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# Fuzzy Based Compensator for Distribution Generation for the Enhancement of Non Linear Loads and Voltage Distortions for the Grid Connected Systems

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**Abstract:**

*This paper presents distribution generation based control strategy for grid connected fuzzy systems which supports the DG to transfer a sinusoidal current into the utility grid despite the distorted grid voltage and nonlinear local load conditions. The proposed current controller is designed in the synchronous reference frame and composed of a Fuzzy logic controller. An RC serves as a bank of resonant controllers, which can compensate a large number of harmonic components with a simple delay function. Hence, the control strategy can be greatly simplified. In addition, the proposed control method does not require the local load current measurement or harmonic analysis of the grid voltage. Therefore, the proposed control method can be easily adopted into the traditional DG control system without installation of extra hardware. Despite the reduced number of sensors, the grid current quality is significantly improved compared with the advanced methodologies like artificial intelligence.. The operation principle of the proposed control method is analyzed in detail, and its effectiveness is validated through simulation results*

## INTRODUCTION

The use of renewable energy sources, such as wind turbines, photovoltaic, and fuel cells, has greatly increased in recent decades to address concerns about the global energy crisis, depletion of fossil fuels, and environmental pollution problems. As a result, a large number of renewable energy sources have been integrated in power distribution systems in the form of distributed generation (DG). DG systems can offer many advantages over traditional power generation, such as small size, low cost, high efficiency, and clean electric power generation.

A DG system is typically operated in a grid-connected mode where the maximum available power is extracted from energy sources and transferred to the utility grid. In addition, to exploit full advantages of a DG system, the DG can be also equipped and operated with local loads, where the DG supplies power to the local load and transfers surplus power to the grid [9]–[14]. In both configurations, i.e., with and without the local load, the prime objective of the DG system is to transfer a high-quality current (grid current) into the utility grid with the limited total harmonic distortion (THD) of the grid current at 5%, as recommended in the IEEE 1547 standards [15]. To produce a high-quality grid current, various current control strategies have been introduced, such as hysteresis, predictive, proportional–integral (PI), and proportional-resonant (PR) controllers. Hysteresis control is simple and offers rapid responses; however, it regularly produces high and variable switching frequencies, which results in high current ripples and difficulties in the output filter design [3].

Meanwhile, predictive control is a viable solution for current regulation of the grid-connected DG. However, despite its rapid response, the control performance of the predictive controller strongly relies on system parameters [4]. Therefore, system uncertainty is an important issue affecting the grid current quality. The PI controller in the synchronously rotating(d–q) reference frame and the PR controller in the stationary(α–β)reference frame are effective solutions that are commonly adopted to achieve a high-quality grid current.

However, these current controllers are only effective when the grid voltage is ideally balanced and sinusoidal. Unfortunately, due to the popular use of nonlinear loads such as diode rectifiers and adjustable-speed ac motor drives in power systems, the grid voltage at the point of common coupling (PCC) is typically not pure sinusoidal, but instead can be unbalanced or distorted. These abnormal grid voltage conditions can strongly deteriorate the performance of the regulating grid current To eliminate the adverse effect of the distorted grid voltage on the grid current quality, several harmonic compensation methods have been introduced [6]–[8], [17], [18]. In [17], a novel compensation approach for reducing the THD of the grid current under distorted grid voltage is introduced. In this method, the harmonic components in the grid voltage are extracted, and the Cauchy–Schwarz inequality theory is adopted to find the minimum point of the grid current THD.

The grid current quality therefore relies heavily on the accuracy of the grid voltage harmonic analysis; if the harmonic components in the grid voltage are varied, it is difficult to maintain a good grid current quality. Moreover, the searching algorithm requires a large calculation time and can operate only offline. In [6]–[8] and [18], several selective harmonic compensators are developed using a resonant controller, in which the resonant controller tuned at the sixth multiple of the fundamental frequency is added to eliminate the effect of fifth and seventh harmonic grid voltages on the grid current quality. The grid current quality can be improved, due to the additional resonant controllers. However, if higher order harmonics are taken into account, more resonant controllers should be added because a single resonant controller can regulate only one specific harmonic component [7], [8]. Unfortunately, adding more controllers increases the complexity of the control system.

One single RC can compensate a large number of harmonic components with a simple delay function. Hence, the control strategy can be greatly simplified. Another advantage of the proposed control method is that it does not demand the local load current measurement and the harmonic analysis of the grid voltage. Therefore, the proposed control method can be easily adopted into the traditional DG control system without the installation of extra hardware. Despite the reduced number of sensors, the performance of the proposed grid current controller is significantly improved compared with that of the traditional PI current controller. In addition, with the combination of the PI and RC, the dynamic response of the proposed current controller is also greatly enhanced compared with that of the traditional RC. The feasibility of the proposed control strategy is completely verified by simulation and experimental results.

## MODELING OF PROPOSED THEORYSYSTEM CONFIGURATION AND ANALYSIS OF GRID VOLTAGE DISTORTION AND NON LINEAR LOCAL LOAD

Fig. shows the system configuration of a three-phase DG operating in grid-connected mode. The system consists of a dc power source, a voltage-source inverter (VSI), an output LC filter, local loads, and the utility grid. The purpose of the DG system is to supply power to its local load and to transfer surplus power to the utility grid at the PCC. To guarantee high-quality power, the current that the DG transfers to grid(ig) should be balanced, sinusoidal, and have a low THD value. However, because of the distorted grid voltage and nonlinear local loads that typically exist in the power system, it is not easy to satisfy these requirements.

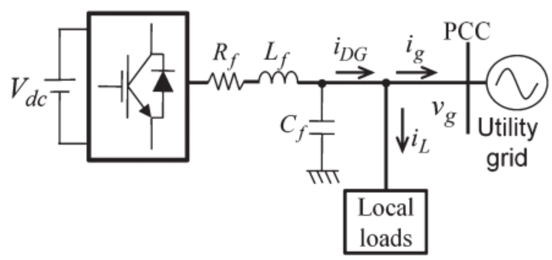


Fig. Configuration of a three-phase DG operating in grid-connected mode.

A. Effect of Grid Voltage Distortion

To assess the impact of grid voltage distortion on the grid current performance of the

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DG, a model of the grid-connected DG system is developed, as shown in Fig. . In this model, the VSI of the DG is simplified as voltage source (vi).The inverter transfers a grid current(ig)to the utility grid(vg).For simplification purpose, it is assumed that the local load is not connected into the system. In Fig. , the voltage equation of the system is given as

$$v_i - v_g - L_f \frac{di_g}{dt} - R_f i_g = 0$$

(16)

Where Rf and Lf are the equivalent resistance and inductance of the inductor Lf, respectively.

