2017

Proposed amendment to IEC/TR 61000.3.6:2008 for harmonic allocation to loads in transmission systems

Tuan Vu
University of Wollongong, tv547@uowmail.edu.au

Duane A. Robinson
University of Wollongong, duane@uow.edu.au

Victor J. Gosbell
University of Wollongong, vgosbell@uow.edu.au

Sarath Perera
University of Wollongong, sarath@uow.edu.au

Rizah Memisevic
Powerlink Queensland

Proposed amendment to IEC/TR 61000.3.6:2008 for harmonic allocation to loads in transmission systems

Abstract

Ensuring harmonic voltage distortion levels in transmission systems remain below acceptable levels relies on appropriate allocations of emissions to customer loads and bulk supply points. A number of practical issues have been identified with the existing harmonic allocation method for transmission systems in the technical report IEC/TR 61000-3-6:2008, Ed.2: the method to assess the total available power of a busbar, a key component to harmonic allocations, is not intuitive and there is a lack of clarity in the report; the method for sharing planning levels also does not allow unused spare capacity at a busbar to be shared with other busbars in the network to increase their global contribution; and the method for allocation of individual limits does not account for the size and harmonic emission of existing loads connected to a busbar. This paper analyses these issues in detail and proposes some clarification and amendments required for the existing allocation method. A simplified transmission network is provided to clarify how total available power can be assessed, how individual limits can be allocated for multiple loads connected to the same busbar, and to demonstrate that a significant increase in global contribution and subsequently higher individual limits can be achieved.

Keywords

proposed, systems, transmission, iec/tr, loads, harmonic, allocation, amendment, 61000.3.6:2008

Disciplines

Engineering | Science and Technology Studies

Publication Details

T. Vu, D. A. Robinson, V. Gosbell, S. Perera & R. Memisevic, "Proposed amendment to IEC/TR 61000.3.6:2008 for harmonic allocation to loads in transmission systems," in 2017 Australasian Universities Power Engineering Conference (AUPEC), 2017, pp. 1-6.

Proposed Amendment to IEC/TR 61000.3.6:2008 for Harmonic Allocation to Loads in Transmission Systems

Tuan Vu, Duane A. Robinson, Vic Gosbell, Sarath Perera
Australian Power Quality & Reliability Centre
University of Wollongong, Australia
tv547@uowmail.edu.au

Rizah MEMISEVIC
Powerlink Queensland, Australia
rmemisev@powerlink.com.au

Abstract— **Ensuring harmonic voltage distortion levels in transmission systems remain below acceptable levels relies on appropriate allocations of emissions to customer loads and bulk supply points. A number of practical issues have been identified with the existing harmonic allocation method for transmission systems in the technical report IEC/TR 61000-3-6:2008, Ed.2: the method to assess the total available power of a busbar, a key component to harmonic allocations, is not intuitive and there is a lack of clarity in the report; the method for sharing planning levels also does not allow unused spare capacity at a busbar to be shared with other busbars in the network to increase their global contribution; and the method for allocation of individual limits does not account for the size and harmonic emission of existing loads connected to a busbar. This paper analyses these issues in detail and proposes some clarification and amendments required for the existing allocation method. A simplified transmission network is provided to clarify how total available power can be assessed, how individual limits can be allocated for multiple loads connected to the same busbar, and to demonstrate that a significant increase in global contribution and subsequently higher individual limits can be achieved.**

***Index Terms*—Harmonic allocation, supply capacity, global contribution, sharing planning level.**

I. NOMENCLATURE

α	Exponent for second summation law.
E_{Uhi}	Harmonic voltage emission limit of customer *i*.
E_{UhmS}	Harmonic voltage emission limit of Spare Capacity at bus m that can be shared with other busbars.
E_{UhmR}	Harmonic voltage emission limit of Reserved Capacity at bus m.
G_{hBm}	Global harmonic contribution at busbar *m*.
G_{hBj}	Maximum global contribution from busbar *j* where one or more loads are connected.
h	Harmonic order.
$K_{hi\text{-}m}$	Influence coefficient at busbar *m* from node *i*.
$L_{hHV\text{-}EHV}$	HV-EHV Planning level at harmonic *h*. Set by the utility.
Q_{Dshunt}	Dynamic rating of TCR or SVC connected.
S_{Din}	Power of HVDC station.
$S_{Existing\_Lds\_l}$	Connected existing load *l*.
$S_{Export\_P\_k}$	Connected export power *k*.
$S_{FutureLoad\_a}$	Proposed future load power *a*.
S_{Gen_i}	Connected generation power *i*.
S_i	Customer *i* agreed power.
$S_{Import\_P\_j}$	Connected import power *j*.
S_{in}	Power flowing into busbar (including future).
S_{mS}	Planned unused spare capacity at bus *m* that can be shared with other busbars.
S_{out}	Power flowing out of busbar (including future).
S_{mR}	Minimum reserved capacity power at bus m.
S_{SC}	Short circuit power of the system.
$S_{SpareCapacity}$	Proposed spare capacity power.
S_t, S_{tm}	An approximation of the total power of all installations at a busbar, e.g. busbar m.
S_{tS}, S_{tSm}	Total supply capacity at a busbar, e.g. busbar m
TSO	Transmission System Operator.
U_h	Net harmonic voltage.
U_{hi}	Harmonic voltage *i*.

