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IMPROVEMENT OF POWER QUALITY INDEX ISSUE IN DISTRIBUTION POWER GRID STATION

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Abstract

This paper presents the euclidian norm primarily based new power quality index (PQI) , that is directly associated with the distortion power generated from non linear masses , to use for a sensible distribution power network by rising the performance of the previous PQ I planned by the authors . The planned PQI is made as a mixture of 2 factors, that square measure the electrical load composition rate (LCR) and also the euclidian norm of total harmonic distortions (THDs) in measured voltage and current waveforms. The reduced variable polynomial (RMP) model with the one-shot coaching property is applied to estimate the LCR. supported the planned PQI, the harmonic pollution ranking, that indicates what proportion negative result every nonlinear load has on the purpose of common coupling (PCC) with relevance distortion power, is decided. Its effectiveness and validity square measure verified by the experimental results from its prototype's implementation in an exceedingly laboratory with a single-phase three power unit electrical phenomenon (PV) grid-connected electrical converter, that contributes to atiny low distortion in voltage at the PCC, and sensible nonlinear masses. Then, the harmonic current injection model primarily based time domain simulations square measure dispensed to prove the effectiveness of the planned PQI beneath the opposite conditions with totally different nonlinear masses**.**

Index Terms —Distortion power, distribution power system, Euclidean norm, harmonic pollution ranking, power quality index, reduced multivariate polynomial (RMP) model.

INTRODUCTION

As the increased utilization of power electronic and nonlinear loads aggravates the distortion in voltage and current waveforms electronic devices and current waveforms, the power quality (PQ) in modern power systems has become a significant issue for both power suppliers and consumers. Moreover, there has been an increasing trend towards electric deregulation and independent power producers (IPPs) based on renewable energies such as fuel cell, photovoltaic, wind, and gas-fuelled micro-turbines, etc. In addition, the distributed generation (DG) [1] by the IPP with poorly controlled synchronization will make it more difficult to handle the PQ problems related with system reliability and stability at both power generation and distribution levels. In other words, electricity has been generally sold from on supplier to one consumer with ownership changing hands at only one physical point: the revenue meter. In contrast, after deregulation accompanied with the DGs, it is expected that the ownership of electric power will be exchanged at several points along the generation-transmission-distribution chains. Then, the proper PQ solutions will be necessary at each physical location where ownership is transferred [2]–[4]. Therefore, it is important to develop the appropriate power quality index (PQI) as well as identity the sources and disturbances deteriorating the PQ. The limits on the amount of harmonic current and voltages generated by customers and/or utilities have been established in the IEEE standards 519 [5] and 1547 [6], and in the IEC-61000-3 standard [7]. Recently, some techniques to achieve the specified levels of PQ while enhancing its performance have been reported [8]–[11]. In addition, several power quality indices through the analysis of measured voltage and current waveforms [12]–[14] and analytical tools to evaluate the harmonic contributions on a point of common coupling (PCC) [15]–[17] have been developed. In particular, the distortion

