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Distinction Between "Destructive" and "Constructive" Harmonic Currents to the Voltage Quality

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Abstract—This paper discusses the distinction between the harmonic currents that have a destructive effect and those that have a constructive effect on the voltage quality. Most standards allocate some limits for the harmonic current magnitude at the point of common coupling (PCC) to restrict the harmonic voltage at the PCC. This paper aims to answer "whether all kinds of harmonic currents are destructive to the voltage quality and should be restricted to reach a better voltage quality." The results of this paper show that in many cases, despite a high harmonic current at the PCC, the customer decreases the harmonic voltage at the PCC and, subsequently, improves the voltage quality. An example of such situations could be connecting a customer with a passive or active harmonic filter to a grid with a high background harmonic distortion. Therefore, restriction of harmonic current at the PCC does not necessarily result in a better voltage quality. This paper proposes a parameter to distinguish the constructive harmonic currents from the destructive ones.

Index Terms—Current quality, harmonic cancellation, harmonic mitigation, harmonics, power quality (PQ), voltage quality.

I. INTRODUCTION

Nonlinear loads and power electronic equipment are increasingly used in grids. These loads inject some harmonic currents in the PCC. The harmonic currents flow in the upstream power grid. Depending on the impedance of upstream grid equipment (lines, cables, transformers, etc.), the harmonic currents cause harmonic distortion in the voltage waveform. Harmonic distortion in the voltage could affect the efficiency and performance of the equipment existed in the network. In order to achieve a voltage with high quality, some responsibilities are allocated to the utility and customers. The utility is responsible for the voltage quality and should provide a proper voltage with low harmonic distortion for the customers. On the other hand, customers are responsible for their current to ensure that their current does not ruin the voltage quality provided by the utility [1]. In this regard, some standards [1], [2] have allocated some limits for harmonic voltage levels in the power grid to enforce the utility to provide customers with a high-quality voltage. On the other hand, these standards allocate some limits also for the harmonic currents injected by the customers to enforce them to maintain the high-quality voltage provided by the utility. What has not been considered in this strategy is the answer

to the question of "whether all kinds of the harmonic current injected by customers ruin the voltage quality."

This paper discusses "which kind of harmonic currents has a destructive effect on the voltage quality and should be limited"; and "which kind of them has a constructive effect on the voltage quality and should be encouraged by the utility."

II. PROBLEM DESCRIPTION

It is common to present the utility and customer sides by their Thevenin or Norton equivalent circuits at each harmonic order [3]–[5]. The analyses in this paper are based on the Norton equivalent circuits (see Fig. 1). In this paper, the "Harmonic Voltage Change Ratio Due to Customer" ($\rho_{\Delta v}$) is chosen as a criterion to distinguish customers which have a destructive effect from which have a constructive effect on the voltage quality. According to [5], $\rho_{\Delta v}$ is defined as follows:

$$\rho_{\Delta v} = \frac{V_{pcc}}{V_u} \quad (1)$$

Based on Fig. 1, $\rho_{\Delta v}$ is defined as the ratio of the post-connection harmonic voltage at the PCC (V_{pcc}), see Fig. 1(a), to the preconnection harmonic voltage at the PCC (V_u), see Fig. 1(b). The customer could affect the harmonic voltage at the PCC by its equivalent admittance ($\underline{Y}_c$) as well as its equivalent current source ($\underline{I}_u$). $\rho_{\Delta v}$ includes both effects. In other words, $\rho_{\Delta v}$ determines the relative harmonic voltage change at the PCC caused by the customer. Table I presents the statements concluded from $\rho_{\Delta v}$ and the proposed countermeasure by this paper to reach a better voltage quality at the PCC (i.e., lower V_{pcc}). Parameter $\frac{I_{Y_u}}{I_u}$ is defined in section III-B.

It should be noted that, in this paper, parameters with underline (e.g., $\underline{\rho}_{\Delta v}$) are complex numbers and parameters without underline (i.e., $\rho_{\Delta v}$) are either the magnitude of complex numbers or scalar numbers.

III. DESTRUCTIVE AND CONSTRUCTIVE HARMONIC CURRENTS

In this section, the "destructive" and "constructive" harmonic currents to the voltage quality are distinguished based on the criterion of $\rho_{\Delta v}$ for two conditions of the utility, which are described in the following sections.