II. INTRODUCTION

Harmonics in power systems have been a major issue for electricity utilities around the world. Excessive harmonic voltage levels can result in higher losses, overheating and malfunction of equipment. Electricity transmission and distribution companies are fully responsible for managing and setting harmonic limits for all network participants connected to their network. The technical report IEC/TR 61000-3-6:2008, Ed. 2 [1] provides the guidelines to help utilities to manage harmonics in their network. However, the application of the technical report is often complex and requires many assumptions. In particular, the existing harmonic allocation method for major loads in transmission systems has a number of practical challenges [2].

The existing method described in [1] heavily relies on the method to assess the approximation of the total power (S_t) of all installations at a busbar; the method for sharing planning levels between HV-EHV busbars; and the method for allocation of individual limits. The foundation of these methods is the second summation law, whereby harmonic voltages (or currents) are summated together using a power law approach to account for time and phase diversity, and the associated alpha constants. The second summation law is given by:

$$U_h = \sqrt[\alpha]{\sum_i U_{hi}^{\alpha}} \qquad (1)$$

Where the net harmonic voltage U_h is a combination of harmonic voltages U_{h1}, U_{h2},..., U_{hn} to the power of α, and α is selected from Table I for the relevant harmonic order.

TABLE I. HARMONIC SUMMATION EXPONENT FROM [2]

Harmonic (h)	Alpha (α)
$h < 5$	1
$5 \le h \le 10$	1.4
$h > 10$	2

The following practical issues have been identified when implementing the above mentioned methods:

- The method to assess the *Total Supply Capacity* at a bus bar (S_{tS}) is not considered in the report [1]. This report only provides instruction to assess the total power of all installations (S_t) at a bus. In addition, there is lack of clarity of the relationship between S_t and S_{tS}.
- The equations for sharing planning levels between HV-EHV busbars does not allow for unused spare capacity of a busbar to be shared among other busbars in the system in order to increase the global contribution at other busbars.
- The method for assessing individual limits does not account for the existing loads connected to the busbar.

This paper provides a comprehensive analysis of the issues and proposes relevant amendments to the technical report IEC/TR 61000-3-6:2008, Ed.2 [1]. The readers will need to familiarise themselves with the technical report due to space limitations of this paper, however references to the relevant equation numbers etc. within the report are provided for cross referencing.

III. PRACTICAL ISSUES WITH IEC/TR 61000-3-6

The following practical issues with the technical report [1] have been identified from [2]:

- Absence of *the Method for assessing* the total supply capacity of a busbar (S_{tS}).
- There is only method *for assessing S_t* in [1]. *Method for sharing planning levels between busbars in meshed HV-EHV system* in Section 9.2.2 and Annex D of [1].
- *Method for assessing individual limits* in Section 9.2.3 of [1].

Each of the above issues is described in more detail in the following subsections.

A. Existing Method for Assessing S_t

S_t is defined by as an approximation of the total power of all installations at a busbar or a substation taking into account of future network augmentation, as given by Equation 10 in [1] and provided here as (2).

$$S_t = \sum S_{Din} + \sum S_{out} + \sum Q_{Dshunt} \qquad (2)$$

It appears that this equation only covers the total power (S_t) of all installations and omits the total supply capacity (S_{tS}) at a busbar. Nevertheless, in practice it would be very difficult to estimate S_t or to calculate S_{tS} for a wide range of network scenarios with unknown future network augmentation. In particular, power flows of a busbar (refer to Figure 1) and network harmonic impedances in a meshed transmission system can change significantly between different network scenarios. The report [1] does not explicitly clarify the relationship between S_{tm} and S_{tSm} at busbar m. In addition, the relationship between the estimated S_t and the capability of a transmission network to absorb harmonic disturbances is not clearly articulated in the IEC technical report. It appears that there is a misalignment between the expression of total supply capacity (S_{tS}), (2) and practical planning assessment of S_t for existing and new installations.

