International Journal of Ethics in Engineering & Management Education
Website: www.ijeee.in (ISSN: 2348-4748, Volume 4, Issue 10, October 2017)

# Power Quality Improvement by using Fuzzy Controlled APF with DG Integration Feature

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***Abstract:*** **Late situation in the dispersion framework is sounds made by Non-direct load and unbalance current. It influences the working of adjoining loads as well as abbreviate the life of energy hardware by making over the top misfortunes. In this paper, a fluffy controlled shunt dynamic power channel is depicted to keep up the (Total Harmonic Distortion) THD inside as far as possible characterized by IEEE Std. 519-1992 and to decrease receptive power and enhance control factor. This Filter draws the contrary sounds containing current from the heap with the goal that source current stay sinusoidal and undistorted. Fluffy rationale controller is utilized to control the shunt dynamic power channel and the execution of the shunt dynamic channel control methodologies has been assessed regarding consonant alleviation. Three-stage reference current waveforms created by proposed conspire are followed by the three-stage voltage source converter in a hysteresis band control plot. A completely useful MATLAB based Simulink model of Shunt Active Power Filter for various sorts of load (nonlinear, unbalance, both) has been outlined in light of `Instantaneous Power Theory' or `p-q Theory'. The aftereffects of reproduction agree to every one of the highlights depicted by the hypothesis, legitimizing work of Shunt Active Power Filter (SAPF) with fluffy controller enhances control quality contrasted with traditional Proportional Integral(PI) controller.**

***Keywords:*** **MATLAB, SAPF, VCM, PCC, DC, frame work**

## 1 INTRODUCTION

As of late Distributed Generation (DG) in view of Renewable Energy Sources (RES) has experienced enormous advancement all around. Because of the expanding vitality request, lessening petroleum derivatives and clean vitality ideas more DG units are associated with the lattice at the circulation level [1]. Smaller scale matrix which coordinates RESs, vitality stockpiling gadgets and nearby loads are an answer for the present day vitality emergency [2].Power quality is a noteworthy issue in a traditional appropriation framework within the sight of expanded utilization of nonlinear loads and power electronic based types of gear. Poor power quality is a major test for the steady, compelling and monetary operation of an inverter ruled small scale matrix [1, 3, 4, and 8]. Soon power will be an item advertised by judging its quality in a focused situation [8]. Various dynamic power separating procedures have been produced to alleviate the customary dispersion framework symphonious issues [6]. The fundamental structure of a dynamic channel is like that of a DG inverter and the essential capacity of these lattice interfacing inverters is to

infuse dynamic energy to the framework. The DG inverter may not work at its full limit at all the time because of the stochastic idea of the sustainable power sources like sun oriented and wind [7]. In the event that controlled legitimately the unused limit of DG inverter check be successfully utilized for giving auxiliary administrations like consonant, receptive power pay and unbalance relief of the power circulation framework [2,]. Such an inverter can be called as a multifunctional network associated inverter (MFGCI). With the current improvements in small scale lattice innovation control quality upgrade utilizing adaptable control of MFGCI is an intriguing examination subject [10]. Utilization of MFGCI kills the need of extra repaying gadgets and results in a financially savvy framework [7-9].

Voltage Source inverters are utilized as the interfacing converters in the greater part of the DG frameworks. Ordinarily these inverters work in current controlled mode (CCM) amid matrix associated operation because of its better consonant remuneration capacity when thought about than the voltage controlled mode (VCM). Different control methodologies and strategies for improved power quality in a framework associated framework have been accounted for as of late [8-[4]. Amid symphonious remuneration of the nonlinear load current, the central DG current provided by the interfacing inverter must be ascertained in view of the dynamic and responsive power reference.

A control method with control quality change highlights for the combination of DG frameworks to the network is talked about in [12]. In this methodology age of crucial DG current segment accept a hardened voltage source at the network side and does not consider non perfect supply conditions. An open circle control technique for ideal power quality remuneration in Micro framework utilizing multifunctional network associated inverters is proposed in [13].An electrical circulation framework is subjected to control variances and vulnerabilities which causes the voltage at the purpose of normal coupling (PCC) to be lopsided.