TABLE I: INTERPRETATION OF $\rho_{\Delta v}$ AND $\frac{I_{Y-u}}{I_u}$

$\rho_{\Delta v}$	$\frac{I_{Y-u}}{I_u}$	Statement	Effect on the voltage quality	Countermeasure
$\rho_{\Delta v} > 1$	$\frac{I_{Y-u}}{I_u} > 1$	Customer increases V_{pcc}	Destructive	Restriction of customer current
$\rho_{\Delta v} < 1$	$\frac{I_{Y-u}}{I_u} < 1$	Customer decreases V_{pcc}	Constructive	Giving the customer an incentive
$\rho_{\Delta v} = 1$	$\frac{I_{Y-u}}{I_u} = 1$	Customer does not change V_{pcc}	Neutral	Not necessary

Fig. 1: Norton equivalent circuit: a) Post-customer-connection state; b) Pre-customer-connection state.

A. Utility with Negligible Background Harmonic Distortion

The utility side in grids with less power electronic interfaced customers has a low background harmonic distortion that could be neglected in many cases ($I_u = V_u = 0$). In such situations, V_{pcc} is determined as follows:

$$V_{pcc} = \frac{I_{pcc}}{Y_u} \quad (2)$$

According to (2), V_{pcc} is directly proportional to I_{pcc} . Therefore, in such cases, all kinds of harmonic current injected into the PCC increase V_{pcc} ($\rho_{\Delta v} > 1$) and should be considered as destructive harmonic currents. In other words, the higher I_{pcc} is, the higher V_{pcc} is. Accordingly, restricting I_{pcc} is a proper countermeasure to reach a better voltage quality (i.e., lower V_{pcc}) in such situations.

B. Utility with Significant Background Harmonic Distortion

By increasing power electronic equipment in the modern power grids, the background harmonic distortion at the PCC cannot be neglected anymore ($I_u \neq 0$). In such situations, V_{pcc} is determined as follows:

$$V_{pcc} = \frac{I_{Y-u}}{Y_u} \quad (3)$$

$$I_{Y-u} = I_{pcc} + (-I_u) \quad (4)$$

According to (3), V_{pcc} is directly proportional to the magnitude of harmonic current injected into the utility equivalent admittance (I_{Y-u}) and not anymore proportional to I_{pcc} . Since I_{Y-u} is equal to the vector summation of I_{pcc} and $-I_u$, the phase angle difference between I_{pcc} and I_u , in addition to the magnitude of I_{pcc} , has a significant impact on the V_{pcc} . For this reason, in the grids with significant background harmonic distortion, I_{pcc} is no longer a valid indicator to demonstrate how the customer affects V_{pcc} . Therefore, allocating a limit

for I_{pcc} could not be necessarily a suitable countermeasure to reach a better voltage quality in all cases. Nevertheless, the limitation of harmonic currents (i.e., I_{pcc}) is the most widespread approach in standards [2]. This paper proposes employing $\frac{I_{Y-u}}{I_u}$ instead of I_{pcc} as an indicator based on current quantity with which the effect of the customer on V_{pcc} can be interpreted. Before the customer connection, the harmonic current injected into the utility equivalent admittance is equal to $-I_u$, which causes a harmonic voltage at the PCC equal to $V_u = \frac{-I_u}{Y_u}$. After the customer connection, the harmonic current injected into the utility equivalent admittance is equal to $I_Y = I_{pcc} + (-I_u)$, and accordingly, the harmonic voltage at the PCC is equal to $V_{pcc} = \frac{I_{Y-u}}{Y_u}$. If I_{Y-u} is bigger than I_u (i.e., $\frac{I_{Y-u}}{I_u} > 1$), the customer increases V_{pcc} after the connection ($\rho_{\Delta v} > 1$) and has a destructive harmonic current to the voltage quality. Therefore, I_{pcc} should be restricted. If I_{Y-u} is smaller than I_u (i.e., $\frac{I_{Y-u}}{I_u} < 1$), the customer decreases V_{pcc} after the connection ($\rho_{\Delta v} < 1$) and has a constructive harmonic current to the voltage quality. Therefore, the customer should be encouraged rather than be restricted by the utility, even if its harmonic current level is relatively high. In such situations, the customer acts as a harmonic filter for the grid, and the utility should give the customer an incentive to encourage it.