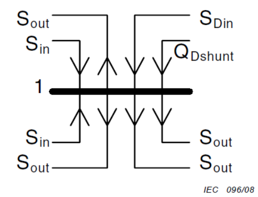


Figure 1. *Forecasted power flows for determining S_t [1]*

B. Existing Method for Sharing Planning Levels Between Busbars in Meshed HV-EHV Systems

The methodology for sharing planning levels amongst HV-EHV busbars is defined by Equation 14 of [1] and further expanded in Appendix D of the same report. It is repeated here as (3).

$$G_{hBm} \le \sqrt[\alpha]{\frac{S_{tm}}{K_{h1-m}^{\alpha}(S_{t1})+K_{h2-m}^{\alpha}(S_{t2})+..+(S_{tm})+..+K_{hn-m}^{\alpha}(S_{tn})}} \times L_{hHV-EHV} \qquad (3)$$

It is noted that the same condition for all busbars needs to be evaluated in order to find the minimum global contribution, G_{hBm}, that will ensure harmonic voltage levels at busbar m are not exceeded. It appears that this method primarily aims at ensuring that planning levels will not be exceeded when all distorting loads take up their full allocation. It has not considered the total supply capacity at the busbar or the possibility to allow for unused spare capacities. The difference between the total supply capacity and total loads at a busbar could be the spare capacity that can be shared with other busbars in order to increase the global contribution of other busbars. Therefore, the current method always results in a lower global contribution at the busbar regardless of how much unused spare capacities can be shared in the network. Lower global contribution at a busbar will unnecessarily limit harmonic allocation to all loads connected to that bus.

C. Existing Method for Assessing Individual Limits in Section 9.2.3

The current method for assessing Individual Limits is expressed by Equation 15 in Section 9.2.3 of [1]. It is repeated here as (4).

$$E_{Uhi} = G_{hBm}\left(\sqrt[\alpha]{\frac{S_i}{S_{tm}}}\right) \quad (4)$$

This equation does not adequately account for the size and harmonic emission of the existing loads connected to a busbar. Therefore, application of this expression for all loads, including existing and new loads, connected to a busbar can lead to over allocation that can cause planning levels to be exceeded. Also, the total supply capacity (S_{tSm}) is not taken into account, therefore any spare supply capacity available for sharing with other busbars has not been considered in the allocation methodology of [1].

IV. Assumptions and Proposed Principles

A. Adhere to the Existing Summation Law and Alpha Constants

One of the key guiding principles of the technical report [1] is that when all distorting installations are injecting levels of harmonic distortion equal to their emission limits, the total disturbance level anywhere in the system should not exceed the planning level and must satisfy:

$$\sqrt[\alpha]{\sum_{i\ at\ B1} E_{Uhi}{}^{\alpha} + \sum_{ii\ at\ B2} E_{Uhi}{}^{\alpha} + \ldots + \sum_{i\ at\ Bn} E_{Uhi}{}^{\alpha}} \le L_{hHV-EHV} \quad (5)$$

$$where \quad \sum_{ii\ at\ Bj} E_{Uhi}{}^{\alpha} \le G_{hBj}{}^{\alpha} \quad (6)$$

This needs to be satisfied for all buses, across all harmonics, with the selection of exponent α as per Table I.

B. Network Limits

Assessment of S_{tSm} must satisfy all relevant contingency conditions and applicable limits, which for a transmission system may include: (*n*-1), (*n*-1-1), (*n*-2), and (*n*-1-50MW) redundancy; thermal limit; steady-state-stability limit; transient stability limit; and electrical damping limit, as part of the network planning process. Refer to Figure 2 for the relative order of magnitudes of each contingency level.

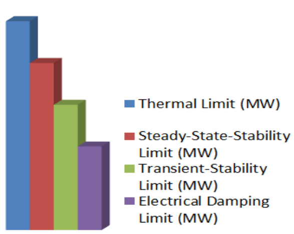


Figure 2. *Indication of Different Power System Limits*

Due to the significant differences in order of magnitude of the various contingency rating, selection of the appropriate conditions for harmonic allocations may have a significant bearing on final emission allocations.

C. First-Come First-Serve Basis

A Transmission System Operator (TSO) must ensure that S_{tSm} is planned in such a manner that it will not adversely affect the existing network participants e.g. loads, generators and other distribution systems connected to the transmission system via bulk supply points.

