



FUZZY CONTROLLED SINGLE-STAGE CONVERTER FED PV SYSTEM

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Abstract : This project shows a new technique for controlling the LG, LL and LLL faults by the fuzzy-integral decision fusion technique method designed to the grid connected to PV system. The method firstly constructs a criterion set which covers all types commonly used criteria for LG, LLL and LL faults. The control targets, for example, maximum power point tracking, synchronization with grid, current control, and constant decrease in yield current, are realized in single stage for high productivity and straightforward power converter topology by the fluffy controller. On this premise, it is indicated by fault qualities, paradigm in the set is individually used to do LG, LL and LLL faults analysis, and fault measure is produced from every model. The active and reactive power are constrained by utilizing dq segments of grid current. The new controller shows the strong exhibition and vigorous steadiness of the DG unit system as for the channel parameters vulnerabilities, grid impedance, grid frequency, and grid voltage just as the obscure burden elements that incorporate unequal burdens and nonlinear burdens with constant and between symphonious currents. It should comment that the neighborhood remuneration of the heaps with between symphonious current utilizing a DG unit system is first projected in this project. At that point when contrasted and the mainstream parallel corresponding thunderous control system, proposed controller offers smoother transient responses and a lower dimension of current twisting. The presentation of the projected control strategy is verified in MATLAB/SimPower Systems toolbox.

IndexTerms - DC-link voltage control, feedback linearization (FBL), photovoltaic (PV) systems, reactive, LG LL LLL faults, fuzzy controller.

I. INTRODUCTION

In the last few years, penetration of power generated from the photovoltaic (PV) systems into the electricity grid has been increasing due to advancement in technology leading to the cost reduction of power electronic device and many incentive programs introduced by the governments [2]. In the grid-connected PV systems, the most important aims are to reduce cost and improve efficiency, reliability of both the PV panels, converters [3], [4]. To achieve these, single-stage three-phase dc-to-ac power converter system consider being the best choice for utility-scale high-power PV system [5]. The continuous increase in the interconnection of these megawatt-sized PV systems in the distribution network requires study of PV system impacts on the distribution network and performance of controllers under steady-state and dynamic conditions. The dynamic response of PV system is characterized by its system architecture, control techniques, distribution network parameters, and weather conditions. Much literature have discussed about these aspects previously. References [6]–[8] suggested different power electronic converter topologies for distributed generation. A survey of largest number power point tracking (MPPT), the common aspect in PV system, is thoroughly discussed in [9] and [11]. However, most of previous work has investigated about two-stage PV system. Only few references have considered control aspects with both the active, reactive powers and stability for single stage utility-scale (high-power) PVs. References [11]–[14] investigate control strategies for single-stage of PV system without stability consideration. Reference [11] highlights the power issues but does not discuss about grid connection and reactive power control. In [12], PV system like reactive power ancillary service is proposed.

For the active power control with incremental conductance MPPT method, a simple and linearized dc-link voltage controller with FBL technique and d -axis current control are used, whereas for reactive power control, a q -axis current controller is used.

- For voltage controller design, FBL scheme is using to avoid the impacts of distribution network parameters variation and the nonlinearity caused for PV characteristics.
- Unlike the regulator scheme used in [14], FBL technique is used in this work only for voltage controller to make the controller simple with improved results.
- The overall control scheme has be modified and improved with a proposed additional block for compensation for grid voltage disturbance/dip (CGVD) to avoid the destabilization of controllers.

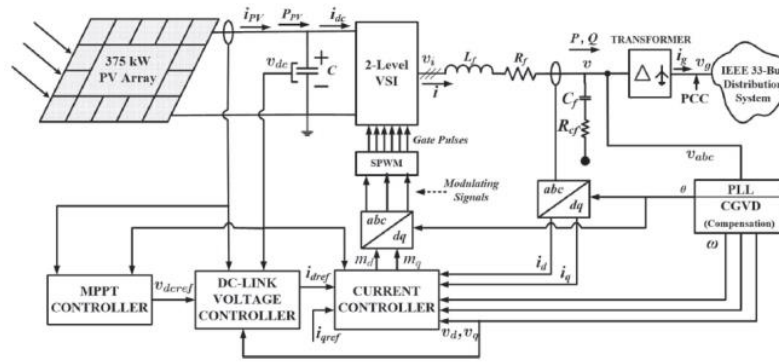


Fig. 1. One of the four 375-kW Subsystems.

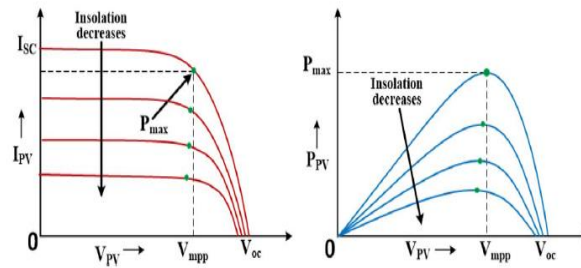


Fig.2. MPPT PV panel properties

To make up for the nearby burden symphonious current, numerous sorts of consonant extraction approaches have be proposed [10], including quick power (pq) hypothesis [11], second-request summed up integrator (SOGI) [12], the postponed sign abrogation based identification [13], and Fourier transformation based discovery [14]. To decrease the computational weight of DG unit controllers, the consonant location less technique has been proposed [7], [15]. The primary grid current generally should be free of consonant mutilation. To improve the power quality of grid current, the DG unit makes up for the consonant current drawn by the nonlinear loads through infusing symphonious current.