In the case of having a negligible background harmonic distortion at the PCC (Section III-A), I_u is equal to 0, and I_{Y-u} is equal to I_{pcc} . Therefore, in such grids, I_{pcc} has a same meaning as I_{Y-u} . For this reason, any harmonic current injected by the customer should be considered as a destructive harmonic current and I_{pcc} should be restricted independent of its phase angle (because always $I_{Y-u} = I_{pcc} > I_u = 0$).

The "statements" concluded from I_{Y-u} and the proposed Countermeasures to reach a better voltage quality at the PCC (i.e., lower V_{pcc}) are presented in Table I. It should be noted that $\frac{I_{Y-u}}{I_u}$ is mathematically equal to $\rho_{\Delta v}$, and accordingly, the statements concluded from both of them are the same (see Table I). This paper employs $\frac{I_{Y-u}}{I_u}$ in the analyses instead of $\rho_{\Delta v}$ because it is based on current quantity, making the analysis of destructive and constructive harmonic currents easier and more understandable.

IV. CALCULATION RESULTS AND INTERPRETATION OF SOME EXEMPLARY CASES

In this section, the destructive harmonic currents are distinguished from constructive ones for some exemplary cases, and it is investigated whether the limits allocated for I_{pcc} by standards (e.g., IEEE Standard 519-2014 [1]) are consistent with the aimed limitations for V_{pcc} .

IEEE Standard 519-2014 recommends some limits for V_{pcc} and I_{pcc} based on the voltage system level, the harmonic order, and the ratio of maximum short-circuit current at PCC to maximum demand load current ($\frac{I_{sc}}{I_L}$). The general assumptions of the case studies and their corresponding harmonic limits allocated by IEEE Standard 519-2014 are presented in Table II. According to this table, the individual harmonic voltage limit and current limit, allocated by IEEE Standard 519-2014, for these cases are 3.0% and 3.5%, respectively. According to IEEE Standard 519-2014, the utility is responsible for the voltage quality and the customer is responsible for the current quality at the PCC. Therefore, in the case of exceeding I_{pcc}^{max} , the customer harmonic current is restricted.

In this section, six exemplary cases are analyzed. The utility Norton equivalent parameters for all the cases are the same. The equivalent current source and admittance of the utility are equal to $\underline{I}_u = 4\% \angle 180^\circ$ and $\underline{Y}_u = 10\% - 142\%j$, respectively. These cases differ only in customer parameters. The customer Norton equivalent parameters for each case are presented in Table III. These six cases are divided into three categories of the customer as follows.

A. Customer with Negligible Equivalent Admittance ($\underline{I}_c \neq 0$ & $\underline{Y}_c = 0$)

Here, it is assumed that the equivalent admittance of the customer is negligible and, therefore, it can be represented by only the equivalent current source. According to this assumption, two exemplary cases (Case I and II) are defined (see Table III). These two cases differ only in the phase angle of the customer current source.

Table IV presents the corresponding quantities (V_u , V_{pcc} , I_{pcc} , and I_{Y-u}) of these two cases as well as the proposed countermeasures based on I_{pcc} (IEEE Standard 519-2014) and based on I_{Y-u} (approach of this paper). As can be seen, the countermeasures suggested by these two approaches are not the same in all cases. Subsequently, this issue is illustrated using phasor diagrams. Fig. 2 demonstrates the phasor diagram of the current quantities ($\underline{I}_{pcc}$, $\underline{I}_{Y-u}$, and $\underline{I}_u$) and the voltage quantities ($\underline{V}_u$ and $\underline{V}_{pcc}$) for each case. The red circles demonstrate I_{pcc}^{max} and V_{pcc}^{max} allocated by IEEE Standard 519-2014.

As shown, in Case I, $-\underline{I}_u$ and $\underline{I}_{pcc}$ (here $\underline{I}_{pcc} = \underline{I}_c$) have a small phase angle difference. Therefore, the vector summation of them, which results in $\underline{I}_{Y-u}$, is higher than $\underline{I}_u$ (i.e. $\frac{I_{Y-u}}{I_u} > 1$). For this reason, V_{pcc} is increased after the connection of the customer. Therefore, in this case, the customer current should be restricted (because of destructive harmonic current).

