488V

NOTES:

Preferred values for guidance purposes only.

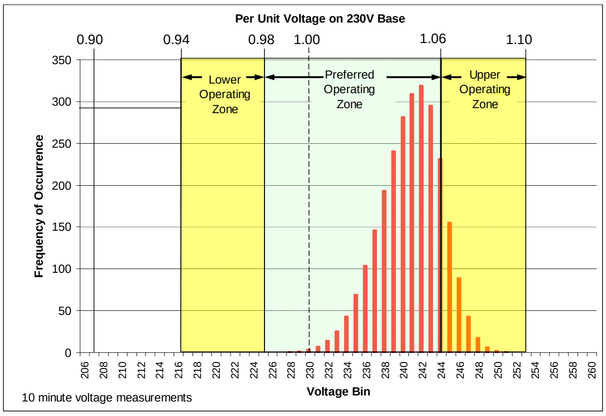

Fig. 1 – 230V Illustrated example showing statistical limits.

VIII. MEDIUM VOLTAGE STEADY STATE VOLTAGE LIMITS

AS61000.3.100 also provides steady state voltage limits for medium voltage customer connections. The limits apply only where a medium voltage electricity customer does not have voltage regulating equipment for the incoming supply such as an On Load Tap Changing (OLTC) transformer or a voltage regulator. The steady state voltage limits in this case are as detailed in table IV.

The innovative part of this table is the use of the voltage spread concept. Voltage spread being defined as the difference $V_{99\%}$ - $V_{1\%}$.

In medium voltage networks, where there are downstream off-load tap (or fixed tap) transformers, variation in voltage levels is vitally important. Whereas variations in MV float voltages (e.g. 10.6kV, 10.8kV, 11.0kV or 11.3kV in an 11kV system) can be accommodated by 11kV/400V distribution transformer tap selections, voltage spread passes straight through to customer terminals.

TABLE IV
MEDIUM VOLTAGE STEADY STATE LIMITS

Highest voltage for equipment U_m **kV**	**Nominal voltage** U_n **kV**	**Phase-to-phase voltage limit (see Notes 1 and 2) (10 minute r.m.s.)**		
		$V_{1\%}$ **min**	$V_{99\%}$ **max**	**Voltage spread** $V_{99\%}$ - $V_{1\%}$ **max**
		kV	**kV**	**kV**
3.6	3.3	2.97	3.50	0.33
7.2	6.6	5.94	7.00	0.66
12.0	11	9.90	11.66	1.10
24.0	12.7	11.43	13.46	1.27
36.0	19.1	17.19	20.25	1.91
24.0	22	19.80	23.32	2.20
36.0	33	29.70	34.98	3.30

NOTES:

1 12.7 kV and 19.1 kV nominal voltages are single wire earth return voltages and are phase-to-earth voltages.

2 For three phase four wire medium voltage systems, the phase-to-neutral limits are the phase-to-phase limits divided by $\sqrt{3}$.

IX. CONCLUSIONS

Australia's new standard AS61000.3.100 "Limits – Steady State voltage limits in public electricity systems", provides a number of innovative concepts designed to economically provide a electricity supply conditions for customers that promote equipment end use efficiency, longer equipment life, and the ongoing connection of small scale distributed generation. The innovative concepts are:

- the establishment of a preferred $V_{50\%}$ percentile range at the low voltage level, and
- limits on voltage spread ($V_{99\%}$ - $V_{1\%}$) at the medium voltage level.

The new 61000.3.100 stands as a model that provides concepts that can be used in other parts of the world.

References

[1] AS 61000.3.100 Limits – Steady State voltage limits in public electricity systems"

[2] S. Elphick, V. Gosbell, V. Smith, R. Barr, *The Australian Long Term Power Quality Survey Project Update*, 14th International Conference on Harmonics and Quality of Power, ICHQP'10, Bergamo, Italy, 26 - 29 September 2010

[3] AS 61000.4.30 "Testing and measurement techniques—Power quality measurement methods"

[4] AS 60038 "Standard Voltages"

[5] IEC 60038 "IEC Standard Voltages"

X. BIOGRAPHIES

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