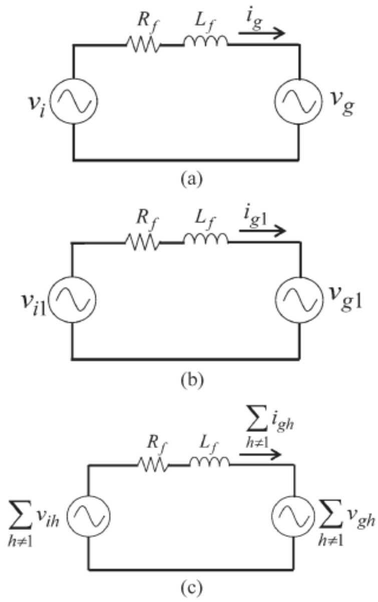


Fig.7.2.Model of grid-connected DG system under distorted grid voltage (a) General Condition,(b) at the fundamental frequency,(c) at the hatmonic frquencies

If both the inverter voltage and the grid voltage are composed of the fundamental and harmonic components as (2), the voltage equation of (1) can be decomposed into (3) and (4), and the system model shown in Fig. 2(a) can be expressed as Fig. 2(b) and (c), respectively. That is

$$v_i = v_{i1} + \sum_{h\neq 1} v_{ih}$$

$$v_g = v_{g1} + \sum_{h\neq 1} v_{gh}$$

$$v_{i1} - v_{g1} - L_f \frac{di_{g1}}{dt} - R_f i_{g1} = 0$$

$$\sum_{h\neq 1} v_{ih} - \sum_{h\neq 1} v_{gh} - L_f \frac{d\left(\sum_{h\neq 1} i_{gh}\right)}{dt} - R_f \sum_{h\neq 1} i_{gh} = 0.$$

B. Effect of Nonlinear Local Load

Fig. 3 shows the model of a grid-connected DG system with a local load, whereby the local load is represented as a current source $i_L$, and the DG is represented as a controlled current Source $i_{DG}$. According to Fig. 3, the relationship of DG current $i_{DG}$, load current $i_L$, and grid current igis described as

$$i_{DG} = i_L + i_g. \quad (21)$$

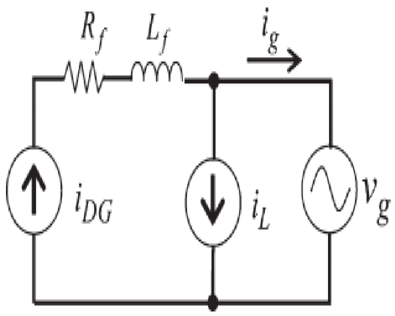

Fig.7.3 Model of grid connected DG system with nonlinear local load

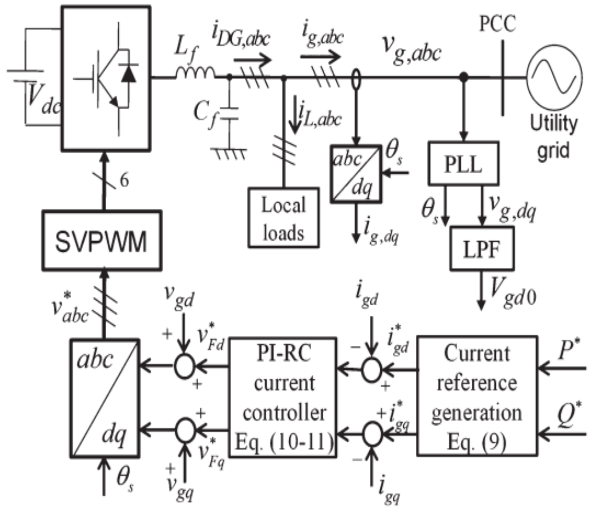


Fig. Overall Block Diagram of proposed control strategy

Assuming that the local load is nonlinear, e.g., a three-phase diode rectifier, the load current is composed of the fundamental and harmonic components as

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$$i_L = i_{L1} + \sum_{h \neq 1} i_{Lh}$$

Where $I_{L1}$ and $I_{LH}$ are the fundamental and harmonic components of the load current, respectively.

$$i_g = i_{DG} - \left( i_{L1} + \sum_{h \neq 1} i_{Lh} \right).$$

it is obvious that, in order to transfer sinusoidal grid current ig into the grid, DG current should include the harmonic components that can compensate the load current harmonics. Therefore, it is important to design an effective and low-cost current controller that can generate the specific harmonic components to compensate the load current harmonics. Generally, traditional current controllers, such as the PI or PR controllers, cannot realize this demand because they lack the capability to regulate harmonic components.

## PROPOSED CONTROLSCHEME

To enhance grid current quality, an advanced current control strategy, as shown in Fig. 4, is introduced. Although there are several approaches to avoid the grid voltage sensors and a phase-locked loop (PLL), Fig. 4 contains the grid voltage sensor and a PLL for simple and effective implementing of the proposed algorithm, which is developed in the d–q reference frame.

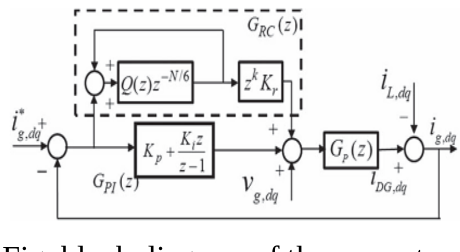

Fig. block diagram of the current controller

The proposed control scheme is composed of three main parts: the PLL, the current reference generation scheme, and the current controller. The operation of the PLL under distorted grid voltage has been investigated, in detail, in [20]; therefore, it will not be addressed in this paper. As shown in Fig. 4, the control strategy operates without the local load current measurement and harmonic voltage analysis on the grid voltage. Therefore, it can be developed without requiring additional hardware. Moreover, it can simultaneously address the effect of nonlinear local load and distorted grid voltage on the grid current quality.