Consequently, the grid current will turn out to be free of contortion and the outcome will be great voltage quality at the point of normal coupling (PCC). It turns out to be increasingly significant for a powerless grid, where the consonant current coursing through high grid impedance may cause more voltage contortions at the PCC. Subsequently, the growth of the conveyance system power quality through the best possible control procedure of DG is an issue with high potential for building arrangements [16]. In addition, under different states of various introductory fault voltage edge and distinctive fault obstruction, electric parameter trademark brought about by LG, LL, LLL is assorted and complex. What's more, customary LG, LL, LLL fault analysis techniques are generally founded on fractional fault trademark, (for example, transient fault signal adequacy, transient fault signal stage, relentless state fault signal sufficiency, consistent state fault signal stage, etc) and as indicated by single measure, (for example, transient wavelet plentifulness examination paradigm, transient wavelet connection rule, unfaltering state abundancy correlation rule, enduring state relative stage basis, etc). Be that as it may, each rule has its very own application degree, and it's difficult to utilize a solitary foundation to realize viable fault finding under different LG, LL and LLL fault conditions. In perspective on this, to improve unwavering quality and versatility of SLG fault analysis, a conclusion strategy dependent on fluffy basic choice combination system is proposed in this paper. In this paper there is an examination between the PI controller and the fluffy for the LG, LL and LLL fault determination. Thereafter, the fault measure is fluffy coordinated about fluffy measure in the standard set to realize successful combination of different analysis results and acquire increasingly dependable end for LG, LL and LLL fault determination. Reproduction demonstrates that, under different states of fluffy controller at neutral-point establishing modes diverse introductory fault voltage edge and distinctive fault opposition, this strategy could generally find fault line precisely.

I. PV SYSTEM ARCHITECTURE:

Fig. 1 demonstrates a solitary stage three-stage PV framework associated with an IEEE 33-transport circulation lattice. The total PV framework (375 kW) comprises of numerous basic units, for example, PV cluster; a three-stage two-level six beat width balanced voltage source inverter (VSI) with an exchanging recurrence of 6 kHz; a low-pass channel; and the transformer associated with the utility matrix at a point of normal coupling (PCC). The 375-kW PV cluster is acknowledged by utilizing arrangement parallel blend of 150-W modules (25 in arrangement and 100 in parallel). The attributes of a regular PV cluster are demonstrated as follows. It is appeared, at zero voltage, control yield is zero and the current is most extreme named as short out current for a specific confinement. The power increments with the voltage up to a specific most extreme power point (MPP). At that point, power and current both reduction until zero at open-circuit voltage.

The PV exhibit is associated with the dc side of the VSI with a dc-connect capacitor. The control of this VSI depends on sinusoidal heartbeat width balance. The air conditioner side of the inverters is associated with the consonant channels. The arrangement part of the channel comprises of an inductor, and the shunt branch is having delta associated capacitors in arrangement with obstruction. By consolidating a few quantities of such PV frameworks in parallel, bigger limit PV frameworks can be shaped, as appeared in the figure a three stage single-organize 1.5-MW PV framework is acknowledged by utilizing four 375-kW frameworks.

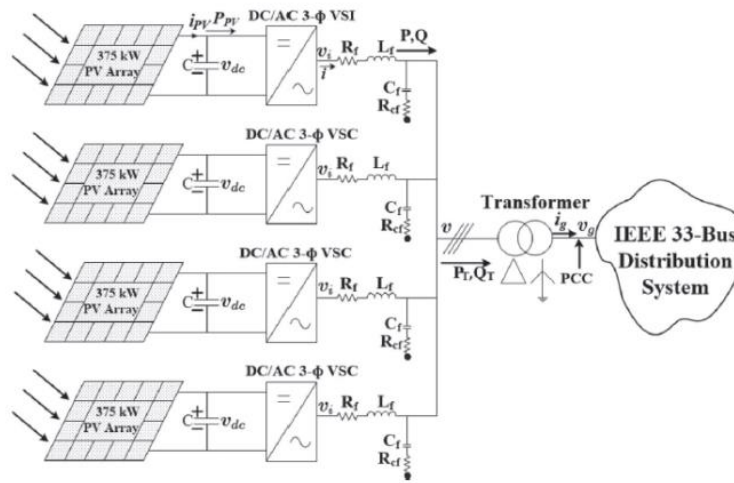


Fig. 3. Overall, 1.5-MW framework.

II. CONTROL SCHEMES

A. PV Circuit

The PV circuit contains a dc-link capacitor, a series filter, the shunt branch of the filter, and transformer impedance. The elements in the dc-interface capacitor is demonstrated as follows; the state variable Vdc. The numerical model of the elements of inverter air conditioning current in the arrangement channel is characterized by the accompanying conditions in dq outline:

$$L_f \frac{di_d}{dt} = -R_f i_d + \omega L_f i_q + v_{id} - v_d \dots (1)$$

$$L_f \frac{di_q}{dt} = -R_f i_q - \omega L_f i_d + v_{iq} - v_q \dots (2)$$

the elements of the shunt part of the filter and the transformer impedance are given by

$$C_f \frac{dv}{dt} = i - N i_g + C_f R_{cf} \left(\frac{di}{dt} - \frac{di_g}{dt} \right) \dots (3)$$

$$L_T \frac{di_g}{dt} = -R_T i_g + N v - v_g \dots (4)$$

Where N, LT, and RT are the turn proportion, the inductance, and the obstruction of the transformer, separately. ig and vg are the network infused current and PCC voltage, individually. State factors id, (1) iq, (2) vd, vq, igd (3) and igq are characterized underneath (4).

