Available online at: http://www.ijmtst.com/vol4issue9.html

International Journal for Modern Trends in Science and Technology

ISSN: 2455-3778 :: Volume: 04, Issue No: 09, September 2018

Implementation of Fuzzy Logic Controller Based Distributed Generation Systems with Hybrid Inverter for Unbalanced Loads

Somanth Geddam[1] | Prof. GopiChand Naik Mudavath[2]

[1]PG Scholar, Department Of Electrical Engineering, Andhra University, Visakhapatnam, Andhra Pradesh, India.
[2]Professor, Department Of Electrical Engineering, Andhra University, Visakhapatnam, Andhra Pradesh, India.

To Cite this Article
Somanth Geddam and Prof. GopiChand Naik Mudavath, "Implementation of Fuzzy Logic Controller Based Distributed Generation Systems With Hybrid Inverter For Unbalanced Loads", *International Journal for Modern Trends in Science and Technology*, Vol. 04, Issue 08, September 2018, pp.-06-13.

Article Info
Received on 05-July-2018, Revised on 11-Aug-2018, Accepted on 21-Sept-2018.

ABSTRACT

In this paper,The three-stage four-leg voltage source inverter (VSI) topology is an intriguing alternative for the three stage four wire framework. With an extra leg, this topology can accomplish predominant execution under the uneven and additionally nonlinear load condition. Be that as it may, because of the low transfer speed of the traditional controllers in high power inverter application, the framework can't ensure the adjusted yield voltage under lopsided load condition. The greater part of the techniques proposed to tackle this issue so far principally utilize the various synchronous casings strategy. Notwithstanding, it requires a great deal of calculation because of the edge change and a few quantities of controllers. This paper proposes a basic half and half controller which consolidates a PI controller and a thunderous controller in the synchronous casing synchronized with positive grouping segment of yield voltage of the three stage four leg inverter. The outline system for the controller plan and the hypothetical investigation are introduced. The execution of the proposed idea can be actualized to Fuzzy Logic Controller and contrasted and that of the customary PI controller.

KEYWORDS: *Fuzzy logic, Hybrid inverter, Distributed generation*

I. INTRODUCTION

As of late, Eco-accommodating distributed generation frameworks (DGS, for example, wind turbines, sun oriented cells, and energy components are significantly developing since they can satisfy the expanding interest of electric power because of the fast development of the economy and strict ecological controls with respect to ozone depleting substance discharges. By and large, the DGSs operate together with the existing framework and supply the demand which is increasing with time and population. Be that as it may, there are a few territories whose integration with the network is unfeasible and after that little scaled independent DGSs are the main proficient alternatives. In such DGSs, contingent upon customers the embedded generation may function together with the network or individually.

Consequently, the voltage controller outline for a solitary DGS unit, which can ensure a decent voltage direction under unequal and nonlinear burdens, is an intriguing subject in the field of the DGSs control. To improve the nature of inverter yield voltage, numerous specialists are taking a shot at planning the controllers for dc– air conditioning power converters. In a vigorous controller is produced for adjusted and uneven frameworks, which thinks about the vulnerabilities of the heap parameters. Be that as it may, nonlinear load isn't completely tended to. In a dull control is utilized to direct the UPS inverters. In any case, the moderate reaction and absence of the methodical strategy to balance out the mistake elements with the dreary control are being the principle issues. In an option control procedure with an encourage forward remuneration part can essentially relieve the impact of load unsettling influence and influence the controller to plan straightforward. In any case, the utilization of this strategy is chiefly restricted to adjusted load conditions. In a present control procedure in view of the spatial monotonous control is connected to a solitary stage inverter and it additionally enhances the execution of the present controller by assessing the unsettling influences. In spite of the fact that this control can get great outcomes under nonlinear load, it may not ensure a decent voltage following limit with respect to a three stage framework. In a hearty servomechanism voltage controller and a discrete-time sliding mode current controller are displayed to control a solitary dispersed age unit in an independent mode which can work well under a sudden load change, a varying load, and a nonlinear load.

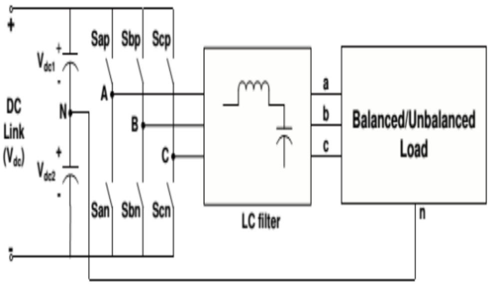


Fig.1: 3-leg inverter

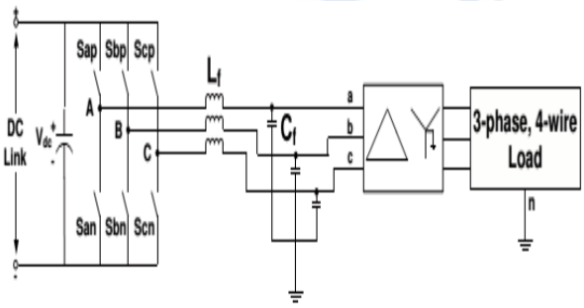


Fig.2: 3-leg inverter interface with transformer connection

By the by this is the most famously utilized topology for 3-stage, 4-wire DG framework. Both the topologies come up short while sustaining a 3-stage, 4-wire lopsided load. Thus extra lopsided load compensators are normally given close to the uneven load end. However with the approach of 4-leg inverters (see Fig.3),it is conceivable to deal with lopsided burdens without influencing terminal voltages [6], [7]. The heap impartial can be associated with the focal point of fourth leg and zero grouping streams moving through nonpartisan can be controlled.