V. Proposed Amendments

The proposed amendments to [1] focus on improving the practicality and effectiveness of the existing method in the technical report. It increases the global contribution of a busbar and hence results in higher individual limits for loads connected to that busbar. The amendments can still guarantee that planning levels will not be exceeded as per the current mandate of [1].

A. Proposed Clarification for Assessing S_t and S_{tS}

The existing method focuses on the total power (S_t) of all installations at a busbar. It heavily relies on S_t to determine the global contribution at a substation and harmonic allocation to a load connected to the bus, as per (4). However, the focus should be on the total supply capacity (S_{tS}) at a busbar because S_{tS} must accommodates all loads connected to a busbar plus any spare supply capacity that can be reserved for future loads, shared with other busbars or simply reserved for safety margin.

Having a clear guideline and structured methodology to assess S_{tS} at each busbar in the network is very important. In general, S_{tS} of a busbar must adequately accommodate all loads connected to that busbar under the lowest applicable contingency limit as mentioned above (network limits).

The *Unused Spare Capacities,* which may be used to share in the network and the *Planned Reserved Capacity* are integral parts of S_{tS}, but have not been expressed in any equations of the existing technical report. The recommended method for assessing S_{tS} as the *Total Supply Capacity* at a busbar is proposed as follows:

- Assessment of S_{tS} must ensure that any changes to S_{tS} in the future due to network reconfiguration will not cause any adverse effects to the existing network participants.
- S_{tS} should be established as the apparent power (MVA) that can be *imported* to a busbar, satisfying all applicable contingency limits.
- Network elements connected to a busbar should be simplified and categorised in two groups:
  - (i) Importing/incoming power to a busbar from other busbars or substations via transmission lines, transformers, generators or HVDC.
  - (ii) Exporting/outgoing power from a busbar to another busbar or substation via transmission lines, transformers, loads which includes SVCs, arc furnaces, thyristor or IGBT controlled loads e.g. HVDC, SVC, STATCOM, Voltage Source Converters (VSCs) and other non-linear loads.
- Distributed Generators and HVDC should be considered both as a generation source and a harmonic load.

- The Total Supply Capacity (S_{tS}) at a substation consists of:
  - *Spare Supply Capacity* reserved for future loads;
  - *Unused Spare Supply Capacity* that can be used to share between HV-EHV substations; and
  - *Minimum Reserved Capacity* (i.e. safety margin/ headroom) as guaranteed minimum safety margin.

In theory, the *Minimum Reserved Capacity* at all busbars can be set as low as zero in order to achieve maximum global contribution at all busbars in the network, and hence allowing higher *individual limits* for loads connected to those busbars. In practice, the *Minimum Reserved Capacity* at each busbar can be set at around 10% of the *Unused Spare Capacity to Share*.

The proposed clarification for the assessment of the supply capacity at busbar *m* (S_{tSm}) is summarised below:

$$S_{tBm} = \left(\sum_{i=1}^{n} S_{Gen\_i} + \sum_{j=1}^{n} S_{\mathrm{Im}port\_P\_j} \right) - \left(\sum_{k=1}^{n} S_{Export\_P\_k} + \sum_{l=1}^{n} S_{Existing\_Lds\_l} \right) \tag{7}$$

$$\mathrm{S}_{\mathrm{tBm}} = \sum_{a=1}^{n} S_{FutureLoad\_a} + S_{Spare\_Capacity} \tag{8}$$

$$\mathrm{S}_{\mathrm{tBm}} = \sum_{a=1}^{n} S_{FutureLoad\_a} + \left(S_{mS} + S_{mR} \right) \tag{9}$$

B. Proposed Modification to the Existing Method for Sharing Planning Levels Between Busbars in Meshed HV-EHV Systems

In order to utilise the shared planning level method more effectively, the *Unused Spare Capacity* of a busbar must be presented in the *Share Planning Level* equation. Therefore (10) is proposed to replace the existing Equation (D.2) from [1], which is derived from (3). As a result, the global contribution of other busbars in the system can be increased depending on their location in the network. Noting S_{ms} is the *Planned Unused Spare Capacity* at busbar *m* that can be shared (*Capacity to Share*) with other busbars in the system.

$$G_{hBm} \leq \sqrt[\alpha]{\frac{S_{tsm}}{K_{h1-m}^{\alpha}(S_{ts1}-S_{1s}) + K_{h2-m}^{\alpha}(S_{ts2}-S_{2s}) + .. + (S_{tsm}-S_{ms}) + .. + K_{hn-m}^{\alpha}(S_{tsn}-S_{ns})}} \times L_{hHV\text{-}EHV} \tag{10}$$