In contrast to the previous case, $-\underline{I}_u$ and $\underline{I}_{pcc}$ (here $\underline{I}_{pcc} = \underline{I}_c$) have almost opposite phase angles in Case II. Therefore, after the customer connection, $\underline{I}_u$ and $\underline{I}_{pcc}$ cancel out each other considerably, resulting in a lower $\underline{I}_{Y-u}$ than $\underline{I}_u$ (i.e. $\frac{I_{Y-u}}{I_u} < 1$). Subsequently, V_{pcc} is decreased after the connection of the customer. In this case, the customer should be encouraged (because of constructive harmonic current), and the utility should give it an incentive. Case II could be an example of a customer with a shunt active harmonic filter. In an

TABLE II: GENERAL ASSUMPTIONS OF CASE STUDIES AND THEIR CORRESPONDING HARMONIC LIMITS BASED ON IEEE STANDARD 519-2014 [1]

Case Studies's General Assumptions	
Harmonic order (h)	13
Voltage system level	69kV
$\frac{I_{sc}}{I_L}$	20
Limits based on IEEE STANDARD 519-2014	
Individual harmonic voltage limit (V_{pcc}^{max})	3.0%
Individual harmonic current limit (I_{pcc}^{max})	3.5%

TABLE III: CUSTOMER NORTON PARAMETERS OF EXEMPLARY CASES

Customer Category	Case	$\underline{I}_c$	$\underline{Y}_c$
A) $\underline{I}_c \neq 0$ & $\underline{Y}_c = 0$	I	$4.7\% \angle 30^\circ$	0
	II	$4.7\% \angle 165^\circ$	0
B) $\underline{I}_c = 0$ & $\underline{Y}_c \neq 0$	III	0	∞ (i.e., $\underline{Z}_c = 0$)
	IV	0	$33\% + 150\%j$
C) $\underline{I}_c \neq 0$ & $\underline{Y}_c \neq 0$	V	$18\% \angle 30^\circ$	$50\% - 495\%j$
	VI	$18\% \angle 165^\circ$	$50\% - 495\%j$

optimal compensation method for system-wide voltage quality improvement [6], an active filter will not only compensate for the harmonic current of the local customer (what local compensation does) but also compensate for the harmonic voltage contribution of other customers distributed in the power grid (e.g., background harmonic distribution). For this reason, it always injects an additional harmonic current, which should be considered as constructive harmonic current, into the grid. Despite this major difference between case I and II, many standards do not distinguish between these cases because I_{pcc} in both cases is the same. According to IEEE Standard 519-2014, the harmonic current at the PCC in both cases should be restricted because I_{pcc} exceeds I_{pcc}^{max} ($I_{pcc} > 3.5\%$).

B. Customer with Negligible Equivalent Current Source ($\underline{I}_c = 0$ & $\underline{Y}_c \neq 0$)

Here, it is assumed that the customer equivalent current source is negligible and, it can be represented by only its equivalent admittance. Here, two cases (Case III and IV) are defined (See Table III). These two cases differ in the customer equivalent admittance. Table V and Fig. 3 correspond to the results of these cases. The phasor diagram scale in case IV (Fig. 3) is five times larger than other phasor diagrams. Case III could be an example of a customer with a shunt passive harmonic filter. A passive filter prepares a low-impedance way, through which the harmonic currents can flow. Consequently, almost all $\underline{I}_u$ flows through the filter, and only a small part of $\underline{I}_u$ flows through utility equivalent admittance ($\underline{I}_{Y-u} \approx 0$). Subsequently, V_{pcc} is decreased effectively after the connection of the filter ($V_{pcc} \approx 0$). For this reason, the customer's harmonic current, in this case, should be considered as a constructive harmonic current and should be encouraged, although I_{pcc} is relatively high. Despite this, most standards do not distinguish between this case and Case I. For example, according to IEEE Standard 519-2014, I_{pcc} , in Case III, should be restricted too because I_{pcc} exceeds I_{pcc}^{max} ($I_{pcc} > 3.5\%$).