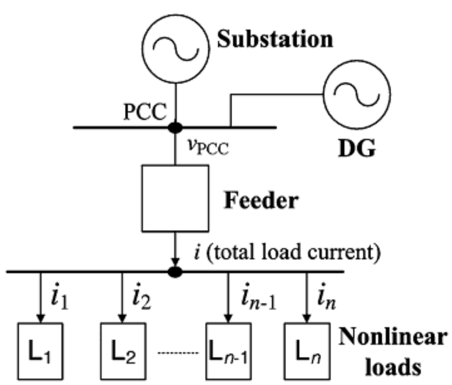

Fig. 1. One-line diagram of a typical distribution power network with the DG

power quality index (DPQI), which accounts for the direct relationship between distortion power and harmonic components of nonlinear loads, has been reported in [14] by the authors. It complements the limitation of total harmonic distortion (THD) informing the distortion of any typical waveforms by representing the separate effect of polluted loads on a PCC with the rank of associated distortion power. In spite of its useful value, the DPQI in [14] cannot provide the good estimation performance of nonlinear load currents when they are severely distorted with high THD or have a low power factor with respect to the voltage at the PCC. These cases are sometimes observed in practice depending on their applications. To overcome this problem and achieve its reliable and consistent performance without regard to any given conditions, this paper proposes the new distortion power quality index($DPQI^{new}$) consisting of the electrical load composition rate (LCR) estimated by the reduced multivariate polynomial (RMP) model [18], [19] and the Euclidean norm of THDs of the measured voltage and current waveforms. The proposed ($DPQI^{new}$) provides the relative harmonic pollution ranking (HPR) of each nonlinear load in the existence of distorted voltage at PCC. The HPR can be practically used as an important factor that determines how much effect each load has on the PCC with the relative ranking for distortion power generation. Moreover, the only uses the load currents and the voltage at the PCC from instrument readings without calculating apparent, fundamental active power, and fundamental reactive power directly. This paper is organized as follows: Section II explains the concepts of DPQI in detail with a comparison of the old formula in [14] and the proposed new one. Section III analyzes distortion power to validate the proposed for its application in a distribution power system. Then, the implementation of is described with its derivation and overall procedure based on the RMP model to estimate the LCR in Section IV. The effectiveness and validity of the proposed is verified by the practical experiment and simulation results given in Section V and Section VI, respectively. Finally, the conclusions are addressed in Section VII.

NEW DISTORTION POWER QUALITY INDEX

Fig. 1 shows a typical distribution power network with the DG. When the nonlinear loads are supplied from a sinusoidal voltage in a substation, the injected currents flowing to each load have undesired harmonic components. They cause harmonic voltage drops through a feeder in supply network and therefore distort the voltage at the PCC [16]. Also, the inverter based grid-connected DG can generate the distorted voltage with the THD less than of 5% [6]. Moreover, under this circumstance, all linear loads connected to the PCC will have harmonic currents injected into them by the distorted PCC voltage. Such currents can be referred to as harmonic sources generating distortion power in a power system. Then, the effect of each load relevant to distortion power, which makes a relative contribution to the PCC, must be evaluated by the appropriate index or function in an effective manner. As mention before, the DPQI providing the relative HPR of each load has been proposed by (1) in [14], where the following three factors need to be considered.

• The relative quantity of the injected currents flowing from the PCC to each nonlinear load,

• The degree of distortion in the current waveforms with high-frequency harmonic components, and

• The degree of distortion in the voltage waveforms at the PCC with high-frequency harmonic components.

The first factor can be estimated by the LCR of each nonlinear load based on the RMP model. The second and third factors can be obtained by the THDs of the load currents (i1, … in) and PCC voltage (vpcc) in Fig. 1, respectively. The DPQI in [14], which is denoted as the for the remainder of this paper to compare with the proposed DPQI, has been obtained by the inner product of the LCR and the THD of the load current as given in (1).

$$DPQI^{old}(n) = LCR(i_n).THD(\hat{\imath}_n) \quad (1)$$

where is the load number. And, $i_n$and $\hat{\imath}_n$ are the measured and estimated load currents, respectively. That is, the THD($\hat{\imath}_n$) in (1) is calculated with the estimated load currents instead of using the measured currents directly under the assumption that a pure sinusoidal voltage is supplied to the PCC. In other words, the third factor seems ignored in (1). As mentioned before, the PCC voltage is mostly distorted in practice due to the harmonics generated from nonlinear loads and the inverter based DGs if they are connected to the grid. To handle this problem, two different procedures were implemented in [14] for the nonlinear load harmonic estimation. One is the training step to predict the optimal admittance weights of the RMP model in the existence of distorted supply voltage at the PCC. The other is the testing step to estimate the load current in (1) with the obtained admittance weights when a pure sinusoidal voltage is applied. Even though the RMP model has the *one-shot* training property [19], which is the more powerful advantage over other neural networks (NNs), the implementation though the above two steps given in [14] is burdensome to some degree. Moreover, if the admittance weights of the RMP model are tested in a completely different condition at which it was not sufficiently trained, the $DPQI^{old}$ in (1) cannot be used in practice because it might lose its reliability and robustness. For example, such case may happen when the nonlinear load currents are severely distorted with a high THD by their high-frequency harmonics or when there are phase differences between the load currents and the PCC voltage (therefore, they have different power factors depending on applications). To overcome the above disadvantage of the $DPQI^{old}$, the $DPQI^{new}$ is proposed as given in (2).