A. Current Reference Generation

As shown in Fig., the current references for the current controller can be generated in the d–q reference frame based on the desired power and grid voltage as follows:

$$i_{gd}^* = \frac{2}{3}\frac{P^*}{v_{gd}}, \qquad i_{gq}^* = -\frac{2}{3}\frac{Q^*}{v_{gd}}$$

Where $P^*$ and $Q^*$ are the reference active and reactive power, respectively; $v_{gd}$ represents the instantaneous grid voltage in the d–q frame; and $i_{gd}^*$ and $i_{gq}^*$ denote the direct and quadrature components of the grid current, respectively. Under ideal conditions, the magnitude ofvgdhas a constant value in the d–q reference frame because the grid voltage is pure sinusoidal. However, if the grid voltage is distorted, the magnitude of $v_{gd}$ no longer can be a constant value. As a consequence, reference current $i_{gd}^*$ and $i_{gq}^*$ cannot be constant in (8). To overcome this problem, a low-pass filter (LPF) is used to obtain the average value of $v_{gd}$, and the d–q reference currents are modified as follows:

$$i_{gd}^* = \frac{2}{3}\frac{P^*}{V_{gd0}}$$

$$i_{gq}^* = -\frac{2}{3}\frac{Q^*}{V_{gd0}}$$

B. Current Controller

An advanced current controller is proposed by using a PI and an RC in the d–q reference frame. The block diagram of the current controller is shown in Fig. 5. The open-loop transfer

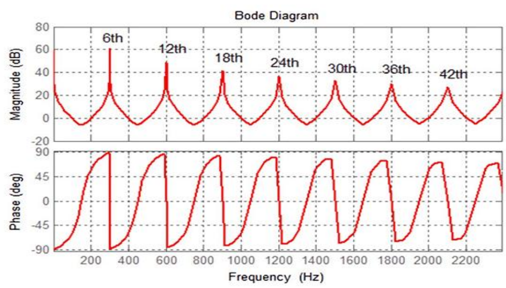


Fig.7.6 Bode Diagram of the PI_RC controller

function of the PI and RC in a discrete-time domain is given respectively in

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$$G_{PI}(z) = K_p + \frac{K_i z}{z-1}$$
$$G_{RC}(z) = \frac{K_r z^k z^{-N/6}}{1 - Q(z) z^{-N/6}}$$

In Fig. , the RC is used to eliminate the harmonic components in the grid current caused by the nonlinear local load and/or distorted grid voltage. Meanwhile, the role of the PI controller is to enhance the dynamic response of the grid current and to stabilize the whole control system.

The number of delay samples of the RC given in (11) is N/6, where N=$\frac{f_{sample}}{f_s}$ is the number of samples in one fundamental period, which is defined as the ratio of the sampling frequency and the fundamental frequency of system(fs). In fact, the traditional RC can be used in this case to compensate the harmonic components. However, the traditional RC suffers the severe drawback of a very slow dynamic response due to the long delay time by N samples. To remove the delay problem of the traditional RC, we consider only the(6n±1)th (n=1,2,3...) harmonics because they are dominant components in three-phase systems. The time delay of the RC in (13) is thereby reduced six times compared with the traditional one as N/6.

In Fig., the current controller is designed at a fixed grid frequency of 50 Hz. However, in practical applications, grid frequency can have small variations around the nominal value

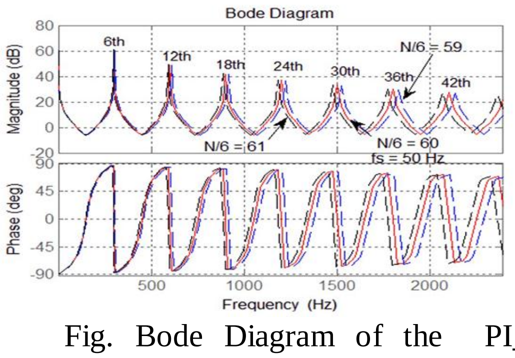


Fig. Bode Diagram of the PI_RC controller with different values

In order to overcome the grid frequency variations, an adaptive control scheme was introduced [23]. Nevertheless, the current controller needs some additional components, such as filters and controllers, to implement the frequency adaptive controllers.

In this paper, the proposed current controller is basically designed to compensate both the current harmonic and the grid frequency variation, simultaneously. When the grid frequency varies, the grid frequency(fs)is quickly detected by the PLL, and the frequency variation is compensated directly by adjusting the number of delay samples, i.e., N/6= N=$\frac{f_{sample}}{6f_s}$, inside the RC in Fig. . Fig. shows the Bode diagram of the PI-RC with different values of the delay samples(N/6). As shown in Fig., by adjusting N/6, the peak gain of the RC can be moved to adapt the grid frequency variations.

## DESIGN OFRC

The RC has three main components that must be determined: the filter Q(z), the phase lead term $z^k$, and the RC controller gain Kr.

Selection of the Filter Q(z): Q(z) is used to improve the system stability by reducing the peak gain of the RC at a high-frequency range. There are two methods that have been commonly used to select Q(z): a closed unity gain Q(z)=0.95 and a zero phase-shift LPF Q(z)=(z+2+z−1)/4. In this paper, we use Q(z)=(z+2+z−1)/4 because it provides the high peak gain of the PI-RC at the low-frequency range and low peak gain (less than 0 dB) at the high-frequency range (higher than 2 kHz), as shown in Fig. It is well known that a low peak gain at the high-frequency range can effectively prevent the system unstable.

Determination of the Phase Lead Term $z^k$: Since the control plant $G_P(z)$, i.e., the LC filter, acts as an LPF, which introduces some phase lag, the phase lead term $z^k$ is required to compensate the phase lag of GP(z), and k is selected to minimize the phase displacement of $G_P(z)z^k$ ,. Fig. 9 presents the Bode diagram of $G_P(z)z^k$ ,with different values ofk.InFig.9,we select k=3 because it provides a minimum phase displacement up to the 31st harmonic order, and the system stability is guaranteed up to the 45th harmonic component at a frequency of 2.25 kHz.

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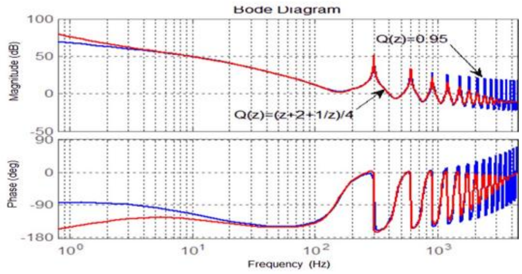


Fig. Bode diagram of the open-loop transfer function of the PI-RC controller withQ(z)=0.95andQ(z)=(z+2+z−1)/4.