The collaboration between the DG inverter nonlinear present and mutilated PCC voltages may contribute control blunders in the relentless state [14-16]. Subsequently a shut circle control methodology is fundamental for exact power following on account of misshaped voltages at the PCC. In [14], a shut circle control system for single stage inverters with dynamic consonant sifting in stationary casing is proposed for symphonious remuneration. The goal of this paper is to build up a control procedure for symphonious current separating in a three stage framework associated DG framework without utilizing additional repaying gadget. The proposed shut circle

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control can track the dynamic power reference and enhance the power quality within the sight of lopsided and mutilated supply voltages. The viability of the control plot is approved by expand reenactment contemplates for various working methods of the DG inverter under perfect and non-perfect supply conditions.

## II SYSTEM DESCRIPTION

A schematic portrayal of the proposed framework is given in Fig 1 and speaks to the lattice protection and inductance up to the point of regular coupling; and speaks to the equal protection and inductance of the inverter channel, coupling transformer and interfacing links; speaks to the smoothing inductance embedded in arrangement with the heap to lessen the spikes in the network current because of exchanging drifters; , speaks to the voltages at the PCC and , speaks to the heap streams.

## III REFERENCE CURRENT GENERATION PRINCIPLE

The control technique employed is based on the analysis of load voltage, load current and inverter currents in the dq synchronous rotating frame. Independent control of active and reactive power can be achieved with more effectiveness in dq frame. The instantaneous angle of the voltage at PCC is obtained by using a phase locked loop (PLL).

***a) Calculation of d-axis and q-axis reference currents to supply load active and reactive power:***

The active and reactive power injected from the DG link to the grid at the fundamental frequency is

$$P_{dg} = \frac{3}{2}\left(v_d I_{dgd} + v_q I_{dgq}\right) \quad (1)$$

$$Q_{dg} = \frac{3}{2}\left(v_q I_{dgd} - v_d I_{dgq}\right) \quad (2)$$

Where ,$I_{dgd}$ and,$I_{dgq}$ and are the dq- components of DG invertercurrent at fundamental frequency to manage the active powerand reactive power exchange between the grid and RES. $v_d$and$v_q$ are the the PCC voltages in dq frame. The currents at fundamental frequency required to deliver the active and reactive power from the RES has to be supplied by the DG inverter. The corresponding reference currents at fundamental frequency are$I^*_{dgd}$ and $I^*_{dgq}$, which can be calculated using the open loop and the proposed closed loop power control strategy as explained below,

***B) Open Loop Power Control:***

In a practical case, the PCC voltages may contain ripple due to the unexpected power fluctuations and excessive use of harmonic polluted loads connected to the system. Hence to generate the fundamental current components, the PCC voltages are filtered in dq frame [13].

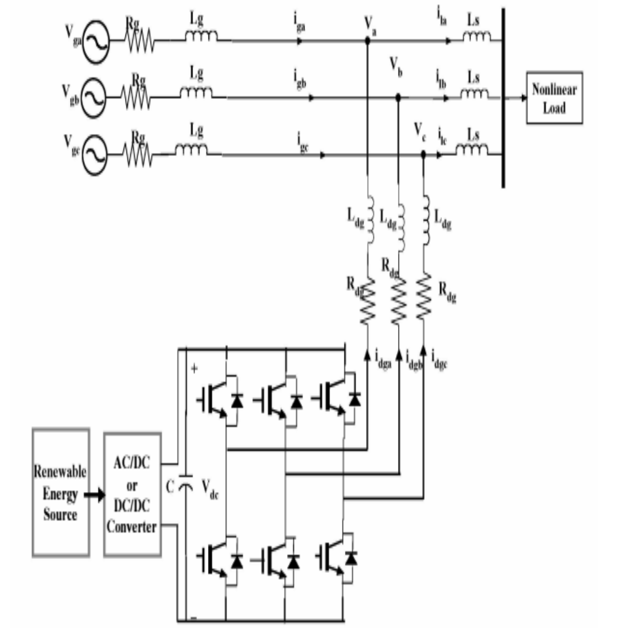


Fig 1 Schematic of the proposed distribution generation system connected to the electrical network

Using equations (1) and (2),

$$\begin{bmatrix} I^*_{dgd} \\ I^*_{dgq} \end{bmatrix} = \frac{1}{\tilde{v}_d^2 + \tilde{v}_q^2} \begin{bmatrix} P^* & Q^* \\ -Q^* & P^* \end{bmatrix} \begin{bmatrix} \tilde{v}_d \\ \tilde{v}_q \end{bmatrix} \frac{2}{3} \quad (3)$$

Where $\tilde{v}_d$and $\tilde{v}_q$are the voltages after passing through a low pass filter. P * and Q*are the active and reactive power references.