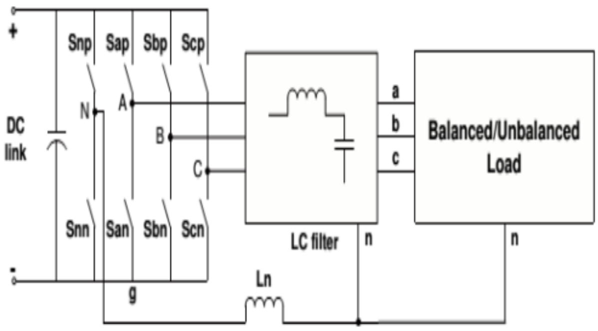


Fig.3: 4-leg inverter

Preferences of 4-leg inverter interfaces are as per the following: There are no swells in DC connect voltage when 4-leg inverters take into account unequal or nonlinear burdens. So there is no need of expansive DC connect capacitors similar to the case of3-leg split DC interface topology. The 3-dimensional Space Vector Modulation (3-D SVM) strategy upgrades the use of DC connect voltage [8].

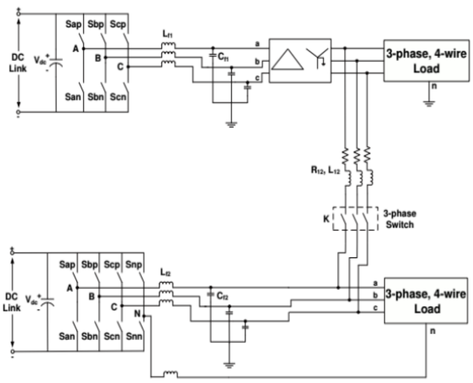


Fig.4: DG system with 3-leg and 4-leg inverter interfaces

Nearness of fourth nonpartisan leg takes out the necessity of massive transformers for control departure (at any rate in little low voltage independent DG frameworks). The 4-leg inverters are generally utilized as dynamic load compensators [9], [10]. The capacity of utilizing

4-leg inverter as an interface for remain solitary microgrid with unequal load is examined in [11]. Its application to deal with crisis mode for line intelligent framework is examined in [12]. Be that as it may, all the current DG frameworks are working with 3-leg inverter interfaces. Be that as it may while extending the current framework, the likelihood of using4-leg inverter interface should be investigated. This thought is tended to in detail in this paper. This is a novel approach to relieve the heap unbalance by shaping cross breed inverter interfaces rather than nearby unbalance compensators. The proposed DG framework with 3-leg and 4-leg inverter interfaces is appeared in Fig.4.

In this paper, we are exhibiting the work completed in outlining the Fuzzy rationale controller for exchanging operation of inverter. A basic control methodology of inverter is embraced where the estimation. At that point the exhibitions of ordinary fuzzy rationale controller are examined. Reproduction comes about demonstrate that Total Harmonic Distortion in source current is definitely decreased fuzzy controller is incorporated into the inverter control circuit. Recreation work has been done using MATLAB/SIMULINK programming.

II. CONTROLLER DESIGN FOR 3-LEG AND 4-LEG INVERTERS

For the 3-leg inverter interface, 2-D SVM conspire [13] is actualized, though for the 4-leg inverter, 3-D SVM [8] isused. 3-D SVM is a superset of 2-D SVM system. In boththe SVM tweak systems, DC connect use is betteras contrasted with other regulation methods. Adjustment indexfor 3DSVM is characterized as Where Vm is crest estimation of stage voltage and Vdc is the DClink voltage. For 230V rms stage voltage, Vm is 325V. Withm = 1, DC connect voltage required is 563V. Be that as it may, to take careof misfortunes, it is kept up at 580V. For closedloop designof every inverter, terminal voltages of inverters, stack currentsand capacitor streams are detected. These are changed intosynchronous reference edge to frame a decoupled shut loopsystem. It is to be noted here that for 3-leg inverters, there areonly q-pivot and d-hub controllers (see Fig.5). This is because3-leg inverters have just two degrees of opportunity (DOF). Onthe other hand, a 4-leg inverter has three DOFs and there areq-pivot, d-hub and 0-hub controllers [14] (see Fig.6).