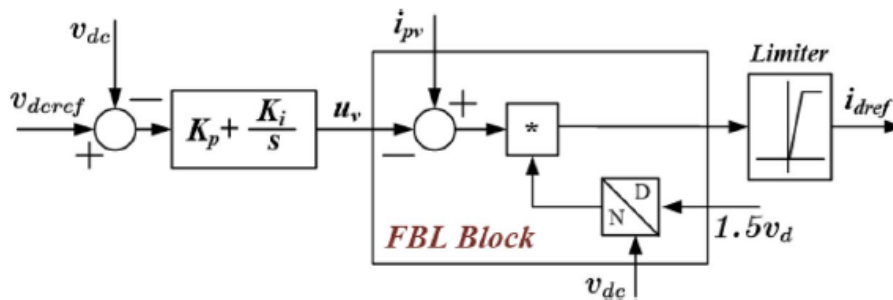


Fig. 4. DC-Interface voltage controller diagram.

B. Grid Synchronization

For PV system synchronization with grid, the amplitude and phase angle of the utility grid voltage are identified. A synchronous reference frame approach based conventional phase locked loop (PLL) [20] with a proposed modified block is used. This modified block is a compensator for grid voltage disturbance (CGVD). The d- and q-axes components vd and vq of the grid voltage vabc are passed through a compensator block and used in the PLL scheme. By setting the q-axis voltage component equal to zero, the PLL angle θ is made equal to the phase angle of the grid phase voltage va, as shown below. By PWM Fluctuations in the d- and q-axes voltage which, consequently improves the performance of the other controllers

C. DC-Interface Voltage Control

The dc-interface voltage controller displayed depends on FBL system [22]. The controller is utilized to direct the dc-interface capacitor voltage as indicated by the reference voltage vdc_ref, which is chosen by the MPPT plot. The dc-connect voltage guideline is accomplished through the control of direct pivot current, which, thus, controls the genuine power infusion into the matrix. Beneath demonstrated figure is the dc-connect voltage control conspire, which is planned based on the FBL strategy. Disregarding the inverter control misfortune, as indicated by the influence equalization of the two sides of the inverter in unflinching state, PPV ought to be

equivalent to the influence yield of the VSI air conditioning side terminals, which is equivalent to the yield matrix influence P, overlooking the channel influence misfortune. The controller chips away at the voltage elements of dc-connect capacitor dependent on power balance rule, as given by

$$\frac{d}{dt} \left(\frac{1}{2} C v_{dc}^2 \right) = P_{PV} - P \quad \dots(5)$$

By using eqn (5) it can be simplified by below eqn

$$C \frac{dv_{dc}}{dt} = i_{PV} - \frac{3}{2} \frac{v_d}{v_{dc}} i_d \quad \dots(6)$$

Where v_d and i_d are the d-hub framework voltage and current, individually; and $P = (3/2) v_d i_d$ [23]. A nonlinear differential condition, as it is obvious from the PV trademark that PV is a nonlinear capacity of $v_{PV}(= v_{dc})$ and it is linearized utilizing FBL.

As indicated by the FBL strategy [24], if $f(x)$ and $b(x)$ are nonlinear elements of a framework with states x , as

$$\dot{x} = f(x) + b(x) * u_i \quad \dots(7)$$

Using the control input u_i as

$$u_i = \frac{1}{b} [u_v - f] \quad \dots(8)$$

the nonlinearities can be cancelled out as

$$\dot{x} = u_v \quad \dots(9)$$

Considering $i_d (= (2/3) (v_{dc}/v_d)[i_{PV} - uv])$ as a control input, can be written in the form of a linear differential equation as below

$$C \frac{d}{dt} (v_{dc}) = u_v \quad \dots(11)$$

From (9), A plant transfer function is derived as below

$$G_p(s) = \frac{v_{dc}(s)}{u_v(s)} = \frac{1}{sC} \quad \dots(12)$$

For the principal plant move work, a PI controller G_{vc} is organized with genuine stage edge and settling time, which is on numerous occasions of that of the present controller. Due to this qualification.

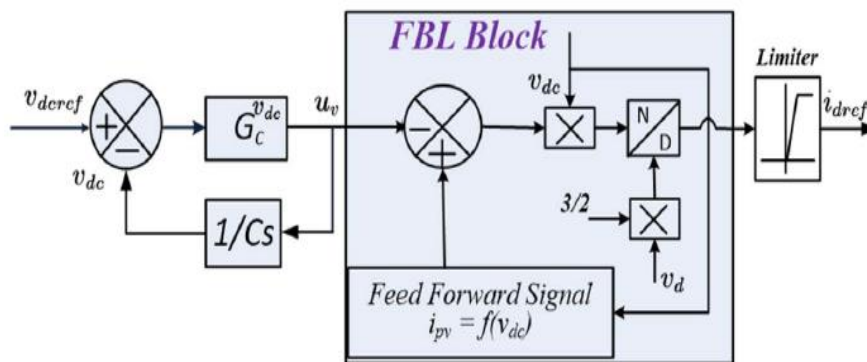


Fig. 5. Block diagram of the dc-Interface voltage control.