$$DPQI^{new}(n) = LCR(i_n).\sqrt{THD(vpcc)^2 + THD(i_n)^2}$$

Basically, the $DPQI^{new}$ is composed of two parts as given in (2). The first part, LCR is the same as that of the $DPQI^{old}$ in (1). The second part, $\sqrt{THD(vpcc)^2 + THD(i_n)^2}$ represents the distortion of corresponding loads as the form of Euclidean norm of THDs computed from the measured voltage and current waveforms. That is, the Euclidean norm of THDs is formulated as a kind of vector magnitude with the two THDs when they are assumed to have orthogonal characteristics. Even though it is difficult to describe its exact physical meaning, the Euclidean norm of THDs can be considered as the quantity of mixed distortion reflecting nonlinearity between the measured voltage and currents. Also, the direct use of measured waveforms to calculate their THDs avoids taking the second testing step, which was required for the load current estimation in (1) for the $DPQI^{old}$.Therefore, the $DPQI^{new}$ can reduce the computational efforts dramatically when compared to the $DPQI^{old}$. Moreover, the $DPQI^{new}$ can provide the relative HPR for each nonlinear load with the powerful robustness under any conditions, where the $DPQI^{old}$cannot achieve its desirable performance, since it considers the effect of the distorted voltage at the PCC itself. More detailed explanations about how to implements the $DPQI^{new}$are given in the following sections with the theoretical analysis based on the simulation and experimental verifications.

ANALYSIS OF DISTORTION POWER TO VALIDATE THE PROPOSED $DPQI^{new}$

A . Distortion Power

To validate the proposed $DPQI^{new}$, the theoretical analysis for distortion power is required based on the mathematical derivation. The apparent power (S_a) , fundamental active power (P_1), fundamental reactive power (Q_1) , and distortion power (D) for the each load are computed as given in (3). Basically, the widely-used Budeanu's concept [20] of reactive power (Q_B) and distortion power D_B, has been controversial with its unsuitability for non-sinusoidal waveforms. Most problems come from the Q_B , which consists of the Q_1 and harmonic reactive power Q_{BH}, Generally, the value of Q_{BH} is negative in many practical cases. This makes the Q_B to be smaller than the Q_1, or even become zero in the worst case. In this case, the decrease in Q_B does not mean a reduction of the oscillations. That is, the D_B is subject to mislead giving the impression that Q_B can be partially or totally cancelled while in reality the oscillations of power will take place [21]. Similarly to the Q_{BH} , the negative value of the harmonic active power (P_H) indicates to what extent the end-user is polluting the power network with the associated harmonics. Especially, for an ac motor, which is the representative nonlinear load, the P_H is not a useful power. Consequently, IEEE standard 1459 recommends separating the P_1 from the P_H [22]. Therefore, it is reasonably acceptable that the dominant components, P_1 and Q_1 are used to represent the reactive and active powers, respectively, as proposed in this paper. Then, all harmonic powers are considered in distortion terms. The formulations in (3) except for the D are described in [22].

$$S_a = \sqrt{\frac{1}{M}\sum_{m=0}^{M-1} v(m)^2} \cdot \sqrt{\frac{1}{M}\sum_{m=0}^{M-1} i(m)^2}$$

$$P_1 = V_1 . I_1 . \cos(\theta_1 - \varphi_1)$$

$$Q_1 = V_1 . I_1 . \sin(\theta_1 - \varphi_1)$$

$$D = \sqrt{S_a^2 - P_1^2 - Q_1^2} \quad (3)$$

Where M is the number of samples obtained during one period T. And, the subscript, 1 of voltage and current denotes the fundamental component. Again, the S_a can be rewritten as given in (4) by assuming that inter-harmonics are negligible.

$$S_a = \sqrt{V_{DC}^2 + \sum_{k-1}^{N-1} V_k^2} \cdot \sqrt{I_{DC}^2 + \sum_{k-1}^{N-1} I_k^2} \quad (4)$$

Where N is the maximum number of harmonics from obtained samples during one period T . And, the subscript, k of voltage and current denotes the order of high-frequency harmonics. Assume that the dc components of voltage and current are zero. Then, with the THD de fined as (5), the S_a and D in (4) and (3) can be approximated as (6) and (7), respectively. This transformation is reasonably acceptable in a practical power system because the dc component of voltage and current are mostly close to zero in practice even when there exists some distortion in their waveforms. Moreover, in the case of dc injection into connection point by the DG in Fig. 1, it is limited to within 0.5% of its full rated output according to the IEEE standard 1547 [6]. Therefore, it can be negligible.