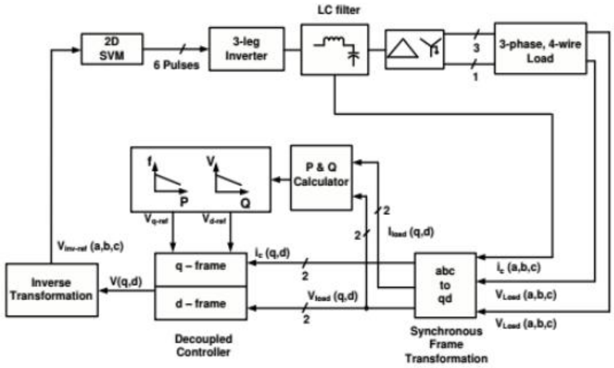


Fig.5: Closed-loop system for 3 leg inverter fed Distributed Generation System

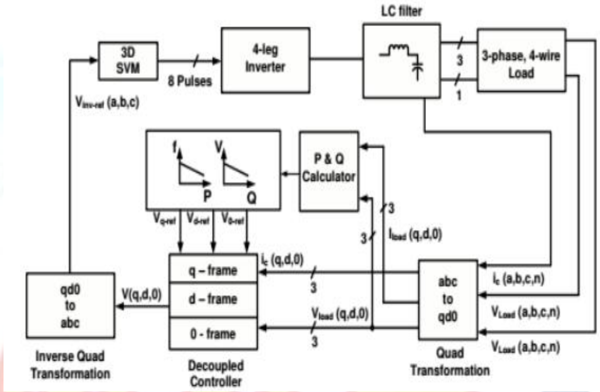


Fig. 6. Closed-loop system for 4 leg inverter fed Distributed Generation System

III. POWER FLOW ANALYSIS

For decentralized operation, P - f and Q-V hang laws are applied. Accordingly there is no correspondence required between the two DG units. For producing references for inward voltage control circles, recurrence and sufficiency of voltages is generated by hang laws. The change proportion of Δ-Y transformer utilized as a part of 3-leginverter interfaced framework is 1:1 for straightforwardness. In simulation, sustainable power wellspring of DC connect is supplanted by3-stage diode connect rectifier. Every one of the reproductions are carried out utilizing MATLAB Simulink tool stash. Information for two inverters is given.

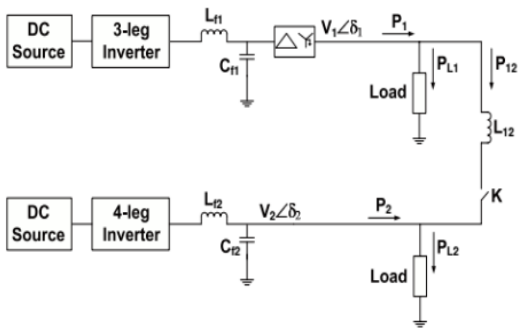


Fig.7: Distributed generation system with hybrid inverter operation

For understanding the power stream in interconnecting line, the single line outline of DG framework with cross breed inverter interfaces is appeared in Fig.7. In this area, investigation of power flow in interconnecting line is completed as given in [11].From the above examination plainly for uneven load on 4-leg inverter side, the negative and zero grouping parts in terminal voltages of DG units are inside worthy points of confinement indicated by the previously mentioned norms. The zero grouping streams never add to the power stream in interconnecting line [15]. The negative grouping segment in terminal voltages isn't unimportant. Thus to calculate prompt power, positive and negative arrangement segments of streams and in addition voltages are thought about [11]. The terminal voltages and interconnecting line streams are spoken to as phasors as:

$$\mathbf{V} = V_{qd}^{p} e^{j\omega t} + V_{qd}^{n} e^{-j\omega t},$$

$$\mathbf{I} = I_{qd}^{p} e^{j\omega t} + I_{qd}^{n} e^{-j\omega t}.$$

In general, they are given as:

$$f_{qd} = f_q + j f_d,$$

Interconnecting power at any moment is represented by:

$$S = \left(V_{qd}^{p} e^{j\omega_1 t} + V_{qd}^{n} e^{-j\omega t}\right)\left(I_{qd}^{p} e^{j\omega_1 t} + I_{qd}^{n} e^{-j\omega_1 t}\right)^{*}$$

The active and reactive power flow given by:

$$\begin{aligned} P_{12}(t) &= P_{01} + P_{02} + (P_{c1} + P_{c2})\cos 2\omega t \\ &+ (P_{s1} + P_{s2})\sin 2\omega t, \\ Q_{12}(t) &= Q_{01} + Q_{02} + (Q_{c1} + Q_{c2})\cos 2\omega t \\ &+ (Q_{s1} + Q_{s2})\sin 2\omega t, \end{aligned}$$

The terms as further explained as :

$$\begin{aligned} P_{01} &= \frac{3}{2}(V_{qp}I_{qp} + V_{dp}I_{dp}),\ P_{02} = \frac{3}{2}(V_{qn}I_{qn} + V_{dn}I_{dn}), \\ P_{c1} &= \frac{3}{2}(V_{dp}I_{dn} + V_{qp}I_{qn}),\ P_{c2} = \frac{3}{2}(V_{dn}I_{dp} + V_{qn}I_{qp}), \\ P_{s1} &= \frac{3}{2}(V_{qp}I_{dn} - V_{dp}I_{qn}),\ P_{s1} = \frac{3}{2}(V_{dn}I_{qp} - V_{qn}I_{dp}), \\ Q_{01} &= \frac{3}{2}(V_{dp}I_{qp} - V_{qp}I_{dp}),\ Q_{02} = \frac{3}{2}(V_{dn}I_{qn} - V_{qn}I_{dn}), \\ Q_{c1} &= \frac{3}{2}(V_{dp}I_{qn} - V_{qp}I_{dn}),\ Q_{c2} = \frac{3}{2}(V_{dn}I_{qp} - V_{qn}I_{dp}), \\ Q_{s1} &= \frac{3}{2}(V_{qp}I_{qn} + V_{dp}I_{dn}),\ Q_{s2} = -\frac{3}{2}(V_{qn}I_{qp} + V_{dn}I_{dp}). \end{aligned}$$

$$P_{01}(t) = B_{12}\sin\delta_{12}, \quad \text{with } B_{12} = \frac{3V_1V_2}{\omega_0 L_{12}},$$