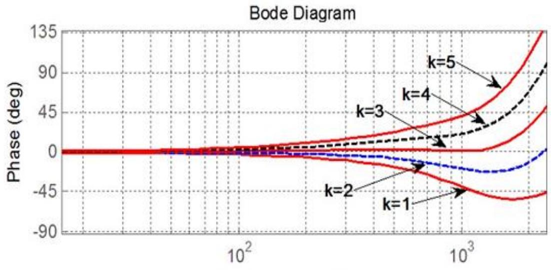


Fig.Phase lag compensation with different values of k

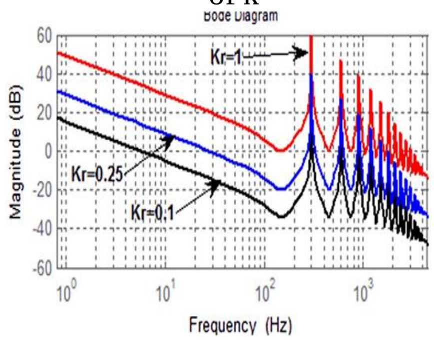


Fig. Bode diagram of the PI-RC with different values ofKr

Determination of the Controller Gain Kr: To determine controller gain Kr, the magnitude response of the PI-RC is investigated. In Fig. 10, the PI-RC provides different frequency responses with different values of Kr; the peak gain of the RC at the resonant frequency is reduced as Kr becomes smaller. In Fig. 10, with Kr=0.1orKr=0.25, the peak gains of the PI-RC are too small; therefore, it is insufficient to offer good steady-state performance for harmonic current compensation. Meanwhile, with Kr=1, the PI-RC has high peaks up to 2 kHz, and it is sufficient to compensate harmonics up to the 39th order. Therefore, we select Kr=1.

TABLE I
SYSTEM PARAMETERS

| *Parameters* | *Values* |
|---|---|
| Grid voltage | 110 V (rms) |
| Grid frequency ($f_s$) | 50 Hz |
| Rated output power | 5 kW |
| DC-link voltage ($V_{dc}$) | 350 V |
| Sampling/switching frequency ($f_{sample}$) | 9 kHz |
| Output filter inductance ($L_f$) | 0.7 mH |
| Output filter resistance ($R_f$) | 0.1 Ω |
| Output filter capacitance ($C_f$) | 27 μF |
| Load of three-phase diode rectifier | R = 30 Ω, C = 2200 μF |
| Three-phase linear load | R = 30 Ω |

## FUZZY LOGIC CONTROLLER

Fuzzy control is a control method based on fuzzy logic. Fuzzy logic can be described simply as computing with words rather than numbers; fuzzy control can be described simply as control with sentences rather than equations. A fuzzy controller can include empirical rules, and that is especially useful in operator controlled plants. Fuzzy logic controller (FLC) is capable of improving its performance in the control of a nonlinear system whose dynamics are unknown or uncertain. Fuzzy controller is able to improve its performance without having to identify a model of the plant. Fuzzy control is similar to the classic closed-loop control approaches but differs in that it substitutes imprecise, symbolic notions for precise numeric measures. The fuzzy controller takes input values from the real world. These crisp input values are mapped to the linguistic values through the membership functions in the fuzzification step. A set of rules that emulates the decision making process of the human expert controlling the system is then applied using certain inference mechanisms to determine the output. Finally, the output is mapped into crisp control actions required in practical applications in the de-fuzzification step. They are non-precise variables that often convey a surprising amount of information. Usually, linguistic variables hold values that are uniformly distributed (μ) between 0 and 1, depending on the relevance of a context dependent linguistic term[3].

1-**Fuzzification**, which converts controller inputs into information that the inference mechanism can easily uses to a activate and apply rules.

2-**Rule-Base**, (a set of If-Then rules), which contains fuzzy logic quantification of the expert's linguistic description of how to achieve good control.

3-**Inference Mechanism**, (also called an "inference engine" or "fuzzy inference" module), which a emulates the expert's decision making in interpreting and applying knowledge about how best to control the system

4-**Defuzzification Interface**, which converts the conclusions of the inference mechanism into actual inputs for the process.

**8.2 FUZZY REPRESENTATION**

Fuzzy logic theory is considered as a mathematical approach combining multi-valued logic, probability theory, and artificial intelligence to replicate the human approach in reaching the solution of a specific problem by using approximate reasoning to relate different data sets and to make decisions. The performance of Fuzzy Logic Controllers is well documented in the field of control theory since it provides robustness to dynamic system parameter variations as well as improved transient and steady state performances. In this study, a fuzzy logic based feedback controller is employed for controlling the voltage injection of the proposed Fuzzy logic controller is preferred over the conventional PI and PID controller because of its robustness to system parameter variations during operation and its simplicity of implementation. Since the proposed DVR uses energy storage system consisting of capacitors charged directly from the supply lines through rectifier and the output of the inverter depends upon the energy stored in the dc link capacitors. But as the amount of energy stored varies with the voltage sag/swell events, the conventional PI and PID controllers are susceptible to these parameter variations of the energy storage system; hence the control of voltage injection becomes difficult. The proposed FLC scheme exploits the simplicity of the Mamdani type fuzzy systems that are used in the design of the controller and adaptation mechanism.

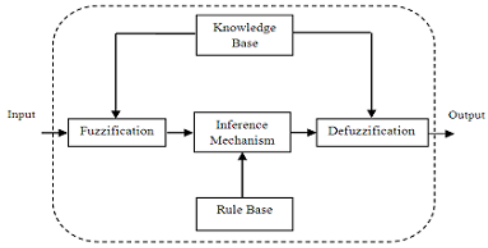


Fig. Schematic representation of Fuzzy Logic Controller

The fuzzy logic based control scheme (Fig ) can be divided into four main functional blocks namely Knowledge base, Fuzzification, Inference mechanism and Defuzzification. The knowledge base is composed of data base and rule base. Data base consists of input and output membership functions and provides information for appropriate fuzzification and defuzzification operations.

The rule-base consists of a set of linguistic rules relating the fuzzified input variables to the desired control actions. Fuzzification converts a crisp input signals, error (e), and change in error (ce) into fuzzified signals that can be identified by level of memberships in the fuzzy sets. The inference mechanism uses the collection of linguistic rules to convert the input conditions to fuzzified output. Finally, the defuzzification converts the fuzzified outputs to crisp control signals using the output membership function, which in the system acts as the changes in the control input (u).The typical input membership functions for error and change in error are shown in Fig a and Fig b respectively, whereas the output membership function for change in control input is shown in Fig c. The output generated by fuzzy logic controller must be crisp which is used to control the PWM generation unit and thus accomplished by the defuzzification block. Many defuzzification strategies are available, such as, the weighted average criterion, the mean-max membership, and center-of-area (centroid) method. The defuzzification technique used here is based upon centroid method.