***c) Proposed Closed Loop Power Control:***

In the proposed closed loop control strategy, the calculated DG active and reactive power are filtered through a low pass filter and compared with the reference powers to get the error signal. The dq - components of inverter reference current at fundamental frequency can be generated by passing the error signal through a PI controller and can be expressed as

$$I^*_{dgd} = (P^* - \tilde{P}_{dg})(k_{p1} + \frac{k_{i1}}{s}) \quad (4)$$

$$I^*_{dgq} = (Q^* - \tilde{Q}_{dg})(k_{p2} + \frac{k_{i2}}{s}) \quad (5)$$

Where $P_{dg}$ and$P_{qg}$ represent the filtered real and reactive power of the DG inverter, $k_{p1}$.$k_{i1}$ $k_{p2}$and $k_{i2}$are theproportional and integral gains for minimizing the real and reactive power control errors, As per IEEE 1547 the inverters in a distributed generation system are not permitted to inject reactive power to the grid [5]. As such, the total q-axis reference current for the inverter is limited to meet only the reactive power demand of the load so that $I^*_{dgq}$= O. Hence only active power control is done in both open loop and closed loop control schemes. In rotating synchronous frame the quadrature component of load current i1q is perpendicular to the direct component of voltage ($i_{lq} \perp v_d$). Accordingly the q-axis reference current of the DO inverter can be expressed as

$$i^*_{dgq} = i_{lq} \tag{6}$$

***d) Calculation of Total D-Axis Reference Current:***

The d-axis component of the load current can be expressed as

$$i_{ld} = i_{ld_1} + \tilde{i}_{ld} \tag{7}$$

Where in $\tilde{i}_{ld}$ is the oscillating component of the load currentand $i_{ld1}$ is the fundamental component of load current. In dq frame the fundamental frequency component of the load current appears as a dc component. The harmonic components of the load current can be obtained by using a high pass filter. But due to the excessive phase lag associated with the high pass filter, a second order low pass filter having a cut off frequency of 25 Hz is used to extract the harmonic component of the load current.

$\tilde{i}_{ld}$ Can be expressed as

$$\tilde{i}_{ld} = \sum_{n=2}^{\infty} i_{ld_n} \tag{8}$$

$$\sum_{n=2}^{\infty} i_{ld_n} = i_{ld}(1 - LPF) \tag{9}$$

The DO inverter has to supply the d-axis component of harmonic load current given by equation (8) and the d-axis component of current at fundamental frequency given by equation (3) or (4) depending upon the type of the power control scheme. Hence the total d-axis reference current for the DO inverter can be expressed as

$$i^*_{dgd} = \tilde{i}_{ld} + I^*_{dgd} \tag{10}$$

***e) DC Link Voltage Control:***

When the power from the RES is equal to zero, the inverter operates in shunt active filter mode. The DO inverter draws an active power component of current for maintaining the dc bus voltage constant and to meet the losses in the inverter. The DC link voltage error can be expressed as

$$v_{dcerr} = v^*_{dc} - v_{dc} \tag{11}$$

The current can be obtained by passing the error through a PI controller and is given by

$$i_{dc} = k_p v_{dcerr} + k_i \int v_{dcerr} dt \tag{12}$$

Where kp and k; are the proportional and integral gain constants.

***f) Hysteresis Current Control Scheme:***

A Hysteresis band current controller is used to generate the switching pulses for the DO inverter. The reference currents generated in dq frame are transformed to natural ABC frame and compared with the inverter currents to generate the error signals.

If $I^*_{dga} - i_{dga} > h_b$,then upper switch is switched ON and lower switch is switched OFF in the inverter leg of phase 'a'.