TABLE IV: CORRESPONDING QUANTITIES OF CASE I AND II (CUSTOMER WITH NEGLIGIBLE EQUIVALENT ADMITTANCE)

Case	V_u	V_{pcc}	I_{pcc}	I_{Y-u}	Countermeasure based on I_{pcc} (IEEE Standard 519-2014)	Countermeasure based on I_{Y-u} (Approach of this paper)
I	2.8%	5.9%	4.7%	8.4%	Restriction of customer current (because $I_{pcc} > I_{pcc}^{max}$)	Restriction of customer current (because $\frac{I_{Y-u}}{I_u} > 1$ or $\rho_{\Delta v} > 1$)
II	2.8%	0.9%	4.7%	1.3%	Restriction of customer current (because $I_{pcc} > I_{pcc}^{max}$)	Giving the customer an incentive (because $\frac{I_{Y-u}}{I_u} < 1$ or $\rho_{\Delta v} < 1$)

Fig. 2: Phasor diagrams of Case I and II (customer with negligible equivalent admittance)

TABLE V: CORRESPONDING QUANTITIES OF CASE III AND IV (CUSTOMER WITH NEGLIGIBLE EQUIVALENT CURRENT SOURCE)

Case	V_u	V_{pcc}	I_{pcc}	I_{Y-u}	Countermeasure based on I_{pcc} (IEEE Standard 519-2014)	Countermeasure based on I_{Y-u} (Approach of this paper)
III	2.8%	0.00	3.9%	0.1%	Restriction of customer current (because $I_{pcc} > I_{pcc}^{max}$)	Giving the customer an incentive (because $\frac{I_{Y-u}}{I_u} < 1$ or $\rho_{\Delta v} < 1$)
IV	2.8%	25.8%	38.7%	36.7%	Restriction of customer current (because $I_{pcc} > I_{pcc}^{max}$)	Restriction of customer current (because $\frac{I_{Y-u}}{I_u} > 1$ or $\rho_{\Delta v} > 1$)

Case IV is an example of a resonance condition between customer and utility. The resonance between the utility and customer results in a high I_{pcc} as well as high I_{Y-u} . The high I_{Y-u} results in a high V_{pcc} . Therefore, the customer harmonic current in resonance conditions should be considered as a destructive harmonic current (because $\frac{I_{Y-u}}{I_u} > 1$) and should be restricted. In Case IV, I_{pcc} is equal to 38.7% that exceeds also the I_{pcc}^{max} limit of IEEE Standard 519-2014 ($I_{pcc} > 3.5\%$).

In the resonance conditions (Case IV), the customer has no harmonic current as well as voltage contribution at the PCC (because the customer has no harmonic source). Nevertheless, it causes a high harmonic current as well as high harmonic voltage at the PCC because of its equivalent impedance. Therefore, the judgment of customers only based on their harmonic contribution is not necessarily a true way to reach a

better power quality in the power grid.

C. Customer with Significant Equivalent Admittance and Current Source ($I_c \& Y_c \neq 0$)

Here, it is assumed that both the equivalent admittance and current source of the customer are significant. According to this assumption, two exemplary cases (Case V and VI) are defined (see Table III). These two cases differ only in the phase angle of the customer current source. Table VI and Fig. 4 correspond to the results of these cases. As it can be derived from the results, although I_{pcc} in Case VI is 3.6 times higher than I_{pcc} in Case V, the resultant V_{pcc} in Case VI is almost 1.5 times lower than V_{pcc} in Case V. The customer in Case V and VI increase (because of destructive harmonic current) and decrease (because of constructive harmonic current) V_{pcc} , re-

Fig. 3: Phasor diagram of Case III and IV (customer with negligible equivalent current source)

spectively. Despite this, according to IEEE Standard 519-2014, I_{pcc} in Case V does not need to be restricted ($I_{pcc} < 3.5\%$) and I_{pcc} in Case VI should be restricted ($I_{pcc} > 3.5\%$).

These exemplary cases confirm that a high I_{pcc} does not necessarily cause a high V_{pcc} . V_{pcc} is proportional to I_{Y-u} , and I_{Y-u} depends on the phase angle difference between I_{pcc} and I_u in addition to the magnitude of I_{pcc} . Therefore, allocating some limits for the factors such as customer harmonic current contribution at the PCC and its scalar projection onto I_{pcc} [5], [7], [8], which are related to customer impact on the magnitude of I_{pcc} , could not necessarily be a proper countermeasure to achieve a better voltage quality (i.e, lower V_{pcc}) as well.