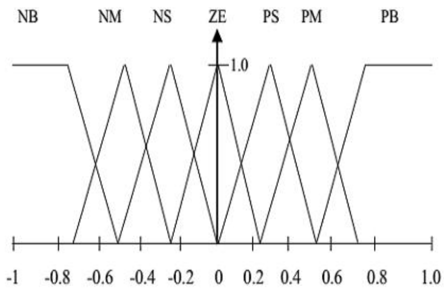


Fig. Membership Function for Input Variable Error, 'e'

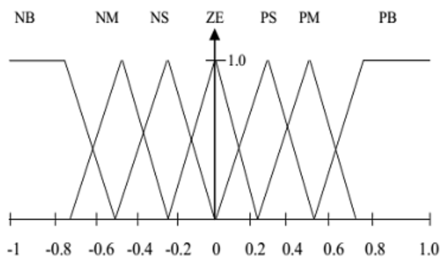


Fig. Membership Function for Input Variable Change in Error, 'ce'

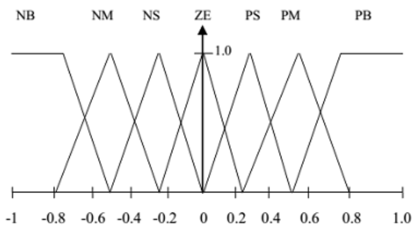


Fig. Membership Function for Output

| 'e' / 'ce' | NB | NM | NS | ZE | PS | PM | PB |
|---|---|---|---|---|---|---|---|
| NB | NB | NB | NB | NB | NM | NS | ZE |
| NM | NB | NB | NB | NM | NS | ZE | PS |
| NS | NB | NB | NM | NS | ZE | PS | PM |
| ZE | NB | NM | NS | ZE | PS | PM | PB |
| PS | NM | NS | ZE | PS | PM | PB | PB |
| PM | NS | ZE | PS | PM | PB | PB | PB |
| PB | ZE | PS | PM | PB | PB | PB | PB |

Variable Change in Control Signal, 'u'.

The set of fuzzy control linguistic rules is given in Table 1. The inference mechanism of fuzzy logic controller utilizes these rules to generate the required output. DVR is generally connected in feeders having sensitive loads whose terminal voltage has to be regulated. The SIMULINK model of proposed fuzzy logic controller is shown in the Fig .