$$THD_v = \sqrt{\frac{\sum_{k=2}^{N-1} V_k^2}{V_1}}, THD_i = \sqrt{\frac{\sum_{k=2}^{N-1} I_k^2}{I_1}} \quad (5)$$

$$S_a \approx V_1 . I_1 \sqrt{(1 + THD_V^2).(1 + THD_I^2)} \quad (6)$$

$$D \approx V_1 . I_1 \sqrt{THD_V^2 + THD_I^2 + (THD_V^2 . THD_I^2)^2} \quad (7)$$

From (6) to (7), it is observed that the distortion power, is related to the fundamental components and THDs of voltage and current. With the detailed analysis for the D in Section IV, the proposed

$DPQI^{new}$ is proved to be valid for providing the information with respect to distortion power without its direct measurement, therefore determining the relative HPR of nonlinear loads.

B. Parseval's Theoremon THD Calculation

The Parseval's theorem states [23] that the average power in a periodic signal equals the sum of the average powers in all of its harmonic components. And, its mathematical description is given in (8).

$$P_x = \frac{1}{M}\sum_{m=0}^{M-1} f(m)^2 = \sum_{k=0}^{N-1} F_k{}^2 \quad (8)$$

With the relation of (8), the THDs of voltage and current in (5) can be represented as given in (9)

$$THD_v = \sqrt{\frac{\frac{1}{M}\sum_{m=0}^{M-1} v(m)^2 - V_{DC}^2 - V_I^2}{V_1}}$$

$$\mathrm{THD_i} = \sqrt{\frac{\frac{1}{M}\sum_{m=0}^{M-1} i(m)^2 - I_{DC}^2 - I_I^2}{I_1}} \quad (9)$$

When there are no inter-harmonics, the values of THD in (5) and (9) become same. In this paper, the proposed $DPQI^{new}$ is developed to measure the power quality in a stationary condition representing all loads in a steady-state condition, where the effect of inter-harmonics is trivial. Moreover, the same assumption is already applied in derivations of apparent and distortion powers in (4) and (7), respectively. Therefore, the value of THD calculated by (9) is almost same as that by (5) in general circumstances, where the $DPQI^{new}$ is applied. Then, it is required to describe the application of (9) in exceptional situation, where inter-harmonics from unexpected disturbances exist. Actually, the use of THD de fined as (9) to implement the D and $DPQI^{new}$ is more preferable to that de fined as (5) since it can reflect the effect of all inter-harmonics into the signal power, which is calculated in implementation procedure. On the other hand, the definition of THD as given in (5) cannot consider inter-harmonics. Therefore, the losses in calculation caused by domain change are ignored. For this reason, the equation (9) can help the proposed index to measure the exact level of power quality in practice

IMPLEMENTATION OF THE $DPQI^{new}$

A. Derivation of the $\mathrm{DPQI^{new}}$ and LCR Estimation

Based on the analysis given in the previous section, the in $DPQI^{new}$ (2) is now derived from D in (7). Firstly, the term, $(THD_V^2.THD_I^2)^2$ in right-hand side of (7) can be ignored because its value is much smaller than the value of $THD_V^2 + THD_I^2$. Their rate is de fined as the square of multiplication ratio (SMR) in (10).

$$\mathrm{SMR} = \frac{\mathrm{THD_V^2.THD_I^2}}{\mathrm{THD_V^2 + THD_I^2}} < 0.0025 \quad (10)$$

Then, the distortion power D, for the individual nonlinear load, n in Fig. 1 is approximated as follows. Note that $I_{1(n)}$ and $V_{1,PCC}$ in (11) are fundamental components of each load current,i_n and PCC voltage, v_{pcc}, respectively.

$$D(n) = V_{1,PCC}.I_{1(n)}\sqrt{THD(vpcc)^2 + THD(i_n)^2} \quad (11)$$

The approximated distortion power in (11) has the same form of Euclidean norm of THDs as the $DPQI^{new}$ in (2). Thereafter, the analysis of the relation between $V_{1,PCC}$ in (11) and LCR(i_n) gives the final solution to derive $DPQI^{new}$ from D. First of all, every load has the same fundamental component of v_{pcc}, as shown in Fig. 1. Therefore, it can be treated as a constant for all loads in the distribution power system. For formulation of the LCR estimation, the relation between the total electric current, i(t)and the load currents $i_1, i_2 \ldots\ldots i_n$, is modeled as (12) with their normalized values, which are denoted by the superscript, *norm*. The normalization is achieved by making each fundamental component of measured currents to be unity in its magnitude.