If $I^*_{dga} - i_{dga} < h_b$then upper switch is switched OFF andlower switch is switched ON in the inverter leg of phase 'a', Where $h_b$ is the assigned hysteresis band? Using the same principle switching pulses for the other switches in phase 'b'&'c' are produced. The hysteresis band directly controls the amount of ripples in the current injected into the grid. The main advantages of hysteresis current controller are ease of implementation, extremely good dynamic response, outstanding robustness and independence of load parameter changes [17]. The switching frequency depends on the width of hysteresis band, the size of interfacing inductor Ldg to the grid and the DC voltage. As per [18], the relation between switching frequency and the filter inductance can be expressed as

$$L_{dg} = \frac{2V_{dc}}{9 h_b f_{sw.\max}} \tag{13}$$

Where $v_{dc}$ is the DC link voltage, $h_b$ is the hysteresis band and $f_{bsw\ max}$ is the maximum switching frequency.

## IV INTRODUCTION TO FUZZY LOGIC CONTROLLER

L. A. Zadeh presented the first paper on fuzzy set theory in 1965. Since then, a new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to dc-to-dc converter system. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of dc-to-dc converter and performance of proposed controllers. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of dc-to-dc converters. The basic scheme of a fuzzy logic controller is shown in Fig 5 and consists of four principal components such as: a fuzzification interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [10].

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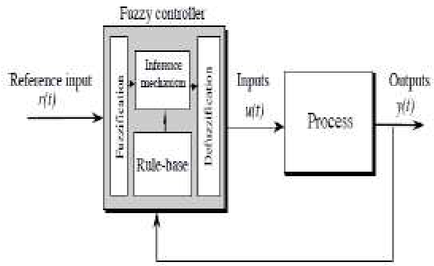



Fig.2. General Structure of the fuzzy logic controller on closed-loop system

The fuzzy control systems are based on expert knowledge that converts the human linguistic concepts into an automatic control strategy without any complicated mathematical model [10]. Simulation is performed in buck converter to verify the proposed fuzzy logic controllers.

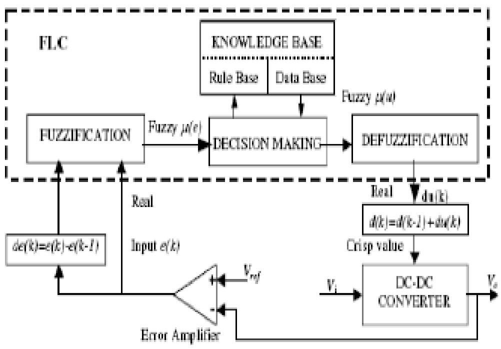



Fig.3. Block diagram of the Fuzzy Logic Controller (FLC) for dc-dc converters

### A. Fuzzy Logic Membership Functions:

The dc-dc converter is a nonlinear function of the duty cycle because of the small signal model and its control method was applied to the control of boost converters. Fuzzy controllers do not require an exact mathematical model. Instead, they are designed based on general knowledge of the plant. Fuzzy controllers are designed to adapt to varying operating points. Fuzzy Logic Controller is designed to control the output of boost dc-dc converter using Mamdani style fuzzy inference system. Two input variables, error (e) and change of error (de) are used in this fuzzy logic system. The single output variable (u) is duty cycle of PWM output.

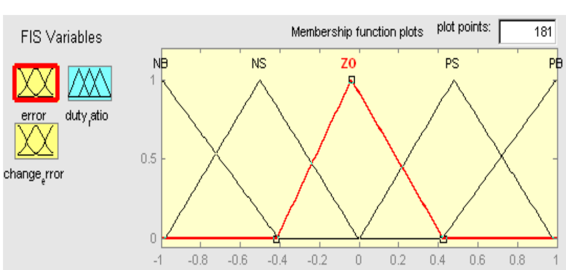



Fig. 4.The Membership Function plots of error

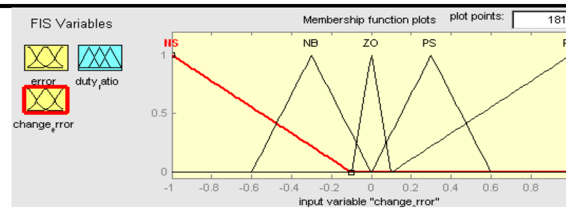
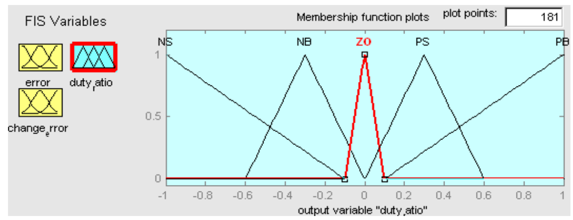