It is additionally appeared in [11] that because of both 4-leg inverter interfaces, terminal voltages of DG units are practically adjusted and normal power P01 is because of positive arrangement segments of voltages and streams. Henceforth the power sharing between two units is according to hang laws. However in the proposed DG framework with cross breed inverter interfaces, the normal power is likewise because of negative grouping parts of voltages and streams (P02) and this segment does not enable P1 and P2 to take after correct partaking in extent to the hang coefficients. This legitimizes the slight distinction in control sharing after load unbalance. Additionally 2ω motions in the power are because of the negative arrangement segments. This swaying power shared by every inverter relies upon the system parameters and yield impedance of inverters. In the present investigation just dynamic power stream in half and half framework is examined and consequently just resistive burdens are considered. In any case, Q-V hang laws can be connected for responsive power sharing. There dynamic power stream will likewise demonstrate 2ω motions as determined in (7).

IV. INTRODUCTION TO FUZZY LOGIC CONTROLLER

L. A. Zadeh introduced the main paper on fuzzy set hypothesis in 1965. From that point forward, another dialect was produced to depict the fuzzy properties of reality, which are exceptionally troublesome and at some point even difficult to be portrayed utilizing ordinary strategies. Fuzzy set hypothesis has been broadly utilized as a part of the control territory with some application to dc-to-dc converter framework. A straightforward fuzzy rationale control is developed by a gathering of tenets in light of the human learning of framework conduct. Matlab/Simulink reenactment show is worked to examine the dynamic conduct of dc-to-dc converter and execution of proposed controllers. Besides, outline of fuzzy rationale controller can give alluring both little flag and substantial flag dynamic execution at same time, which isn't conceivable with straight control procedure. Along these lines, fuzzy rationale controller has been potential capacity to enhance the strength of dcto-dc converters. The fundamental plan of a fuzzy rationale controller is appeared in Fig 5 and comprises of four primary parts, for example, a fuzzification interface, which changes over information into appropriate phonetic esteems; a learning base, which comprises of an information base with the essential semantic definitions and the control administer set; a basic leadership rationale which, reproducing a human choice process, construe the fuzzy control activity from the learning of the control rules and etymological variable definitions; a de-fuzzification interface which yields non fuzzy control activity from a derived fuzzy control activity [10].

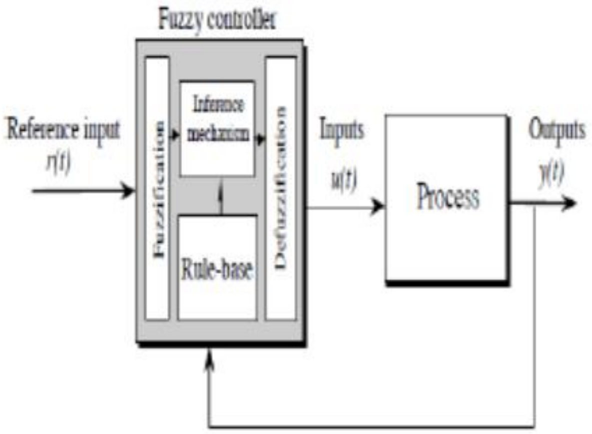


Fig.8. General Structure of the fuzzy logic controller on closed-loop system

The fuzzy control frameworks depend on master learning that changes over the human phonetic ideas into a programmed control methodology with no confounded scientific model [10]. Recreation is performed in buck converter to check the proposed fuzzy rationale controllers.

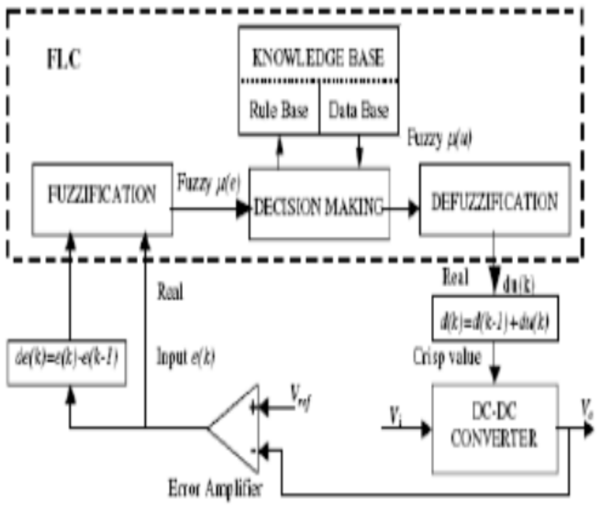
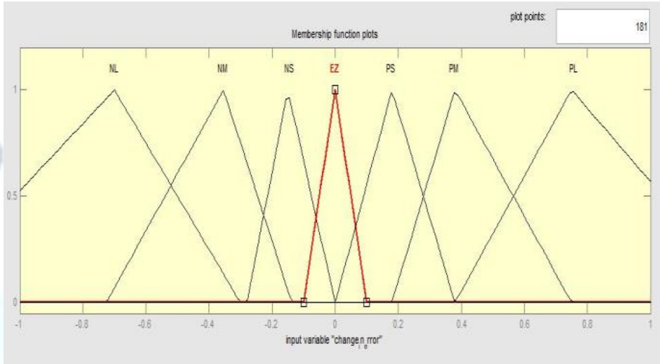