$$i_2^{nprm}(t) + \cdots\ldots - k_n i_n^{nprm}(t) \quad (12)$$

where k_1, k_2 , and k_n are the unknown coefficients, which provide the actual rate of the composition of each load current with respect to total current without any calculation of powers. Also, the estimation scheme through the normalization is always valid without regard to me asurement scales used with different current transformer (CT) ratios. This LCR can give a standard for current injection limits from each load with the benefit of being an effective evaluation tool for the effects of individual load types [14]. Each load current $i_n(t)$, is formed by the superposition of all harmonic components including its fundamental, which is higher than the other harmonic components. Then, the LCR is proportional to the rate of its fundamental components; therefore $V_{1,PCC}$, $I_{1(n)}$ and LCR(i_n) also have the proportional relationship. Finally, the relative HPR provided by the $DPQI^{new}$ represents the original ranking for the associated D of nonlinear loads. As mentioned before, the RMP model is applied to estimate the LCR. This optimization technique is a kind of training algorithm to search the weight parameters for the nonlinear input output mapping such as NN. The main advantage of the RMP model over NNs is that it has the one-shot training property [19]. In other words, it does NOT require iteration procedures during the process to find a solution weight vector. The brief descriptions for the RMP model are summarized in below.The more detailed explanations of how to select the proper RMP model and then how to apply it for the LCR estimation are given in [14], [18].

B. Reduced Multivariate Polynomial Model

The general multivariate polynomial (MP) model can be expressed as:

$$\mathrm{g}(\alpha, \mathrm{x}) - \sum_{i}^{k} \alpha_i x_1^{n1} x_2^{n2} \ldots x_l^{n1} \qquad (13)$$

where the summation is taken over all non negative integers $n_1, n_2, \ldots, n_l$ for which$n_1 + n_2 + \ldots + n_l \le r$ with r being the order of approximation. The vector $\alpha = [\alpha_1, \ldots \alpha_k]$ is the parameter vector to be estimated, and x denotes the regressor vector as $[x_1, \ldots x_l]^T$ containing inputs. K is the total number of terms in $\mathrm{g}(\alpha, \mathrm{x})$.

The general MP model in (13) can be replaced with (14) by using the parameter vector, α and the function, (x) , which is composed of variables of the regressor vector.

$$\mathrm{g}(\alpha, \mathrm{x}) = \alpha^{\mathrm{T}} p(x)$$

Given data points with and using the least-squares error minimization error objective given by

$$\mathrm{s}(\alpha, \mathrm{x}) = \sum_{i=1}^{m} [y_i - \mathrm{g}(\alpha, \mathrm{x})]^2 + b\,||\alpha||_2^2 - [y - P\alpha]^T [y - P\alpha] + b\alpha^T \alpha \qquad (15)$$

where || ||2 denotes the Euclidean norm, and b is a regularization constant.

Minimizing the error objective function (15) result in

$$\alpha = \{P^T P - bI\}^{-1} P^T y \qquad (16)$$

where $P \in R^{mxk}$ denotes the Jacobian matrix of P(x) , and $y = [y_1 \ldots y_m]^T$, and I is the K × K identity matrix. The approximation capability of polynomials is well known form the Weierstrass approximation theorem [24], which states that every continuous function de fined on an interval can be approximated as closely as desired by a polynomial function [19]. However, for the rth-order model with input dimension l, the number of independent adjustable parameters would grow as l^T . Thus, the MP model would need a huge quantity of training data to ensure that the parameters are well determined. To significantly reduce the huge number of terms in the MP model, the RMP model (17) is considered.

$$\hat{f}_{RMP}(\alpha, x) = \alpha_0 + \sum_{k=1}^{r}\sum_{j=1}^{l} \alpha k_j x_j^k + \sum_{j=1}^{r} \alpha_{rl} + j\,(x_1 + x_2 + \cdots + x_l)^j + \sum_{j=2}^{r} (\alpha_j^T . x)(x_1 + x_2 + \cdots + x_l)^{j-1}, l, r \geq 2 \qquad (17)$$

The number of terms in this model can be expressed as k=l+r+l(2r-l) . It is shown that the RMP model, in which the number of weight parameters increases linearly, is a much more efficient algorithm in a complicated polynomial system with the higher-order when compared to the MP model, in which the number of parameters increases exponentially with respect to the order of polynomials [19]. The reader should refer to [18], [19] for a clear understanding of the RMP model.