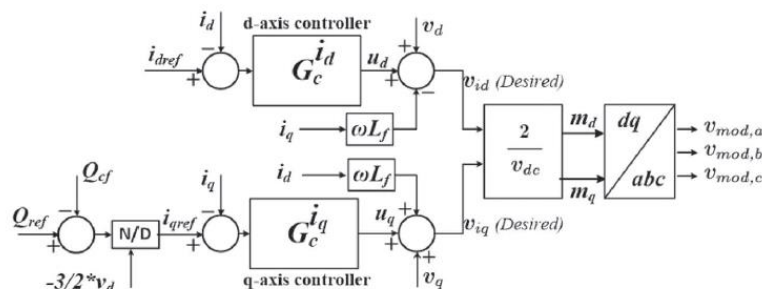


Fig. 6. Complete real and reactive power control scheme (d- and q-axes current control).

For the aforementioned FBL technique, there is a singular point $b(x) = 0$ or close to zero, which makes the system unstable.

This happens when v_d is close to zero, which is possible only in the case of three phase lines to ground (LLLG) fault with very small resistance, which is rare in power system.

D. Current Controller

To create the adjusting signals for VSI, the proposed dq hub current control methodology is talked about in Section III-D (see Fig. 8). From the present controller, the yield voltage signals (v_{id} and v_{iq}) for the inverter are acquired. In displaying of the present controller, the inverter is considered as a solidarity increase square, and the time postponement brought about by the inverter to create the yield voltage sign is ignored. The conditions portraying the elements of the d- and q-tomahawks current controllers in time space are inferred as

$$\frac{dv_{id}}{dt} = K_P \left(\frac{di_{dref}}{dt} - \frac{di_d}{dt} \right) + K_I (i_{dref} - i_d) + \frac{dv_d}{dt} - \omega L \frac{di_q}{dt} - L i_q \frac{d\omega}{dt} \quad (13)$$

$$\frac{dv_{iq}}{dt} = -K_P \frac{di_q}{dt} - K_I i_q + \frac{dv_q}{dt} + \omega L \frac{di_d}{dt} + L i_d \frac{d\omega}{dt} \quad (14)$$

where vid and viq are the state factors. KP and KI are the corresponding and essential additions of the PI controllers (Gid c and Giq c).

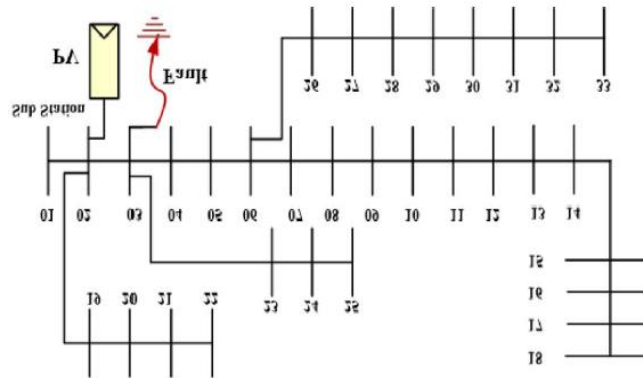


Fig. 7. IEEE 33-bus distribution network associated with a PV plant.

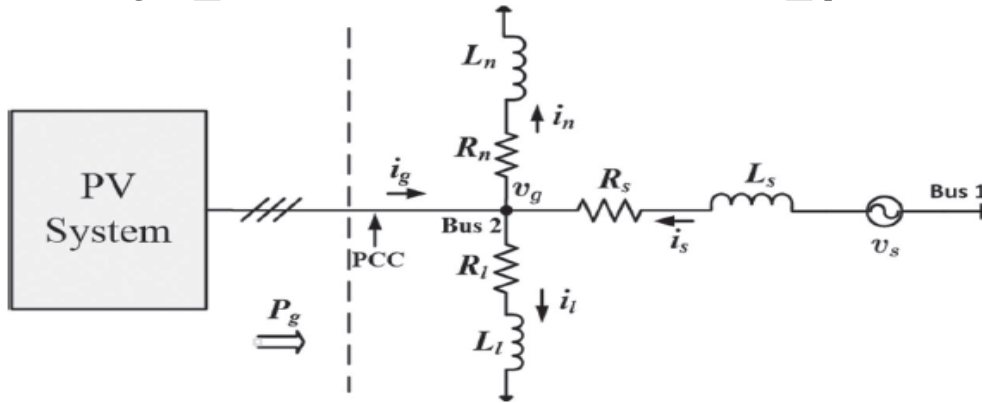


Fig. 8. PV framework combination with identical distribution network. For numerical displaying, the condition depicting the PLL (see Fig. 4) is given as

$$\frac{d\theta}{dt} = \omega \quad (15)$$

In the altered PLL control structure utilized in this paper, the q-pivot segment of the transformer's essential side voltage v_q is passed to a low-breathe easy consistent τ , and the yield v'_q can be composed as

$$\frac{dv'_q}{dt} = \frac{1}{\tau} [v_q - v'_q] \quad (16)$$

In this way, the dynamic condition depicting PLL control rationale can be given by

$$\frac{d\omega}{dt} = -k_p \frac{dv'_q}{dt} - k_i v'_q \quad (17)$$

Where k_p and k_i are the corresponding and essential increases of the PI controller, separately; and ω , θ , and v_q are the state factors of the PLL.