Table. Rule Base For Fuzzy Logic Controller

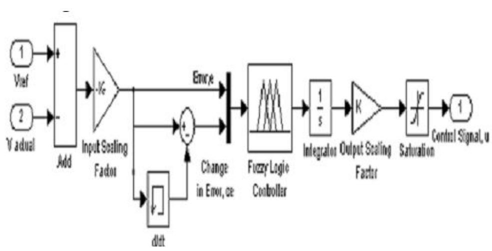


Fig.. SIMULINK model of proposed FLC

## MATLAB MODELS

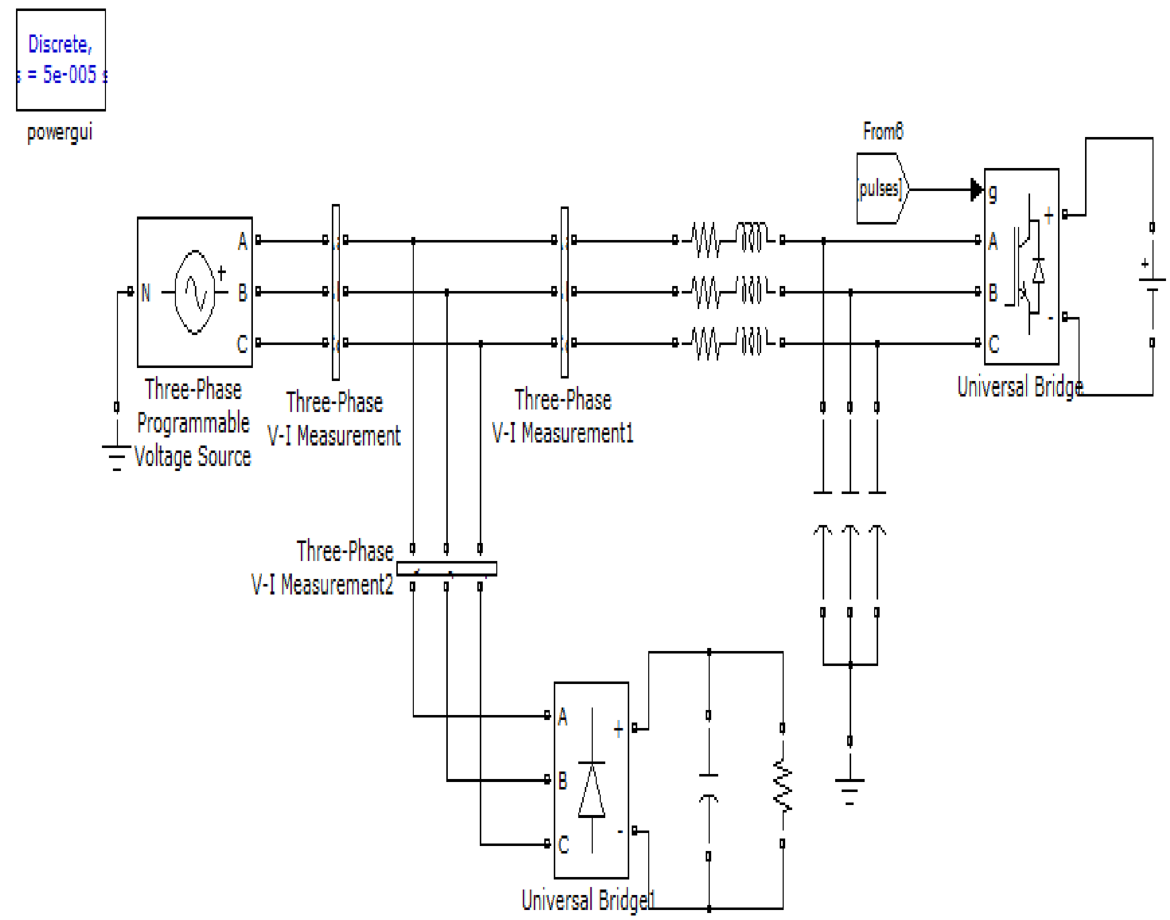


Fig. Matlab
Model For Proposed
Converter

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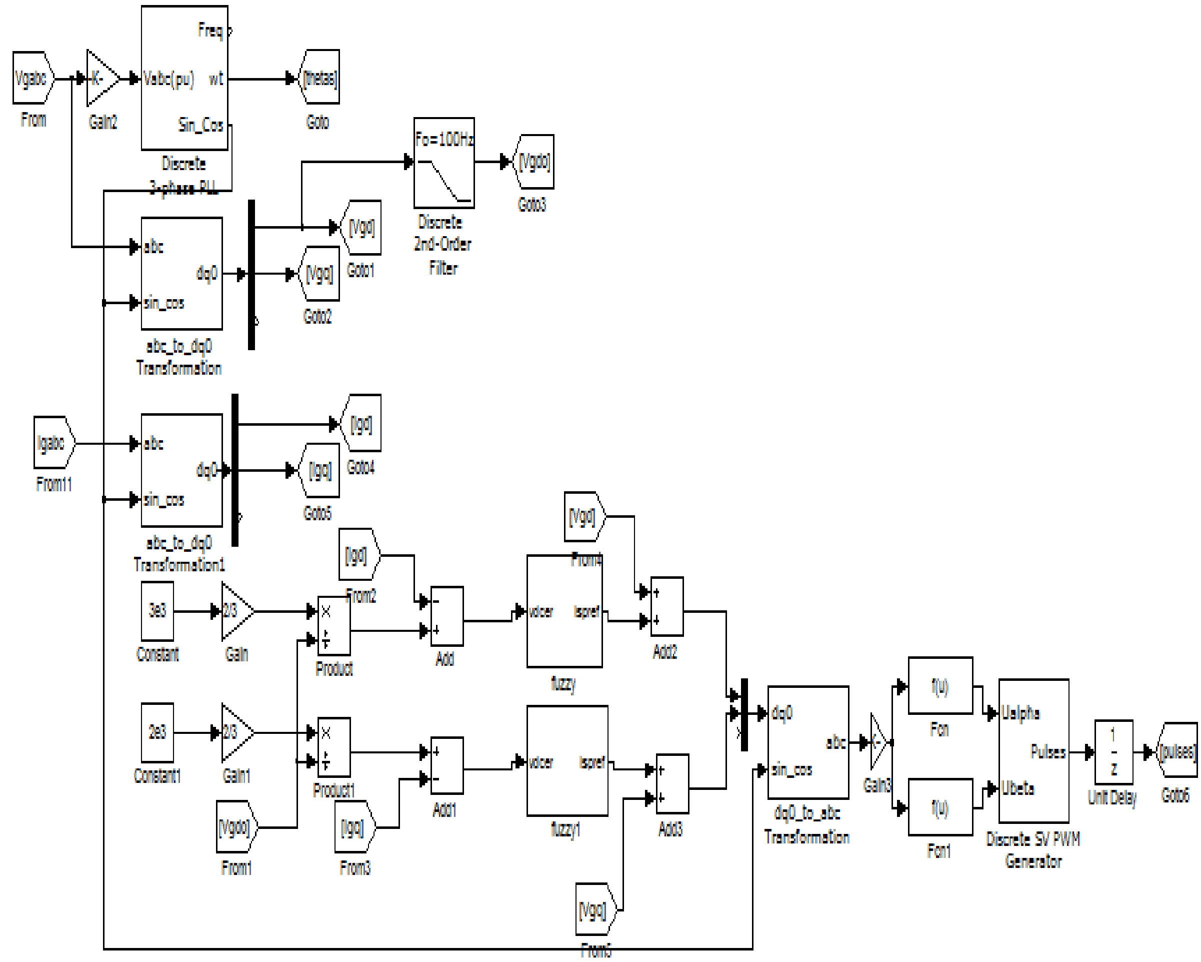

Fig.Controll Circuit for the proposed fuzzy controller

## SIMULATIONRESULTS

A simulation model of the DG system is built by PSIM simulation software to verify the effectiveness of the proposed control method. The system parameters are given in Table I. In the simulation, three cases are taken into account.

1) Case I: The grid voltage is sinusoidal and the linear local load is used.
2) Case II: The grid voltage is sinusoidal and the nonlinear local load is used.
3) Case III: The grid voltage is distorted and the nonlinear local load is used.

In Cases I and II, the grid voltage is assumed as a pure sinusoidal waveform. In Case III, the distorted grid voltage is supplied with the harmonic components: 3.5% 5th harmonic, 3% 7th harmonic, 1% 11th harmonic, and 1% 13th harmonic.

The THD of grid voltage is about 4.82%. This grid voltage condition complies with the IEEE 519-1992 harmonic restriction standards, where the THD of grid voltage is less than 5% [25]. In all test cases, the reference grid current is set at $i^*_{gd}$ =10A and $i^*_{gq}$ =0, and the conventional PI current controller and the proposed current controller are investigated to compare their control performances. Fig. depicts the steady-state performance of the grid connected DG by using the conventional PI current controller, in which the waveforms of grid voltage, grid current, local load current, and DG current are plotted. As shown in Fig. , the PI current controller is able to offer a good performance only in Case I, when the grid voltage is ideal sinusoidal and the local load is linear. In the other circumstances, due to the effect of distorted grid voltage and the nonlinear local load, the PI current controller is unable to

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transfer a sinusoidal grid current to the utility grid.

In fact, because of the popular use of nonlinear loads in the DG local load and distribution system, the ideal sinusoidal condition of the grid voltage is very rare. On the other hand, the conditions, as given in Cases II and III, frequently occur in practice. As a result, the conventional PI controller is insufficient to offer a good quality of the grid current.To demonstrate the superiority of the proposed current controller over the traditional PI controller, the DG system with the proposed current controller is also simulated, and the results are shown in Fig. . As shown in the results, the proposed control strategy can provide a good quality grid current, i.e., sinusoidal grid currents, despite the distorted grid voltage and nonlinear local load conditions. Therefore, with the aid of the RC in the proposed current controller, the distorted grid voltage and nonlinear load current no longer affect the grid current quality.