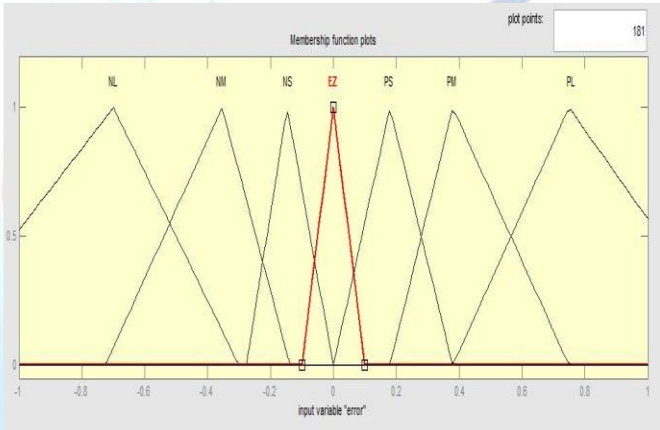
Fig.9. Block diagram of the Fuzzy Logic Controller (FLC) for dc-dc converter

A. Fuzzy Logic Membership Functions:

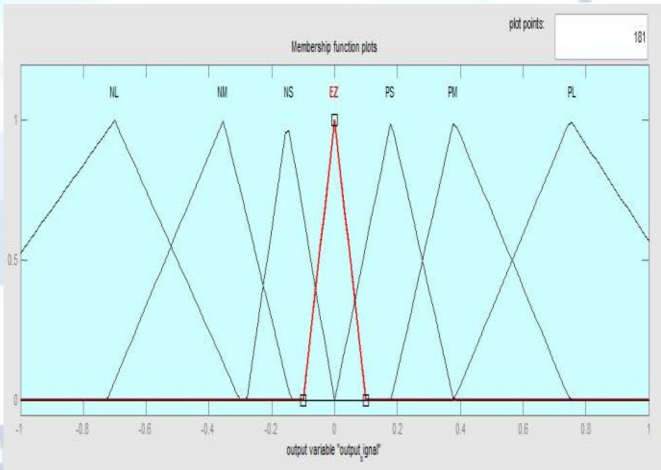
The dc-dc converter is a nonlinear capacity of the obligation cycle on account of the little flag model and its control technique was connected to the control of lift converters. Fuzzy controllers don't require a correct numerical model. Rather, they are composed in light of general information of the plant. Fuzzy controllers are intended to adjust to changing working focuses. Fuzzy Logic Controller is intended to control the yield of lift dc-dc converter utilizing Mamdani style fuzzy deduction framework. Two information factors, blunder (e) and change of mistake (de) are utilized as a part of this fuzzy rationale framework. The single yield variable (u) is obligation cycle of PWM yield.



The Membership Function plots of error



The Membership Function plots of change in error.



The Membership Function plots of duty ratio

B. Fuzzy Logic Rules:

The error and change of error of the output voltage will be the inputs of fuzzy logic controller. [10]. These fuzzy control rules are shown in Table II as per below:

Table II Table rules for error and change of error

de/e	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	NM	NS	ZE
NM	NB	NB	NM	NS	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NM	NS	NS	ZE	PS	PS	PM
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PS	PM	PB	PB
PB	ZE	PS	PM	PM	PB	PB	PB

V. SIMULATION RESULTS

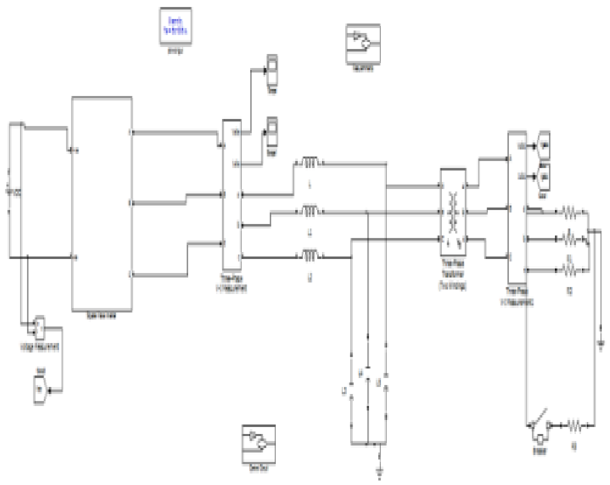


Fig 10 Matlab/simulation circuit of 3-leg inverter with split DC link capacitor

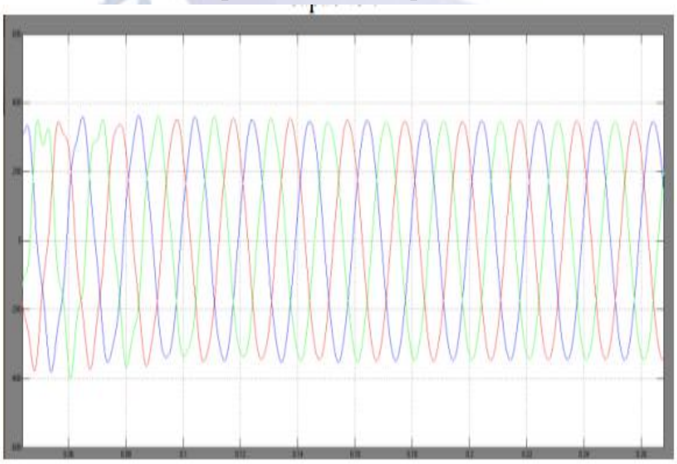


Fig 11 simulation wave form of Terminal voltages of stand-alone DG unit with 3-leg inverter interface with unbalance load