C . Overall Procedure

The overall procedure to implement the $DPQI^{new}$ is shown in Fig. 2. There are two parts; one is to estimate the LCR by using the RMP model, and the other is simply to calculate their THDs of the measured current and voltage based on the Parseval's theorem. When the RMP model is applied to estimate the LCR, it is important to determine the proper order r, in (17) of the

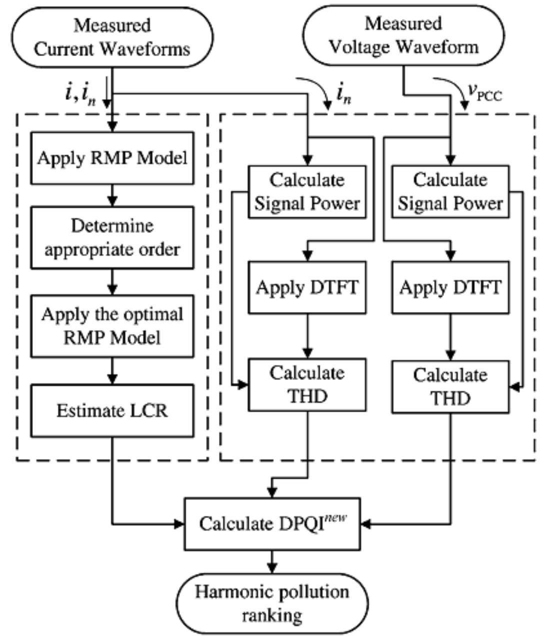

Fig. 2. Overall procedure to implement the $DPQI^{new}$.

RMP model. In a physical application in the existence of noise and/or complex correlations among the many nonlinear harmonic loads, the relatively high-order of RMP model might be preferably used to enhance estimation accuracy. However, the estimation process by very high-order RMP models requires extensive computations and memory in real-time operation. Also, its weight-solution vector mapping to high dimension is hard to analyze. Moreover, it is not true that the high-order

RMP model always outperforms the relatively low-order RMP model. There is no firm solution for selecting its optimal order. By several tests, the sixth-order RMP model is optimally selected to estimate the LCR in this paper. Meanwhile, the estimation of nonlinear load harmonics, which was required to implement the $DPQI^{old}$ in (1), is not necessary here for calculating the THD of waveforms (see [14]). Therefore, it avoids applying another RMP model. This makes the implementation of $DPQI^{new}$ more efficient and effective for use in practice.

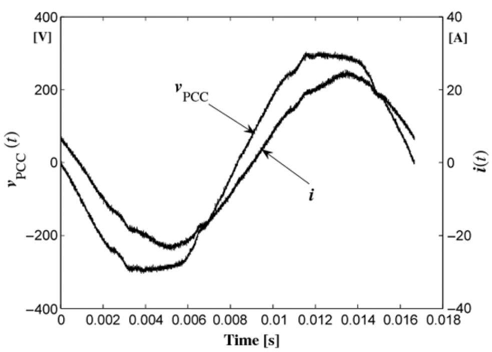

Fig 3 The voltage, and the total electric load current, at the PCC during one period of the fundamental.

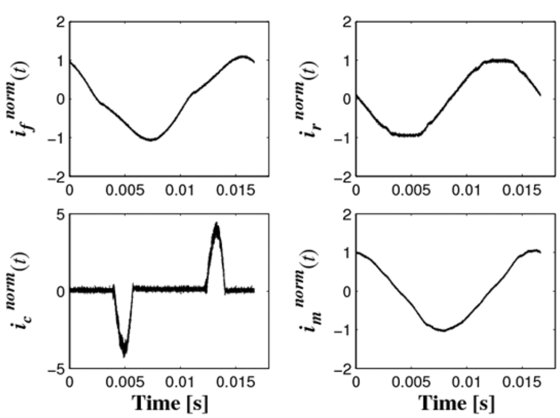

Fig 4 Normalized load currents of if ,ir ,ic , and im during one period of the fundamental.