Fig.5. The Membership Function plots of change error




the Membership Function plots of duty ratio

### B. Fuzzy Logic Rules:

The objective of this dissertation is to control the output voltage of the boost converter. The error and change of error of the output voltage will be the inputs of fuzzy logic controller. These 2 inputs are divided into five groups; NB: Negative Big, NS: Negative Small, ZO: Zero Area, PS: Positive small and PB: Positive Big and its parameter [10]. These fuzzy control rules for error and change of error can be referred in the table that is shown in Table II as per below:

Table II: Rules for error and change of error

| (de) \ (e) | NB | NS | ZO | PS | PB |
|---|---|---|---|---|---|
| NB | NB | NB | NB | NS | ZO |
| NS | NB | NB | NS | ZO | PS |
| ZO | NB | NS | ZO | PS | PB |
| PS | NS | ZO | PS | PB | PB |
| PB | ZO | PS | PB | PB | PB |

## V MATLAB/SIMULINK RESULTS

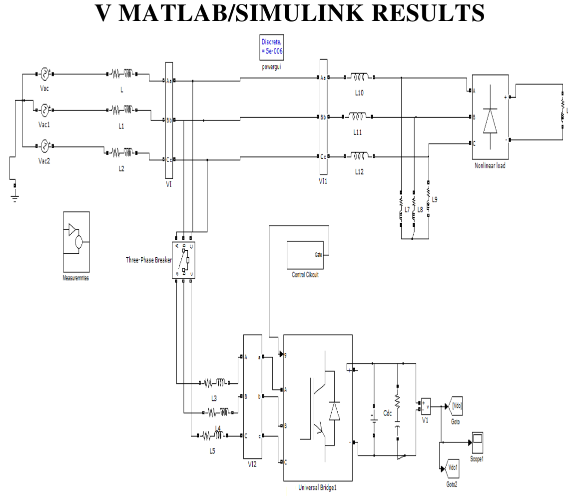


Fig 6 Simulation model for generation of switching pulses for the DG inverter

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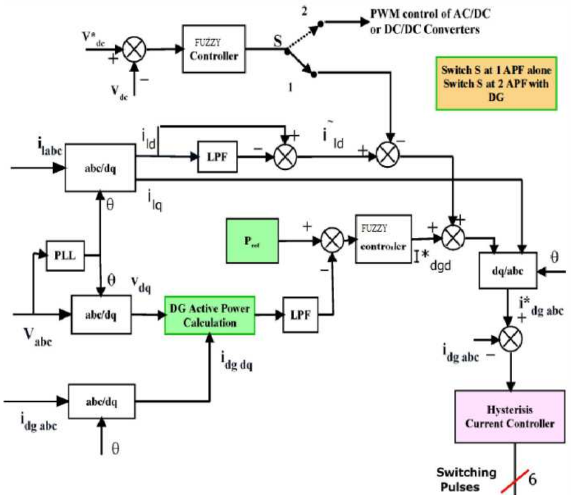


Fig.7 shows the Control block diagram for generation of switching pulses for the DG inverter.