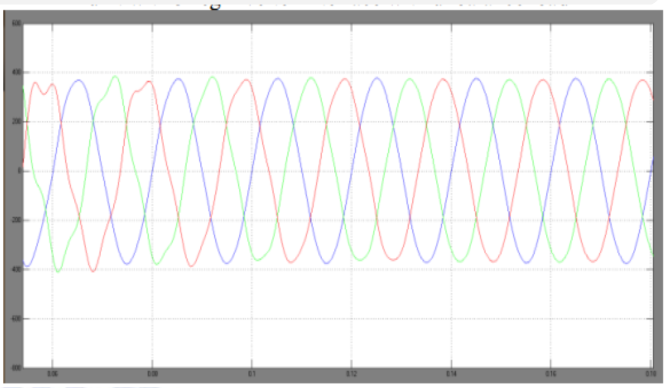


Fig 12 simulation wave form of Terminal voltages of stand-alone DG unit with 4-leg inverter interface with unbalance load

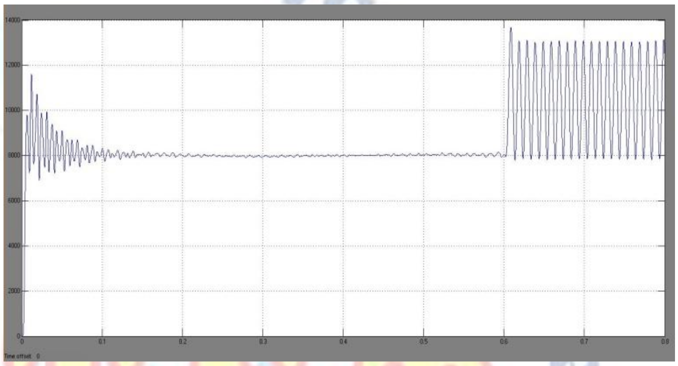


Fig.13(b) simulation wave form of Power sharing with unbalance on 3-leg inverter side.

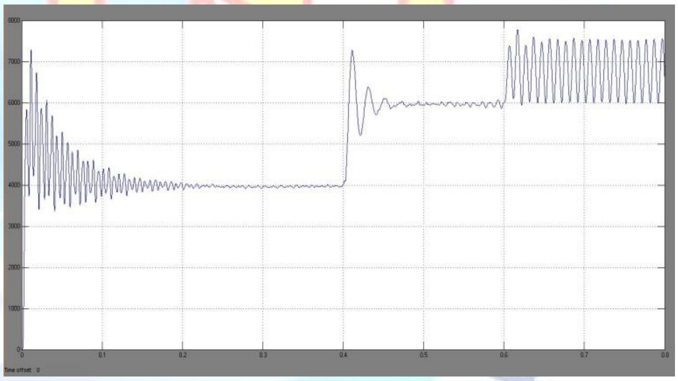


Fig.13(b) simulation wave form of Power sharing with unbalance on 3-leg inverter side.

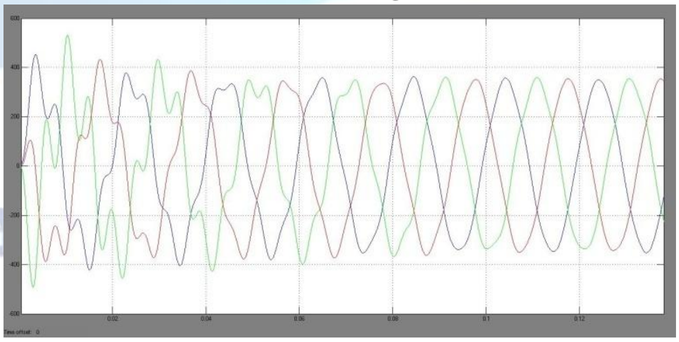


Fig.14. simulation wave form of Terminal voltages of DG units with unbalance on 3-leg inverter side.

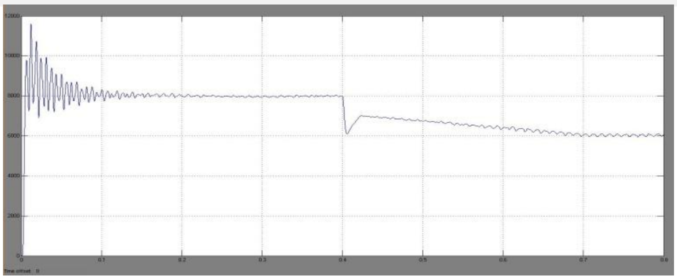


Fig.15. (a) simulation wave form of Power sharing with unbalance on 4-leg inverter side