V. APPLICATION OF THE PROPOSED APPROACH

Since I_{Y-u} and I_u cannot be measured directly, the application of the proposed approach in practice may be questionable. In this regard, some practical possibilities are suggested:

- Direct calculation of $\frac{I_{Y-u}}{I_u}$: $\frac{I_{Y-u}}{I_u}$ could be calculated according to $I_{Y-u} = V_{pcc} \cdot Y_u$ and $I_u = |I_{pcc} - V_{pcc} \cdot Y_u|$. The requirements for this suggestion are the measurement of V_{pcc} and I_{pcc} as well as the information about Y_u .
- Calculation of $\rho_{\Delta V}$ instead of $\frac{I_{Y-u}}{I_u}$: As in Section III-B mentioned, $\rho_{\Delta V}$ is mathematically equal to $\frac{I_{Y-u}}{I_u}$. $\rho_{\Delta V}$ could be calculated according to (1) by measurement of voltage in the post-customer-connection (V_{pcc}) and pre-customer-connection (V_u) states (see Fig. 1). But in this case, the customer should not have a considerable impact on the fundamental voltage at the PCC so that the assumption of the same harmonic parameters for the utility in two states would be correct. Another way to calculate $\rho_{\Delta V}$ is the employment of "Voltage-Current

Ratio" [3] or "Voltage-Current Ratio Difference" [4], [5] methods. In these methods, information of Y_u and Y_c is required in addition to V_{pcc} and I_{pcc} to calculate $\rho_{\Delta V}$.

VI. CONCLUSION

This paper has introduced a concept named "Destructive and Constructive Harmonic Currents." This paper has categorized the grids into grids with negligible and significant background harmonic distortion.

In the grids with negligible background harmonic distortion, all harmonic currents injected by the customer should be considered destructive to the voltage quality and should be restricted. Because in such grids, the harmonic voltage at the PCC is directly proportional to the magnitude of harmonic current at the PCC. Therefore, each kind of harmonic current at the PCC, independent of their phase angle, increases the harmonic voltage at the PCC.

In the grids with significant background harmonic distortion, the harmonic voltage at the PCC is proportional to the magnitude of harmonic current injected into the utility equivalent admittance rather than the magnitude of harmonic current at the PCC. Therefore, the harmonic currents injected by the customers could, depending on their magnitude and phase angle, increase (destructive) or decrease (constructive) harmonic voltage at the PCC. This paper has demonstrated that the destructive and constructive harmonic currents can be distinguished based on comparing the harmonic current injected into the utility equivalent admittance and the utility equivalent current source (i.e. $\frac{I_{Y-u}}{I_u}$):

- $\frac{I_{Y-u}}{I_u} > 1$: the harmonic current injected by the customer is destructive and should be restricted.

TABLE VI: CORRESPONDING QUANTITIES OF CASE V AND VI (CUSTOMER WITH SIGNIFICANT EQUIVALENT ADMITTANCE AND CURRENT SOURCE)

Case	V_u	V_{pcc}	I_{pcc}	I_{Y-u}	Countermeasure based on I_{pcc} (IEEE Standard 519-2014)	Countermeasure based on I_{Y-u} (Approach of this paper)
V	2.8%	3.4%	2.0%	4.8%	Not necessary (because $I_{pcc} < I_{pcc}^{max}$)	Restriction of customer current (because $\frac{I_{Y-u}}{I_u} > 1$ or $\rho_{\Delta v} > 1$)
VI	2.8%	2.2%	7.0%	3.2%	Restriction of customer current (because $I_{pcc} > I_{pcc}^{max}$)	Giving the customer an incentive (because $\frac{I_{Y-u}}{I_u} < 1$ or $\rho_{\Delta v} < 1$)

Fig. 4: Phasor diagram of Case V and VI (customer with significant equivalent admittance and current source)

- $\frac{I_{Y-u}}{I_u} < 1$: the harmonic current injected by the customer is constructive, and the customer should be encouraged by an incentive.

Afterward, some cases for the destructive and constructive harmonic currents have been presented and analyzed. The analysis of these cases has confirmed that a high harmonic current at the PCC does not necessarily mean the customer increases the harmonic voltage at the PCC. In some cases, although the harmonic current at the PCC exceeds the limit allocated by IEEE Standard 519-2014, the customer significantly decreases the harmonic voltage at the PCC. A customer with a passive or active harmonic filter in a grid with a high background harmonic distortion could be a good example.

These results show that the restriction of harmonic current magnitude at the PCC is not necessarily a proper countermeasure to achieve a better voltage quality. In other words, a low-quality current at the PCC does not necessarily ruin the quality of voltage at the PCC. Therefore, the standards should revise their guideline so that the destructive and constructive harmonic currents are distinguished. This paper has also offered some practical suggestions for applying its approach. In follow-up studies, a multi-point analysis is necessary.

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