In order to ensure that the planning level will not be exceeded, the global contribution G_{hBm} at busbar *m* in a system of <u>*n* busbars</u> must satisfy all <u>*n* conditions</u> below - example provided for busbar 1:

Condition 1:

$$G_{hB1} \leq \sqrt[\alpha]{\frac{S_{ts1}}{(S_{ts1}-S_{1s}) + K_{h2-1}^{\alpha}(S_{ts2}-S_{2s}) + .. + K_{hn-1}^{\alpha}(S_{tsn}-S_{ns})}} \times L_{hHV-EHV} \tag{11}$$

Condition 2:

$$G_{hB1} \leq \sqrt[\alpha]{\frac{S_{ts1}}{K_{h1-2}^{\alpha}(S_{ts1}-S_{1s}) + (S_{ts2}-S_{2s}) + .. + K_{hn-2}^{\alpha}(S_{tsn}-S_{ns})}} \times L_{hHV-EHV} \tag{12}$$

Condition *n*:

$$G_{hB1} \leq \sqrt[\alpha]{\frac{S_{tS1}}{K_{h1-n}^{\alpha}(S_{tS1}-S_{1S}) + K_{h2-n}^{\alpha}(S_{tS2}-S_{2S}) + .. + (S_{tSn}-S_{nS})}} \times L_{hHV-EHV} \tag{13}$$

C. Proposed Modification to the Method for Assessing Individual Limits

The recommended amendment for (4) is shown below in (14) to account for both new and existing installations under consideration.

$$E_{Uhi} = \sqrt[\alpha]{\left(G_{hBm}{}^{\alpha} - \sum_{l=1}^{n} E_{Uh\_ExistingLoads\_l\_@Bm}{}^{\alpha} \right) \left(\frac{S_i}{S_{tSm} - \sum_{l=1}^{n} S_{ExistingLoads\_l\_@Bm}} \right)}$$

(14)

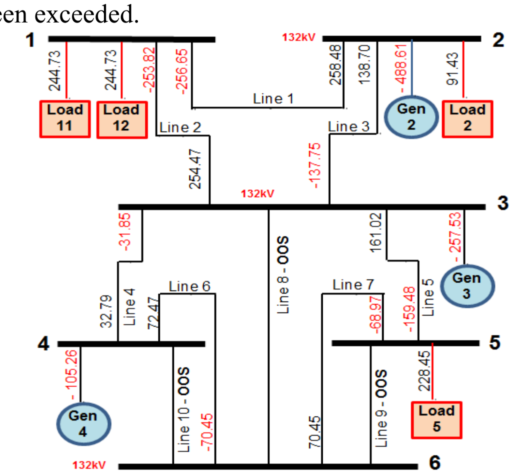
New equation (14) is proposed to supersede (4) above, which is currently used by the IEC technical report. Noting $E_{Uh\_Existingloads\_l\_@Bm}$ is the emission limit of the existing loads connected to busbar *m*, and $S_{Existingloads\_l\_@Bm}$ is the agreed power of the existing loads.

D. Harmonic Allocation to Major Loads in Transmission System - With and Without Proposed Modification to IEC/TR 61000-3-6:2008, Ed.2.

A case study has been conducted to allocate harmonic emissions to three major loads in a simplified Six-Bus Transmission Network, as shown in Figure 3, with line parameters provided in Table II.

- Bus 1: Load 11, Load 12
- Bus 2: Load 2
- Bus 5: Load 5

The focus of this case study is to demonstrate how the global contribution (G_{hBm}) of the busbars and the individual limits (E_{Uhi}) for loads can be increased by utilising the *Unused Spared Capacities* in the network. The results have confirmed that while the global contribution and individual limits are increased, the planning levels of all harmonics have not been exceeded.



-ve: Importing Power into the Bus

Figure 3. *A Simplified Six-Bus Transmission Network*

TABLE II. TRANSMISSION LINE PARAMETERS

Parameters	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6	Line 7
R (Ω)	7.18	4.44	5.92	5.92	4.44	11.41	11.41
X (Ω)	55.74	33.42	44.57	44.57	33.42	46.79	46.79
L (km)	180	90	120	120	90	120	120
C ((uF/km)	1.18E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	9.50E-03	9.50E-03