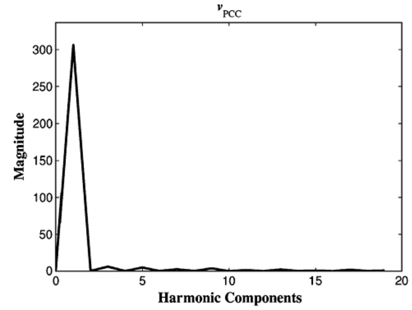

Fig 5 Harmonic components of the PCC voltage

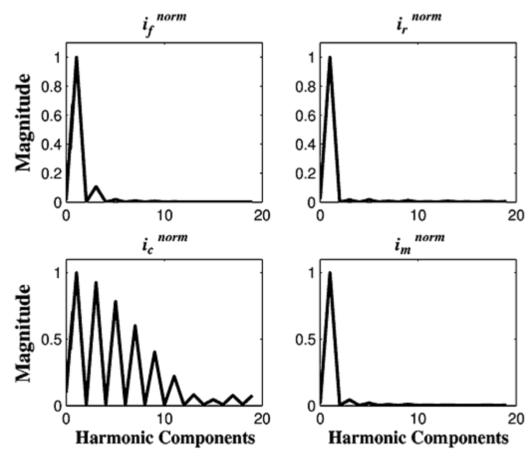

Fig 6 Harmonic components of each load current.

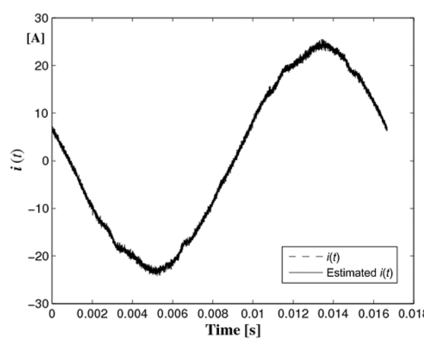

Fig 7 Estimation of the total current, by the RMP model.

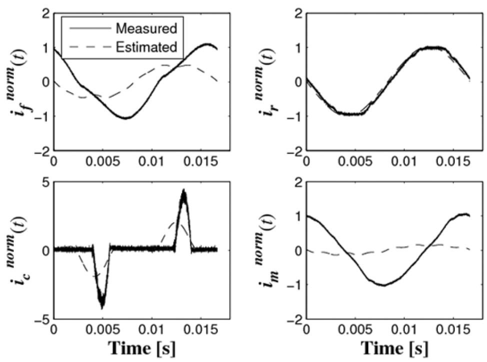

Fig 8 Estimation for each load current by the RMP model.

SIMULATION RESULTS

In this Section, the case study related to a numerical simulation of a simple test circuit with different nonlinear loads is carried out to more clearly show the potential of the proposed

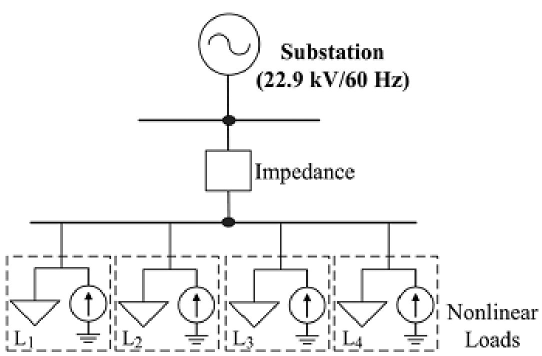

Fig 12 One-line diagram of system used in the simulation by the harmonic current injection model .

A. Harmonic Current Injection Model

For the harmonic load modeling, several methods such as a constant current source (CCS), crossed frequency admittance matrix (CFAM), Norton model, and harmonic current injection model have been commonly used [25]. These can be selected by considering the trade-off between simplicity and sensitivity. In this paper, the harmonic current injection model is properly chosen on the purpose of simulation. In this method, any loads are represented by aggregating each effect of individual loads at a distribution level. Then, the aggregate harmonic load is represented by a harmonic current source in parallel with some linear impedances [25]. The one-line diagram of system used in the simulation is shown in Fig. 12 with the representation of harmonic loads. Each nonlinear load in Fig. 12 consists of a constant power load and a harmonic current injection source, which can generate up to 19th-order high-frequency harmonic. To reflect various conditions close to the practical situation, all related parameters such as power, harmonic injections, and power factor, etc to represent the nonlinear loads are randomly generated in every single simulation by uniform probability distribution defined in a certain range, which includes the severe conditions where voltage distortion is almost close to its harmonic limits de fined in [6] and [7]. Then, the total number of 10 000 simulations is carried out.