D. Distribution System

The PV framework with a nearby burden (R_l is arrangement with L_l) is associated at transport 2 of the IEEE 33-transport circulation framework, as appeared in Fig. 11. Kron's decrease method is utilized [24] to get the comparable diminished system of the dispersion organize for linearized investigation. Fig. 12 demonstrates the single-line portrayals of the PV framework interfaced with diminished dissemination organize.

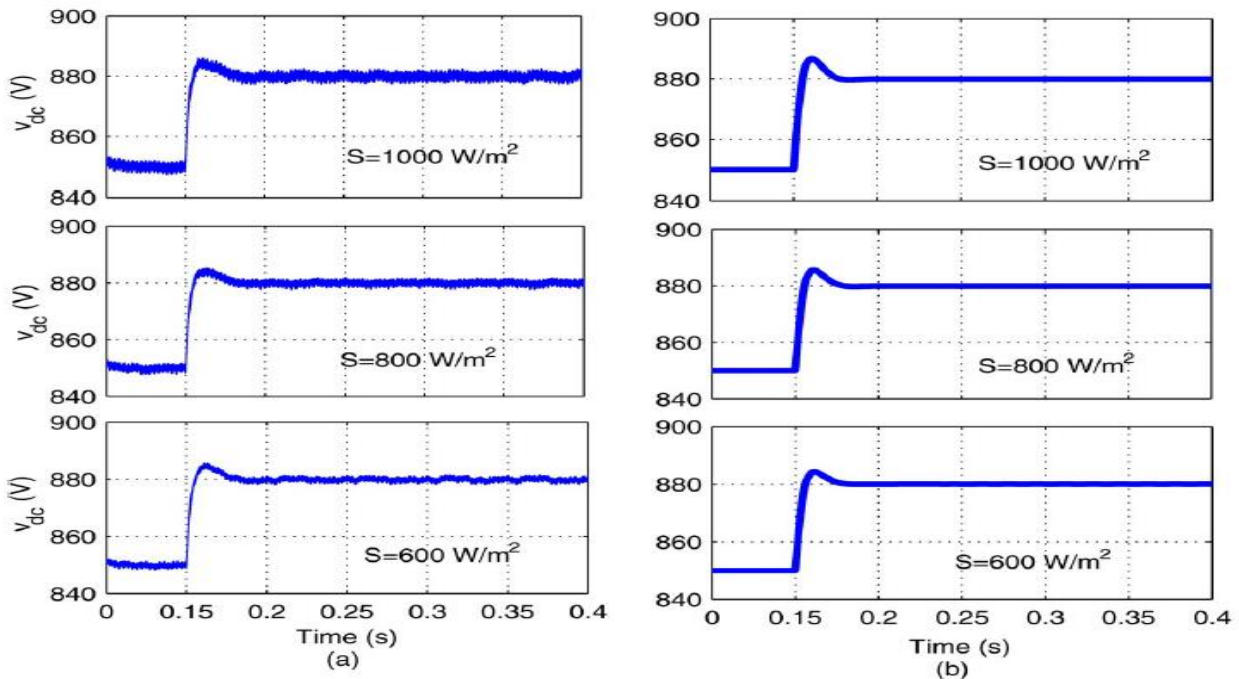


Fig. 9. Vdc reaction at various insolation levels

From the (a) RSCAD model and the (b) linearized framework model. 2 are held and the remainder of the transports are killed. Rn and Ln speak to the identical system, and Rl and Ll speak to the neighborhood load at the held transport 2. The elements of the dissemination system are portrayed in dq outline as

$$L_{nl} \frac{di_{nld}}{dt} = -R_{nl}i_{nld} + \omega L_{nl}i_{nlq} + v_{gd} \dots (18)$$

$$L_{nl} \frac{di_{nlq}}{dt} = -R_{nl}i_{nlq} - \omega L_{nl}i_{nld} + v_{gq} \dots (19)$$

$$L_s \frac{di_{sd}}{dt} = -R_s i_{sd} + \omega L_s i_{sq} + v_{sd} - v_{gd} \dots (20)$$

$$L_s \frac{di_{sq}}{dt} = -R_s i_{sq} - \omega L_s i_{sd} + v_{sq} - v_{gq} \dots (21)$$

where inld, inlq, isd, and isq are the state factors of the dispersion organize; and vgd and vgq are the d-and q-tomahawks of the PCC voltage vg, separately.

V.FUZZY-INTEGRAL DECISION FUSION TECHNIQUE

Fluffy necessary is a sort of nonlinear choice combination technique dependent on fluffy thickness. It could deal with the cooperation between elements which are autonomous. The fundamental procedure does not just incorporate the nearby yield of each factor, yet in addition considers the significance level of each factor. So as to improve the versatility and unwavering quality of symptomatic strategy, fluffy essential choice combination technique could be connected. In light of DN genuine working condition, it considers the versatile distinction of each customary shortcoming symptomatic technique, utilizes numerous SLG-flaw qualities, incorporates different nearby demonstrative outcomes, and makes a conclusive inference. Contrasted and other choice combination strategy, fluffy indispensable keeps away from the earlier data discourse, and does not have to make the suspicion of freedom among neighborhood symptomatic strategies. In the interim, it could more readily manage the vulnerability brought about by observational incentive during determination process. Therefore, fluffy essential is progressively appropriate for DN issue analysis.