TABLE III. EXAMPLE ASSESSMENT OF SUPPLY CAPACITIES S_{tS}

Network Elements	Bus1 (MVA)	Bus 2 (MVA)	Bus 3 (MVA)	Bus 4 (MVA)	Bus 5 (MVA)	Bus 6 (MVA)
Line 1 [Bus 1-2]	-256.95	258.48				
Line 2 [Bus 1-3]	-253.82		254.47			
Line 3 [Bus 2-3]		138.70	-137.75			
Line 4 [Bus 3-4]			-31.85	32.79		
Line 5 [Bus 3-5]			161.02		-159.48	
Line 6 [Bus 4-6]				72.47		-70.45
Line 7 [Bus 5-6]					-68.97	70.45
Line 8 [Bus 3-6]			0.00			0.00
Line 9 [Bus 5-6]					0.00	0.00
Line 10 [Bus 4-6]				0.00		0.00
Line 11 [Bus NA]						
Line 12 [Bus NA]						
Base Load Generator 2		-488.61				
Base Load Generator 3			-257.53			
Base Load Generator 4				-105.26		
HVDC Source						
Voltage Source Converter						
Distributed Generator						
Supply Capacity - S_{tsm}	**-510.77**	**-91.43**	**-11.64**	**0.00**	**-228.45**	**0.00**
SVC 1	0.00					
Distributed Generator						
HVDC						
Voltage Source Converter						
Load 11	244.73					
Load 12	244.73					
Load 2		91.43				
Load 5					228.45	
Spare Capacity	-21.31	0.00	-11.64	0.00	0.00	0.00
Spare Capacity to Share S_{sm}	19.18		10.48			
Reserved Capacity	-2.13	0.00	-1.16	0.00	0.00	0.00

E. Case Study Results

- Application of the proposed clarification for Assessing S_{tS} is demonstrated in Table III – Assessment Supply Capacities.
- Increased global contribution obtained from the proposed amendment to the *Sharing Planning Level* method utilising *Unused Spare Capacity* is shown in Table IV.
- Desirable Harmonic voltage performance is obtained from the proposed clarification for the assessment of S_{tS} and amendments to the methodology of Sharing Planning Level and the methodology of assessing Individual Limits (Table V).

F. Example: Assessment of Individual Limits Based on the Proposed Modification

This example demonstrates how the increased global contribution (G_{hBm}) at Bus 1 can be fairly distributed to Load 11, Load 12 and Reserved Capacity for Safety Margin at Bus 1.

a) Total Supply Capacity at Bus 1.

$$S_{tS1} = S_{Ld\_11} + S_{Ld\_12} + S_{1S} + S_{1R} \tag{15}$$

TABLE IV. INCREASED PERCENTAGES OF GLOBAL CONTRIBUTION DUE TO MODIFICATION TO IMPROVED PLANNING LEVEL METHOD

Increased Percentages of The Global Contribution G_{hBm} at Loaded Buses Due to Proposed Modification to the Sharing Planning Levels Methodology to Utilise Sharing Unused Spare Capacities in the Network			
h	Loaded Buses		
	1	2	5
2	4.645%	4.191%	4.191%
3	4.597%	4.143%	4.143%
4	4.534%	4.080%	4.080%
5	3.545%	3.224%	3.224%
6	3.339%	3.019%	3.019%
7	4.734%	4.410%	4.410%
8	23.719%	23.336%	23.336%
9	2.184%	1.867%	1.867%
10	1.012%	0.699%	0.699%
11	1.405%	1.185%	1.185%
12	2.080%	1.858%	1.858%
13	2.068%	1.847%	1.847%
14	1.308%	1.088%	1.088%
15	2.023%	1.801%	1.801%
16	1.873%	1.652%	1.652%
17	2.036%	1.815%	1.815%
18	0.966%	0.747%	0.747%
19	0.642%	0.423%	0.423%
20	82.039%	81.644%	81.644%
21	5.321%	5.093%	5.093%
22	0.831%	0.612%	0.612%
23	2.119%	1.898%	1.898%
24	2.091%	1.870%	1.870%
25	2.214%	1.992%	1.992%