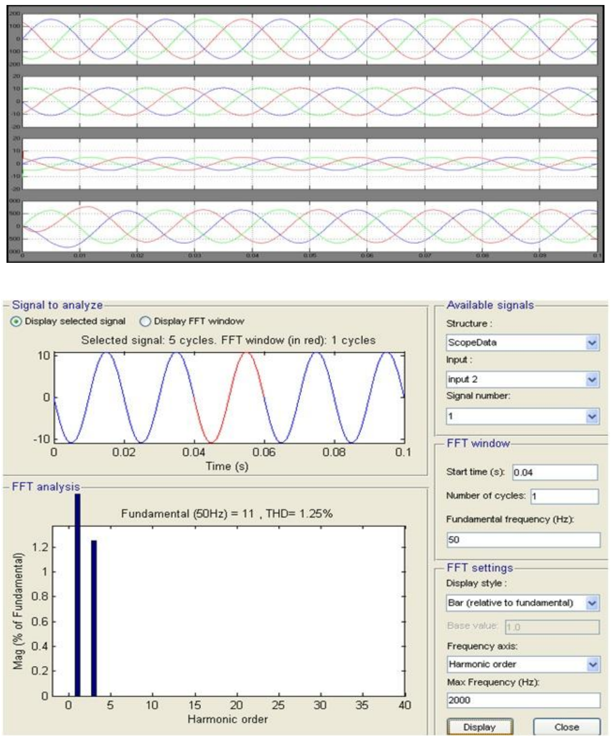
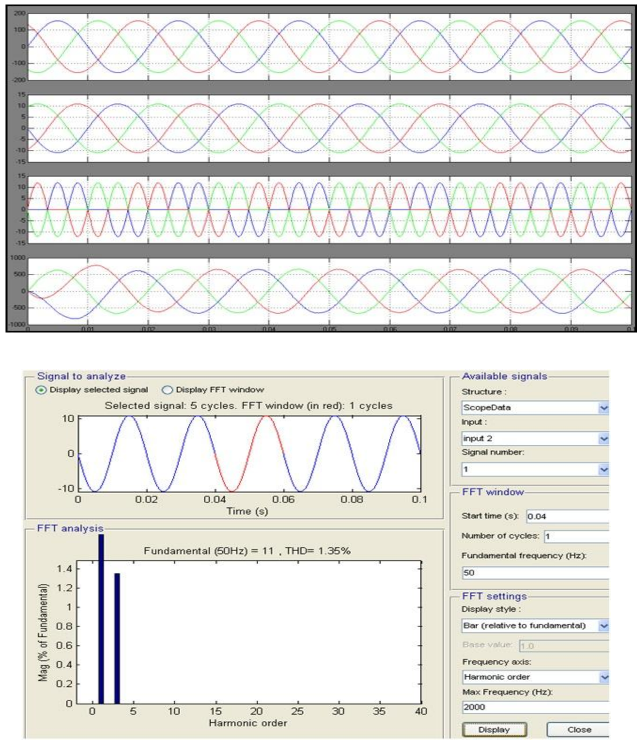
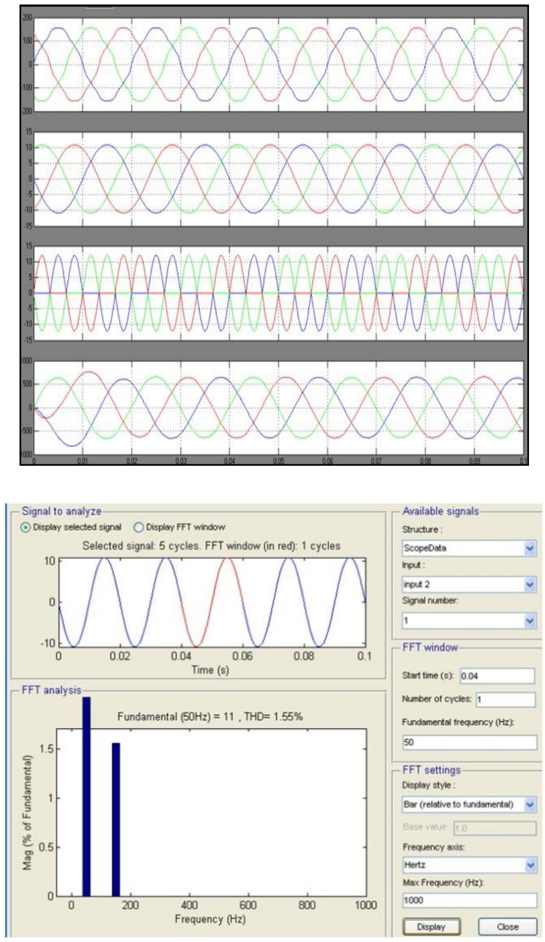



Fig. Simulation results with the proposed Fuzzy current controller:
(a) Case I;




(b) Case II;.




and (c) Case III

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Moreover, the proposed control method can bring the THD of the grid current to less than 2% in all cases, as given in Table II, which complies completely with IEEE 1547 standards. These results obviously validate the effectiveness of the proposed control approach.

In addition, to assess the feasibility of the proposed current controller under grid frequency variations, simulation results of the proposed PI-RC current controller, when the grid frequency changes from 50 to 49 Hz and from 50 to 51 Hz, are illustrated in Fig. 13(a) and (b), respectively. In Fig. 13, the PLL quickly detects the grid frequency variation and accurately compensates it within a short period of time, i.e., less than 10 ms without any influence on the grid current. Therefore, we can say that the proposed current controller is able to maintain a high-quality grid current even under the grid frequency variations.

## CONCLUSION

This paper has proposed an artificial intelligence based control strategy ie fuzzy based algorithm for grid connected DG to simultaneously eliminate the effect of grid voltage distortion and nonlinear local load on the grid current. The simulation results established that the DG with the proposed current controller can sufficiently transfer a sinusoidal current to the utility grid, despite the nonlinear local load and distorted grid voltage conditions. The proposed current control scheme can be implemented without the local load current sensor and harmonic analysis of the grid voltage; therefore, it can be easily integrated in the conventional control scheme without installation of extra hardware. Despite the reduced number of current sensors, the quality of the grid current is significantly improved: the THD value of the grid current is decreased considerably compared with that achieved by using the conventional PI current controller. In addition, the proposed current controller also maintained a good quality of grid current under grid frequency variations.