The reason of choice combination is , for every nearby indicative technique $m_i(i=1,2,\dots,n)$ getting the information (deficiency trademark the output (fault measure $h_{ij}(i=1,2,\dots,n j=1,2,\dots,m)$ of each suspected fault object $(i=1,2,\dots,n j=1,2,\dots,m)$ and fuzzy density gi.

In light of this interest, for SLG shortcoming analysis in circulation organize, right off the bat, this paper utilizes wavelet technique for sign's peculiarity location and highlight extraction to get the exact data about event time, transient recurrence attributes, relentless state qualities of deficiency sign and unequal working qualities of DN's own.

At that point, utilizing the transient recurrence qualities and consistent state attributes of unadulterated issue signal which avoids DN's own lopsided working variable, for every neighborhood symptomatic technique $m_i(i=1,2,\dots,n)$ this paper proposes a strategy to produce shortcoming measure hij of each speculated deficiency object. $p_j(j=1,2,\dots,m)$.

Also, through the correlation between DN's real status to blame minute and relevant state of every neighborhood symptomatic technique, this paper builds up the quantitative measure strategy for certainty for every nearby demonstrative strategy (1, 2,...,) I m In , and changes over the certainty into fluffy thickness Ig for fluffy fundamental.

In light of the above work, as indicated by fluffy fundamental choice combination strategy, this paper utilizes fluffy thickness circulation in the arrangement of neighborhood shortcoming demonstrative techniques $M(M=\{m_i(i=1,2,\dots,n)\})$ to get fluffy measure g(.)

of monotonic subsets in M, and afterward doe fluffy coordination of deficiency measure ij h about fluffy measure g(.) in M to get a solitary outcome, which means incorporating numerous symptomatic outcomes and drawing an authoritative and solid finding end.

VI. DISCUSSION

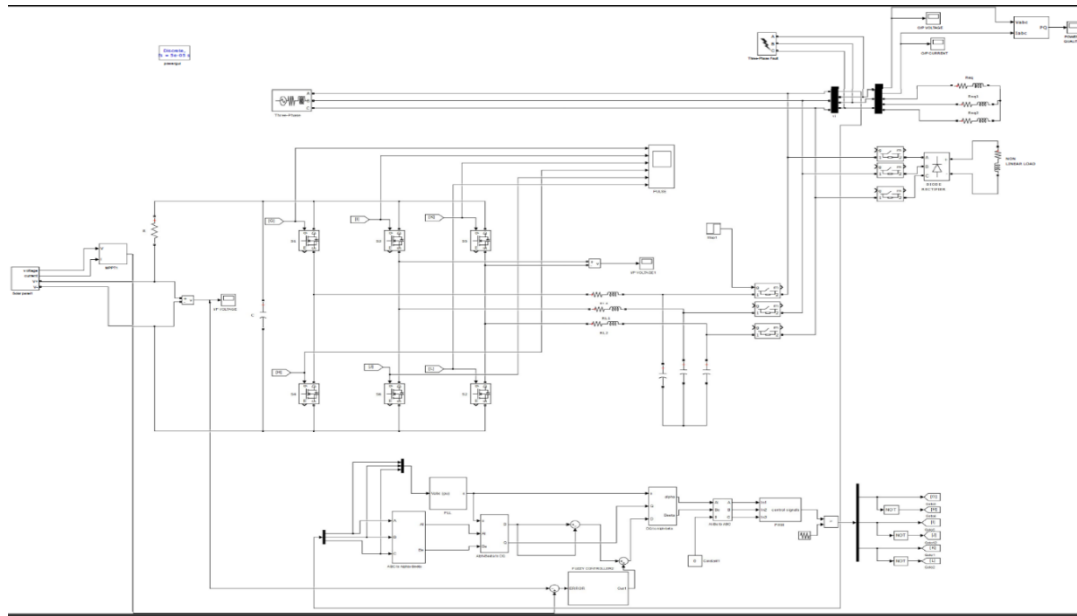


Fig.10.Simulink circuit of Fuzzy controlled single-stage converter fed Pv system

A. Performance of the DC-Link Voltage Controller

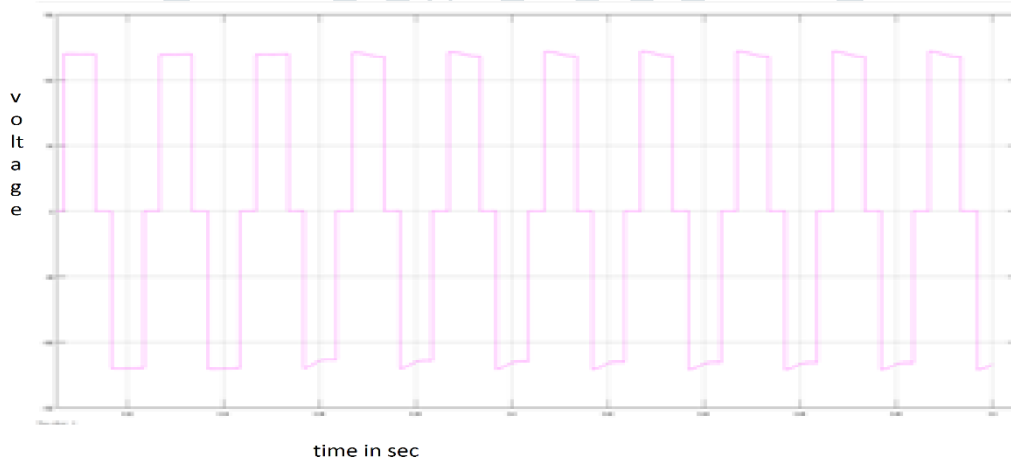


Fig.11. Source voltages

Here in the fig 11 the out wave form of three phase multi-inverter had been shown.