TABLE V. DESIRED HARMONIC VOLTAGE PERFORMANCE DUE TO MODIFICATION TO IMPROVED PLANNING LEVEL METHOD

Desired Harmonic Voltage Performance Due To Proposed Amendment to IEC/TR 61000-3-6:2008, Ed. 2								
h				Bus				
	Plan	1	2	3	4	5	6	7
1	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
2	1.400%	1.400%	0.702%	0.803%	0.442%	1.143%	0.820%	1.400%
3	2.000%	2.000%	1.041%	1.234%	0.726%	1.778%	1.353%	2.000%
4	0.800%	0.778%	0.430%	0.543%	0.353%	0.800%	0.664%	0.778%
5	2.000%	1.604%	0.960%	1.295%	0.972%	2.000%	1.861%	1.604%
6	0.400%	0.130%	0.104%	0.203%	0.199%	0.371%	0.400%	0.130%
7	2.000%	0.638%	0.258%	0.510%	0.897%	1.572%	2.000%	0.638%
8	0.400%	0.203%	0.118%	0.089%	0.182%	0.229%	0.400%	0.203%
9	1.000%	0.334%	0.261%	0.307%	0.545%	0.268%	1.000%	0.334%
10	0.350%	0.085%	0.085%	0.098%	0.217%	0.058%	0.350%	0.085%
11	1.500%	0.813%	0.930%	0.689%	0.902%	0.569%	1.500%	0.813%
12	0.318%	0.165%	0.314%	0.255%	0.117%	0.112%	0.318%	0.165%
13	1.500%	0.652%	1.402%	1.401%	0.359%	0.540%	1.500%	0.652%
14	0.296%	0.111%	0.113%	0.279%	0.056%	0.158%	0.296%	0.111%
15	0.300%	0.204%	0.300%	0.261%	0.212%	0.153%	0.260%	0.204%
16	0.279%	0.273%	0.279%	0.056%	0.166%	0.170%	0.048%	0.273%
17	1.200%	1.200%	1.138%	0.378%	1.012%	0.802%	0.269%	1.200%
18	0.266%	0.174%	0.166%	0.114%	0.266%	0.121%	0.117%	0.174%
19	1.074%	0.234%	0.385%	0.493%	1.074%	0.171%	0.713%	0.234%
20	0.255%	0.183%	0.252%	0.089%	0.237%	0.210%	0.255%	0.183%
21	0.200%	0.114%	0.122%	0.062%	0.159%	0.200%	0.196%	0.114%
22	0.246%	0.092%	0.090%	0.133%	0.207%	0.246%	0.235%	0.092%
23	0.887%	0.757%	0.843%	0.787%	0.867%	0.887%	0.874%	0.757%
24	0.239%	0.196%	0.226%	0.225%	0.231%	0.239%	0.235%	0.196%
25	0.816%	0.403%	0.763%	0.816%	0.752%	0.706%	0.729%	0.403%

b) Harmonic allocation for Load 11 can be based on (15).

There was no Existing Load before Load 11.

$$\sum S_{Existing\_Loads\_@Bus1} = 0$$

$$\sum E_{Uh\_Existing\_Loads\_@Bus1}{}^{\alpha} = 0$$

Harmonic allocation for Load 11 can be calculated from (16) below:

$$E_{Uh\_Ld\_11} = \sqrt[\alpha]{\left(G_{hB1}{}^{\alpha} - 0^{\alpha}\right)\left(\frac{S_{Ld\_11}}{S_{tS1} - 0}\right)} = \sqrt[\alpha]{\left(G_{hB1}{}^{\alpha}\right)\left(\frac{S_{Ld\_11}}{S_{tS1}}\right)} \qquad (16)$$

c) Harmonic allocation for Load 12. Load 11 is now considered as existing load.

$$\sum S_{Existing\_Loads\_@Bus1} = S_{Ld\_11}$$

$$\sum E_{Uh\_Existing\_Loads\_@Bus1}{}^{\alpha} = E_{Uh\_Ld\_11}{}^{\alpha}$$

$$E_{Uh\_Ld\_12} = \sqrt[\alpha]{\left(G_{hB1}{}^{\alpha} - E_{Uh\_Ld\_11}{}^{\alpha}\right)\left(\frac{S_{Ld\_12}}{S_{tS1} - S_{Ld\_11}}\right)} \qquad (17)$$

d) Estimate Harmonic Emission Right that could have been allocated for the *Unused Spare Capacity* (E_{Uh1S}) that has now been shared with other buses to increase their *Global Contribution*.

$$\sum S_{Existing\_Loads\_@Bus1} = S_{Ld\_11} + S_{Ld\_12}$$

$$\sum E_{Uh\_Existing\_Loads\_@Bus1}{}^{\alpha} = E_{Uh\_Ld\_11}{}^{\alpha} + E_{Uh\_Ld\_12}{}^{\alpha}$$

$$E_{Uh1S} = \sqrt[\alpha]{\left(G_{hB1}{}^{\alpha} - E_{Uh\_Ld\_11}{}^{\alpha} - E_{Uh\_Ld\_12}{}^{\alpha}\right)\left(\frac{S_{1S}}{S_{tS1} - S_{Ld\_11} - S_{Ld\_12}}\right)}$$