B. Tests in Three-Phase Balanced System

The clear definition of distortion power is necessary to evaluate and verify the $DPQI^{new}$. Although many theories have been developed for the single-phase case, their extension to the three-phase system is also important. Therefore, the proposed index is now applied to a three-phase balanced system in Fig. 12. Then, the results are shown in Table V. The average error in Table V represents the absolute average value differences between the actual LCR(S_a) and the estimated L during 10,000 simulations, and it is 0.0074. It is small enough to prove the good estimation performance of the proposed $DPQI^{new}$. Also, the performances of the $DPQI^{old}$ and $DPQI^{new}$ the to determine the HPR are compared in Table VI. It is clearly shown that the proposed $DPQI^{new}$ has the superior performance to the $DPQI^{old}$. In Table III, the relationship between $DPQI_R^{new}$ and D_R was not perfectly linear even though they are closely

TABLE V
ESTIMATION PERFORMANCE OF PROPOSED $DPQI^{new}$

10,000 Simulations	Average Error
Absolute difference between the actual LCR(S_a) and the estimated **L**	0.0074

TABLE VI
COMPARISON WITH $DPQI^{old}$ AND $DPQI^{new}$ TO DETERMINE THE HPR

Index	$DPQI^{old}$	$DPQI^{new}$
Error Rate [%]	48.5	0.1

TABLE VII
VERIFICATION OF LINEAR RELATIONSHIP BETWEEN $DPQI_R^{new}$ and D_R

Case	Load type	L_1	L_2	L_3	L_4
Case 1	$DPQI_R^{new}$	0.0642	0.1989	0.2732	0.4637
	D_R	0.0639	0.1991	0.2732	0.4638
Case 2	$DPQI_R^{new}$	0.0360	0.5830	0.1859	0.1860
	D_R	0.0359	0.6198	0.1583	0.1859
Case 3	$DPQI_R^{new}$	0.1076	0.6093	0.2361	0.0470
	D_R	0.1076	0.6093	0.2361	0.0470
Case 4	$DPQI_R^{new}$	0.0739	0.3111	0.0195	0.0954
	D_R	0.0740	0.3111	0.0195	0.5954

CONCLUSIONS

This paper projected the new distortion power quality index ($DPQI^{new}$) to exchange the antecedently projected index($DPQI^{old}$). Its

computation was dispensed supported the load composition rate (LCR) and Euclidian norm of total harmonic distortions (THDs) of the measured voltage and current waveforms at the purpose of common coupling (PCC). The reduced variable polynomial (RMP) model with the one-shot coaching property was with success applied to estimate the LCR. Moreover, the employment $DPQI^{new}$of might avoid applying another RMP model, that is needed within the implementation of $DPQI^{old}$to estimate the nonlinear load harmonics. This advantage of $DPQI^{new}$permits for more practical and desirable use in observe. Also, the experimental results showed that the $DPQI^{new}$will offer the relative harmonic pollution ranking (HPR) of many nonlinear hundreds with smart performance, that is directly associated with their distortion powers while not the necessity for direct measurements. In distinction, the results additionally verified that $DPQI^{new}$the has the intense disadvantage of getting wrong associateswers with an incorrect HPR. This was the case once the load current was severely distorted with the high THD and/or once it had an oversized part distinction with the PCC voltage with a coffee power issue. Moreover, the nice estimation performance of the projected $DPQI^{new}$and its pertinency in observe was verified by the simulation results supported the harmonic current injection model. it's expected to use the projected $DPQI^{new}$as a good tool for observation and regulation the facility quality in distribution system likewise as during a residence. the appliance of projected $DPQI^{new}$to the domestic distribution power network in JeJu Island, Korea, that is chosen as an indication advanced for the implementation of the smart-grid, is presently being investigated

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