B. MPPT and Current Controller Performance

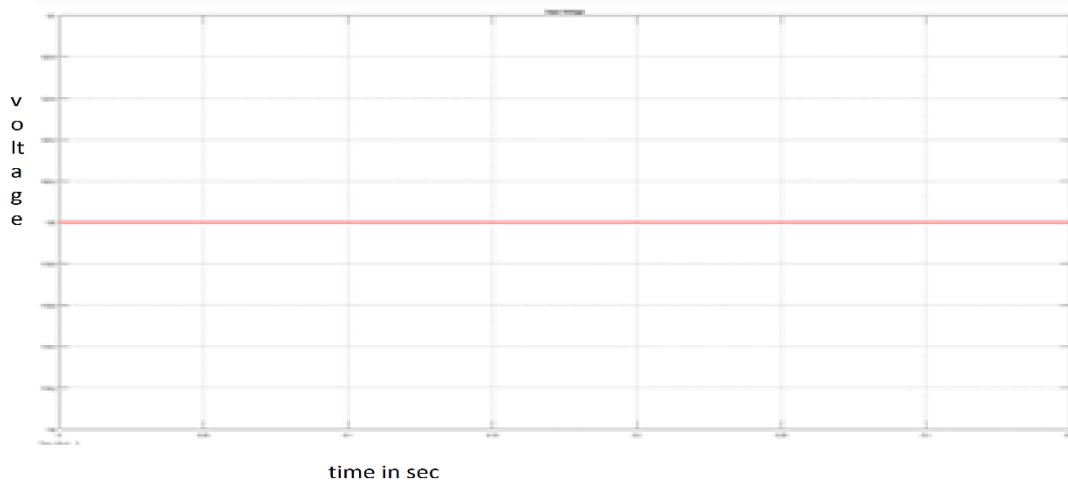


Fig.12. PV panel output after the performance of the MPPT technique.

The MPPT technique is replaced by fuzzy controller for the fast response.

C. Voltage Dip Response

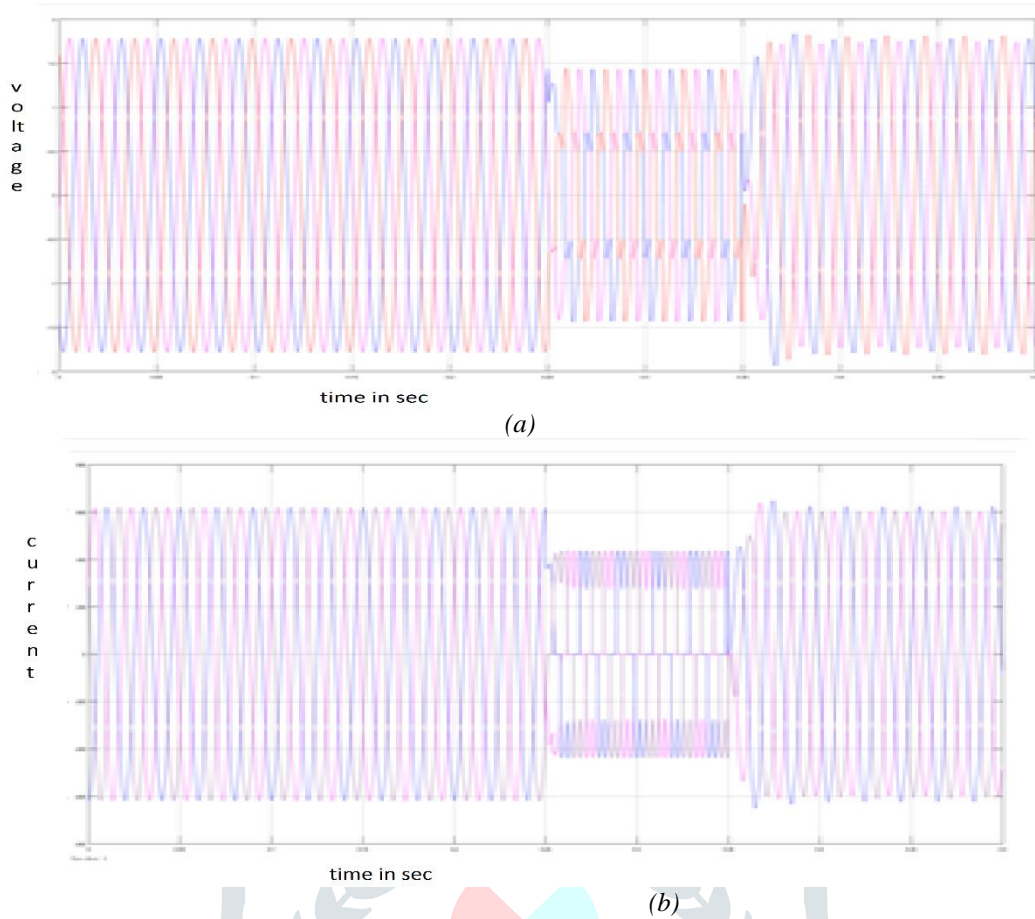


Fig .13.Dips at the loads. (a) Voltages (b) currents

In the above fig 13. The voltage dips and current dips occur when the nonlinear load is varied in the power system.