(18)

Estimate Harmonic Emission Right that could have been allocated for the *Reserved Capacity* (E_{uh1R}) - safety margin.

$$\sum S_{Existing\_Loads\_@Bus1} = S_{Ld\_11} + S_{Ld\_12} + S_{1S}$$

$$\sum E_{Uh\_Existing\_Loads\_@Bus1}{}^{\alpha} = E_{Uh\_Ld\_11}{}^{\alpha} + E_{Uh\_Ld\_12}{}^{\alpha} + E_{Uh1S}{}^{\alpha}$$

$$E_{Uh1R} = \sqrt[\alpha]{\left(G_{hB1}{}^{\alpha} - E_{Uh\_Ld\_11}{}^{\alpha} - E_{Uh\_Ld\_12}{}^{\alpha} - E_{Uh1S}{}^{\alpha}\right)\left(\frac{S_{1R}}{S_{tS1} - S_{Ld\_11} - S_{Ld\_12} - S_{1S}}\right)}$$

(19)

The proposed modification for assessing the Individual Limits as shown in (19) confirms the summation law and displays in (20) below because

$$S_{1R} = S_{tS1} - S_{Ld\_11} - S_{Ld12} - S_{1S}$$

$$G_{hB1} = \sqrt[\alpha]{E_{Uh\_Ld\_11}{}^{\alpha} + E_{Uh\_Ld\_12}{}^{\alpha} + E_{Uh1S}{}^{\alpha} + E_{Uh1R}{}^{\alpha}} \qquad (20)$$

It is important to note that the *Unused Spare Capacity to Share* has been deducted from the denominator terms of the Share Planning Levels equations. Therefore, the *Spare Capacity* no longer exists because it has been used to increase the global contribution at other buses. Subsequently, the allocation of individual limits for the *Unused Spare Capacity to Share* (E_{Uh1S}) should not be included in the calculation of the total harmonic emission at the bus. Harmonic Emission at bus 1 should be:

$$E_{Uh1} = \sqrt[\alpha]{E_{Uh\_Ld\_11}{}^{\alpha} + E_{Uh\_Ld\_12}{}^{\alpha} + E_{Uh1R}{}^{\alpha}} \qquad (21)$$

VI. CONCLUSION

A number of issues have been identified when applying the IEC/TR 61000-3-6 Edition 2:2008 for major loads in transmission system. These include: the method to assess S_t or S_{tS} is not clear; the method for sharing planning levels between HV-EHV busbars does not allow any *Unused Spare Capacity* to be shared in order to increase G_{hBm}; and the method for allocating individual limits to loads does not include for size and emissions of existing loads in the system.

This paper has put forward recommendations to improve the useability and accuracy of the IEC / TR report. The results obtained from the proposed amendment have been very positive. The method for assessment of S_t has been clarified. The global contribution *(G_{hBm})* has been significantly increased and higher individual limits (E_{Uhi}) for loads have also been achieved while planning levels have not been exceeded.

VII. REFERENCES

[1] IEC/TR 61000-3-6, Edition 2, 2008. "Electromagnetic Compatibility (EMC) – part 3.6: Limits – Assessment of Emission Limits for the Connection of Distorting installations to MV, HV and EHV Power Systems".

[2] T. Vu, D. Robinson, V. Gosbell, S. Perera, R. Memisevic, CIRED Lyon, 2015, "Practical Issues with Transmission System Harmonic Allocation Using IEC/TR 61000.3.6, Edition 2, 2008".

[3] T.J. Browne, V.J. Gosbell, S. Perera, D.A. Robinson, L.M. Falla, P.J. Windle, A.C.D. Perera, 2006, "Experience in the Application of IEC/TR 61000-3-6 To Harmonic Allocation in Transmission Systems", Cigre Paris, Paper C4-401.

[4] T.J. Browne, V.J. Gosbell, S. Perera, 2005, "Harmonic Allocation to Aggregated Regions within a Transmission Network", Proc.AUPEC'05, Hobart, Australia, Paper S24.4.

[5] M.H.J. Bollen, S. Mousavi-Garigari, S. Bahramirad, 2014, "Harmonic resonances due to transmission system cables", Inter. Conf. on Renewable Energies and Power Quality (ICREPQ'14), Spain, 8-10 April, Paper 463.

[6] D. Robinson, 2003, Harmonic Management in MV Distribution Systems, University of Wollongong, Doctor of Philosophy Thesis.

[7] E. Acha, M. Madrigal, 2001, "Power Systems Harmonics – Computer Modelling and Analysis", Wiley.