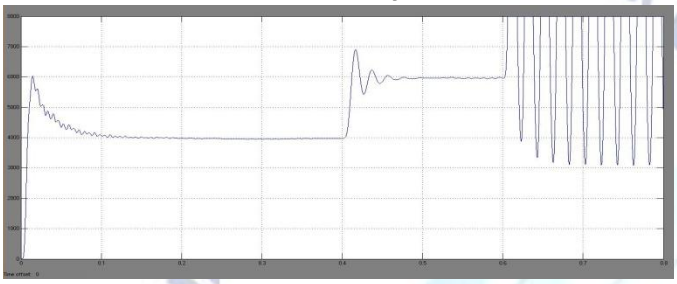


Fig.15. (b) simulation wave form of Power sharing with unbalance on 4-leg inverter side

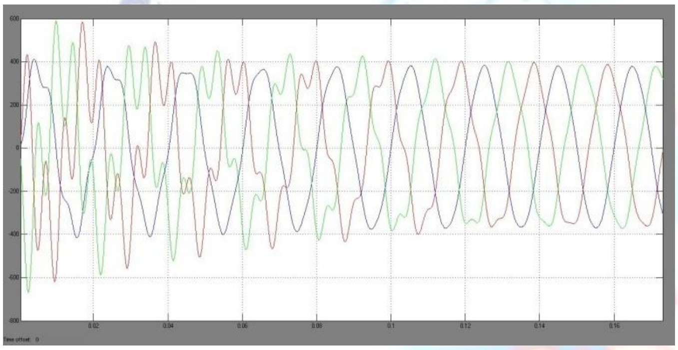


Fig.16. simulation wave form of Terminal voltages of DG units with unbalance on 4-leg inverter side

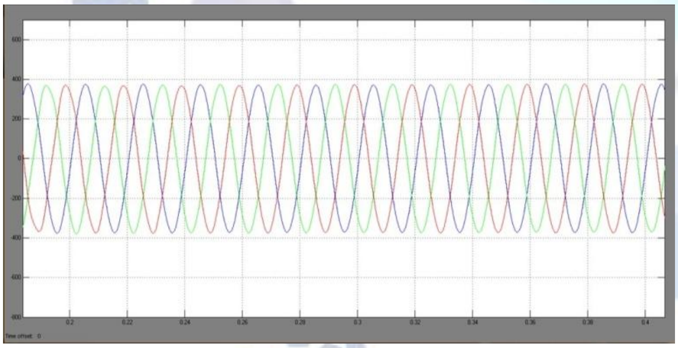


Fig.17. Combined 3leg and 4Leg terminal voltage.

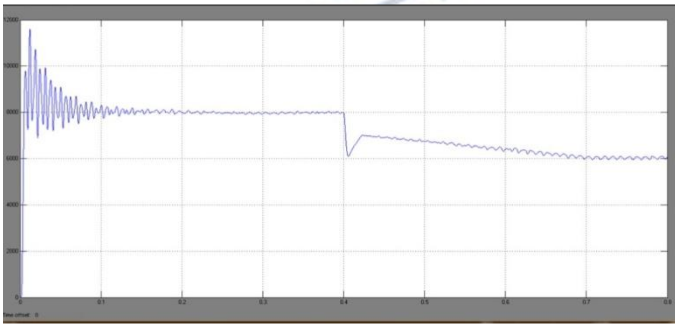


Fig.18. Combined 3 and 4 leg Power sharing (3 leg inverter)

Fig19 Combined 3 and 4 leg Sharing (4 leg inverter)

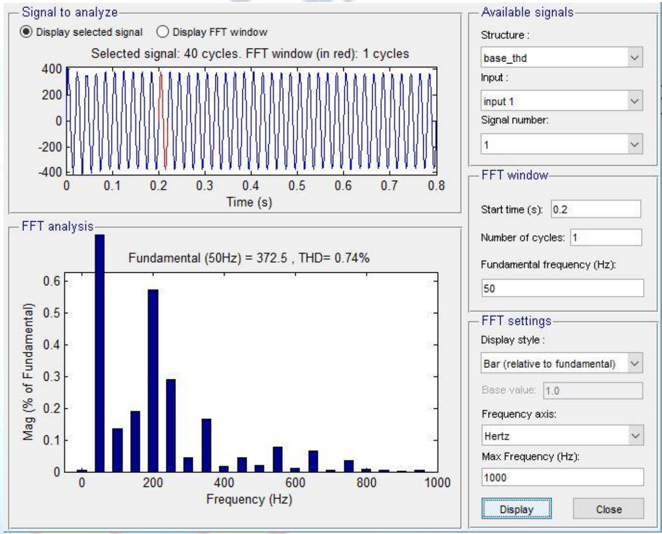


Fig.20. THD analysis of voltage and current in 3-leg and 4-leg inverter with PI Controller.

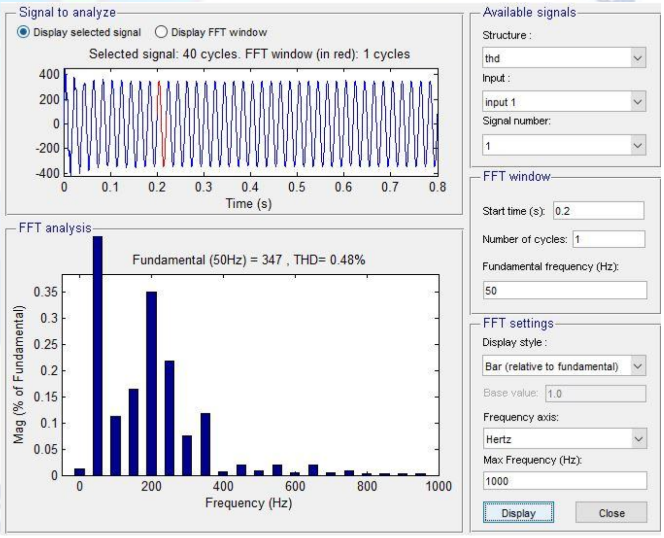


Fig.21. THD analysis of voltage and current in 3-leg and 4-leg inverter with fuzzy logic