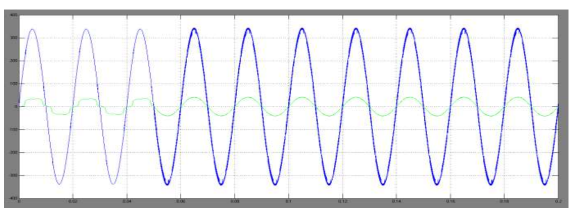

Fig 8 Simulation waveform for source voltage, source currents

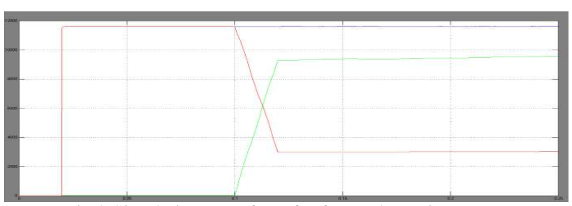

Fig 9 Simulation waveform for forward reactive power

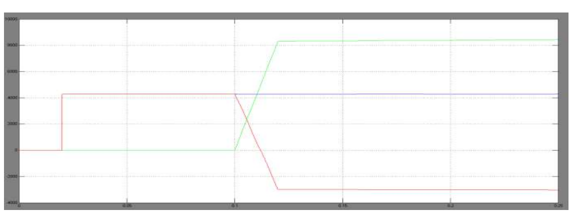

Fig 10 Simulation waveform for reverse reactive power

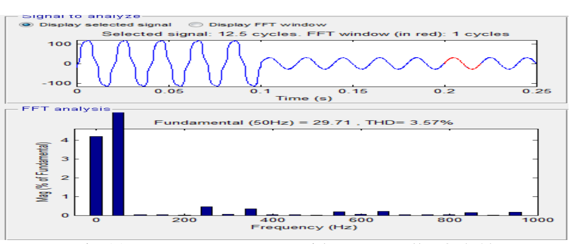


Fig 11 source current THD with PI controller 3.57%

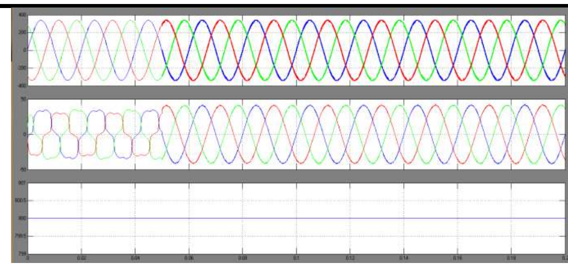

Fig 12 Simulation waveform for Grid voltage, Grid currents and DC link voltage during shunt active filter mode of the DG inverter with PI controller

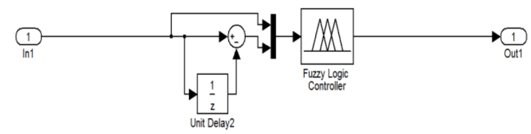


Fig 13 Fuzzy logic control block diagram for generation of switching pulses for the DG inverter

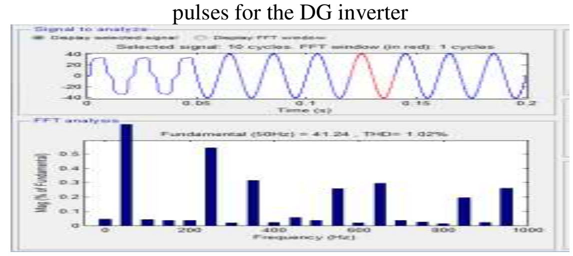


Fig 14 source current THD is 1.02 with fuzzy logic controller

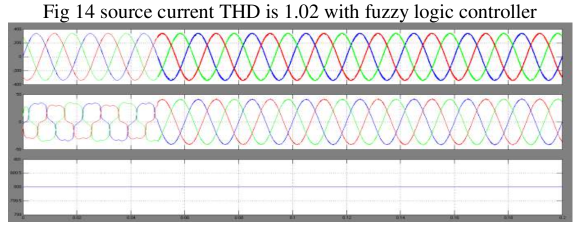

Fig 15 simulation wave form of Grid voltage, Grid current and DC voltage with Fuzzy logic controller

## V CONCLUSION

This paper talks about the abilities of a MFGCI for improving the power quality in a lattice associated circulated age framework. It has been demonstrated that the DG inverter can be successfully used to infuse genuine power from the RES in the forward and turn around control stream modes and additionally work as a shunt dynamic power channel. The proposed shut circle dynamic power control system accomplishes exact power following with zero unfaltering state mistakes under perfect and non-perfect supply conditions and can be utilized as a control method for reconciliation of DG inverters to the utility network. The technique covers the need of additional power molding gadgets to enhance the power quality. The viability of the control conspire is checked under adjusted and uneven non straight load conditions. From the proposed idea the blend of nonlinear burdens and the DG inverter is viewed as a resistive load at the PCC and the matrix streams are looked after sinusoidal. The proposed fluffy rationale controller is to decreased the THD and enhance the power quality and keep up the network streams are looked after sinusoidal.

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