## FUTUTE SCOPE

To complete this project, Grid Connected Compensator using fuzzy controller, there is a great need of designing the control system that would control the designed inverter power of this thesis. The control shall be able to integrate the inverter with other renewable energy sources available. The control strategy plays an important role of making the system smart by coordinate with the IT systems such as internet synchronization EtherCAT networks.

The second important work is the inverter prototype. After the simulation of the inverter power stage obtained the next step is the implementation of the prototype. However with the help of LabView it can be implemented in the real time environment and analyze the performances.

Selection of the components and rating is another work to be done. In this design the value obtained are calculated value for simulation. In engineering work, the standard values are needed in order to suit certain working environments. The selection or even design of high frequency transformer, IGBT/MOSFET switches with driver circuits is indispensable.

## REFERENCES

[1] R. C. Dugan and T. E. McDermott, “Distributed generation,”IEEE Ind. Appl. Mag., vol. 8, no. 2, pp. 19–25, Mar./Apr. 2002.

[2] F. Blaabjerg, R. Teodorescu, M. Liserre, and A. V. Timbus, “Overview of control and grid synchronization for distributed power generation systems,” IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1398–1409, Oct. 2006.

[3] J. A. Suul, K. Ljokelsoy, T. Midtsund, and T. Undeland, “Synchronous reference frame hysteresis current control for grid converter applications,” IEEE Trans. Ind. Appl., vol. 47, no. 5, pp. 2183–2194, Sep./Oct. 2011.

[4] Q. Zeng and L. Chang, “An advanced SVPWM-based predictive current controller for three-phase inverters in distributed generation systems,” IEEE Trans. Ind. Electron., vol. 55, no. 3, pp. 1235–1246, Mar. 2008.

[5] S. Buso and P. Mattavelli, "Digital control in power electronics," inSynthesis Lectures on Power Electronics. San Rafael, CA, USA: Morgan & Claypool, 2006.

[6] C. A. Busada, S. Gomez Jorge, A. E. Leon, and J. A. Solsona, "Current controller based on reduced order generalized integrators for distributed generation systems,"IEEE Trans. Ind. Electron., vol. 59, no. 7, pp. 2898–2909, Jul. 2012.

[7] M. Liserre, R. Teodorescu, and F. Blaabjerg, "Multiple harmonics control for three-phase grid converter systems with the use of PI-RES current controller in a rotating frame,"IEEE Trans. Power Electron., vol. 21, no. 3, pp. 836–841, May 2006.

[8] M. Castilla, J. Miret, A. Camacho, J. Matas, and L. G. de Vicuna, "Reduction of current harmonic distortion in three-phase grid-connected photovoltaic inverters via resonant current control,"IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1464–1472, Apr. 2013.

[9] R.-J. Wai, C.-Y. Lin, Y.-C. Huang, and Y.-R. Chang, "Design of highperformance stand-alone and grid-connected inverter for distributed generation applications," IEEE Trans. Ind. Electron., vol. 60, no. 4,pp. 1542–1555, Apr. 2013.

[10] I. J. Balaguer, Q. Lei, S. Yang, U. Supatti, and F. Z. Peng, "Control for grid-connected and intentional islanding operations of distributed power generation,"IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 147–157, Jan. 2011.

[11] G. G. Pozzebon, A. F. Q. Goncalves, G. G. Pena, N. E. M. Mocambique, and R. Q. Machado, "Operation of a three-phase power converter connected to a distribution system,"IEEE Trans. Ind. Electron., vol. 60, no. 5, pp. 1810–1818, May 2013.

[12] Q.-C. Zhong and T. Hornik, "Cascaded current-voltage control to improve the power quality for a grid-connected inverter with a local load," IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1344–1355, Apr. 2013.

[13] Z. Yao and L. Xiao, "Control of single-phase grid-connected inverterswith nonlinear loads,"IEEE Trans. Ind. Electron., vol. 60, no. 4, pp. 1384–1389, Apr. 2013.

[14] Z. Liu, J. Liu, and Y. Zhao, "A unified control strategy for three-phase inverter in distributed generation,"IEEE Trans. Power Electron., vol. 29, no. 3, pp. 1176–1191, Mar. 2014.

[15] IEEE Application Guide for IEEE Std 1547, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems, IEEE Std.1547.2-2008, 2008.

[16] R. Teodorescu, F. Blaabjerg, M. Liserre, and P. C. Loh, "Proportional resonant controllers and filters for grid-connected voltage-source converters,"Proc. Inst. Elect. Eng.—Elect. Power Appl., vol. 153, no. 5,pp. 750–762, Sep. 2006.

[17] T.-V. Tran, T.-W. Chun, H.-H. Lee, H.-G. Kim, and E.-C. Nho, "Control method for reducing the THD of grid current of three-phase gridconnected inverters under distorted grid voltages,"J. Power Electron.,vol. 13, no. 4, pp. 712–718, Jul. 2013.

[18] Q.-N. Trinh and H.-H. Lee, "Improvement of current performance for grid connected converter under distorted grid condition," inProc. IET Conf. RPG, Sep. 6–8, 2011, pp. 1–6.

[19] Y. A.-R. Mohamed and E. F. El-Saadany, "Adaptive discrete-time gridvoltage sensorless interfacing scheme for grid-connected DG-inverters based on neural-network identification and deadbeat current regulation," IEEE Trans. Power Electron., vol. 23, no. 1, pp. 308–321, Jan. 2008.

[20] V. Blasko and V. Kaura, "Operation of a phase locked loop system under distorted utility

conditions,"IEEE Trans. Ind. Electron., vol. 33, no. 1, pp. 58–63, Jan./Feb. 1997.

[21] Q.-N. Trinh and H.-H. Lee, "Advanced repetitive controller to improve the voltage characteristics of distributed generation with nonlinear loads,"J. Power Electron., vol. 13, no. 3, pp. 409–418, May 2013.

[22] Characteristic of the Utility Interface for Photovoltaic (PV) Systems,IEC Std. 1727, Nov. 2002.

[23] S. Gomez Jorge, C. A. Busada, and J. A. Solsona, "Frequency-adaptive current controller for three-phase grid-connected converters," IEEE Trans. Ind. Electron., vol. 60, no. 10, pp. 4169–4177, Oct. 2013.

[24] B. Zhang, D. Wang, K. Zhou, and Y. Wang, "Linear phase lead compensation repetitive control of a CVCF PWM inverter," IEEE Trans. Ind. Electron., vol. 55, no. 4, pp. 1595–1602, Apr. 2008.

[25] IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems, IEEE Std. 519-1992, 1992.