VI. CONCLUSION

This paper displays a novel technique to enhance the power quality at purpose of regular coupling for a3-stage 4-wire DG framework utilizing PI controller and fuzzy rationale controller for matrix interfacing inverter. The network interfacing inverter is adequately used for control molding. This approach disposes of the extra power molding gear to enhance control quality at PCC. The lattice interfacing inverter with the proposed approach can be used to infuse genuine power age from RES to the framework, and work as a shunt Active Power Filter (APF). The present unbalance, current sounds and load receptive power, because of lopsided and non-direct load associated with the PCC, are repaid successfully to such an extent that the network side streams are constantly kept up as adjusted and sinusoidal at solidarity control factor. Besides, the heap unbiased current is kept from streaming into the matrix side by repaying it locally from the fourth leg of inverter. At the point when the power produced from RES is more than the aggregate load control request, the network interfacing inverter with the proposed control approach not just satisfies the aggregate load dynamic and responsive power request (with symphonious compensation)but additionally conveys the overabundance created sinusoidal dynamic energy to the framework at solidarity control factor. The settling of the framework is enhanced henceforth proposed fuzzy rationale controller has quick reaction, high exactness of following the DC-voltage reference, and ability to tackle with load sudden variations.

References

[1] M. Dai, M. N. Marwali, and A. Keyhani, "A three-phase four wireinverter control technique for a single distributed generation unit inisland mode," IEEE Transactions on Power Electronics, vol. 23, no. 1,pp. 322–330, 2008.

[2] S. El-Barbari and W. Hofmann, "Digital control of a four leg inverter forstandalone photovoltaic systems with unbalanced load," inTwenty-sixthAnnual conference of IEEE, IECON, (Nagoya, Japan), pp. 729–734,October 2000.

[3] X. Song, Y. Wang, W. Hu, and Z. Wang, "Three reference framecontrol scheme of 4-wire grid-connected inverter for microgrid underunbalanced grid voltage conditions," inTwentyFourth Annual IEEEApplied Power Electronics Conference and Exposition, (Washington,USA), pp. 1301–1305, February 2009.

[4] M. N. Marwali and A. Keyhani, "Control of distributed generationsystems - Part I : voltages and currents control," IEEE Transactionson Power Electronics, vol. 19, no. 6, pp. 1541– 1550, 2004.

[5] M. N. Marwali and A. Keyhani, "Control of distributed generationsystems - Part II : load sharing control,"IEEE Transactions on PowerElectronics, vol. 19, no. 6, pp. 1551– 1561, 2004.

[6] I. Vechiu, H. Camblong, G. Tapia, B. Dakyo, and O. Curea, "Control offour leg inverter for hybrid power system applications with unbalancedload," Energy Conversion and Management, vol. 48, no. 7, pp. 2119–2128, 2007.

[7] I. Vechiu, O. Curea, and H. Camblong, "Transient operation of a fourleg inverter for autonomous applications with unbalanced load," IEEETransactions on Power Electronics, vol. 25, pp. 399–407, February2010.

[8] R. Zhang, V. H. Prasad, D. Boroyevich, and F. C. Lee, "Threedimensional space vector modulation for four-leg voltage-source converters," IEEE Transactions on Power Electronics, vol. 17, no. 3,pp. 314–326, 2002.

[9] R. R. Sawant and M. C. Chandorkar, "A multifunctional four-leg gridconnected compensator,"IEEE Transactions on Industry Applications,vol. 45, no. 1, pp. 249–259, 2009.

[10] A. Kouzou, H. A. Rub, M. O. Mahmoudi, M. S. Boucherit, andR. Knennel, "Four wire shunt active filter based on four-leg inverter,"in International Aegean Conference on Electric Machines and PowerElectronics &Electro motion, (Istanbul, Turkey), pp. 508–513, September 2011.

[11] D. Vyawahare and M. C. Chandorkar, "Power flow analysis in standalone 4-wire, 4-leg inverter microgrid with unbalanced loads," inSixteenth European Conference on Power Electronics and ApplicationsEPE-ECCE, (Lappeenranta, Finland), pp. 1–10, August 2014.

[12] D. Vyawahare and M. C. Chandorkar, "Line interactive distributed 4-leg inverter system with unbalanced and nonlinear loads," in IEEEInternational Conference on Power Electronics, Drives and EnergySystems (PEDES), (Mumbai, India), pp. 1–6, December 2014.

[13] M. P. Kazmierkowski, R. Krishnan, and F. Blaabjerg,Control in PowerElectronics: Selected Problems. USA: Academic Press, 2002.

[14] M. J. Ryan, R. D. Lorenz, and R. W. D. Doncker, "Modeling of multilegsine wave inverters: A geometric approach," IEEE Transactions onIndustrial Electronics, vol. 46, no. 6, pp. 1183–1190, 1999.

[15] H. Saadat, Power System Analysis. USA: PSA Publishing, 2010.