D. Three-Phase Fault

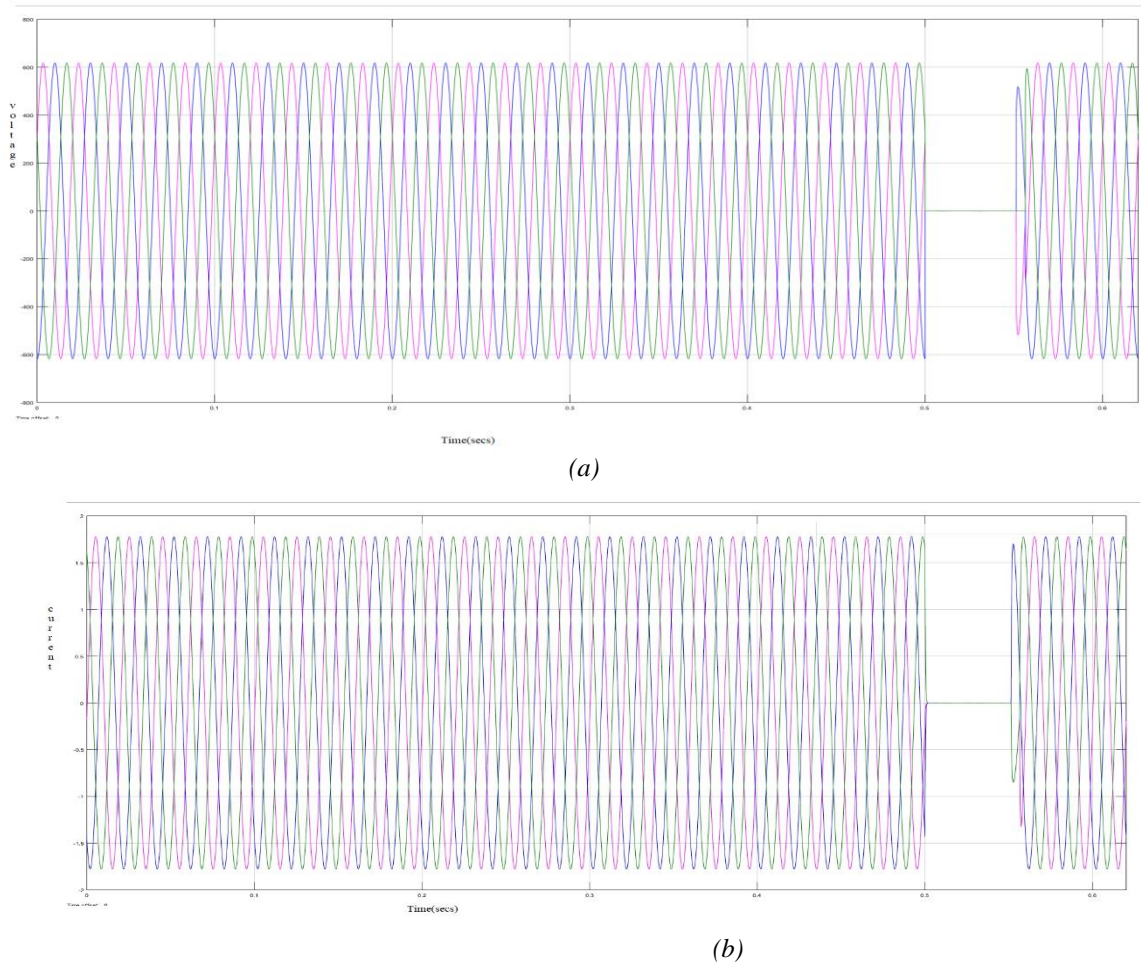


Fig.14. Three-Phase fault (a) voltages (b) currents

Fig.14. Shows the Three-Phase faults that occurred in the power system.

E. LG Fault



Fig.15. LG fault analysis (a) voltages (b) Currents.
Here in fig.15. The line to ground fault occurred.

F.THD:

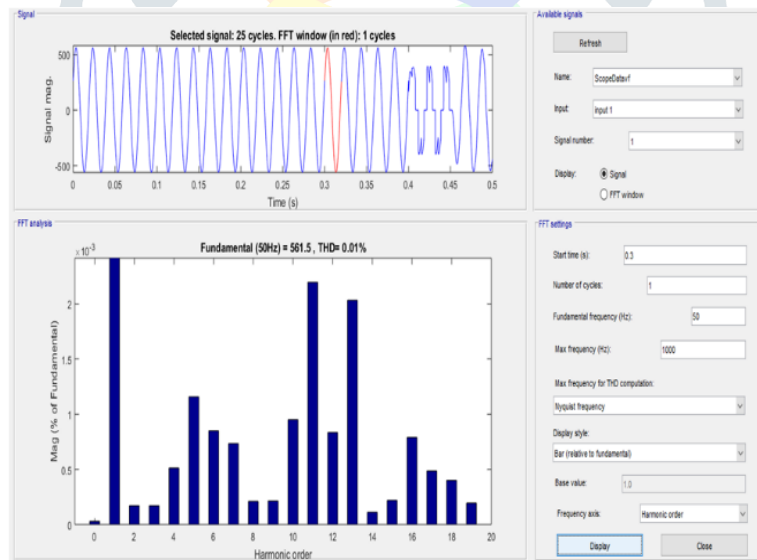


Fig.16. THD of PI controller

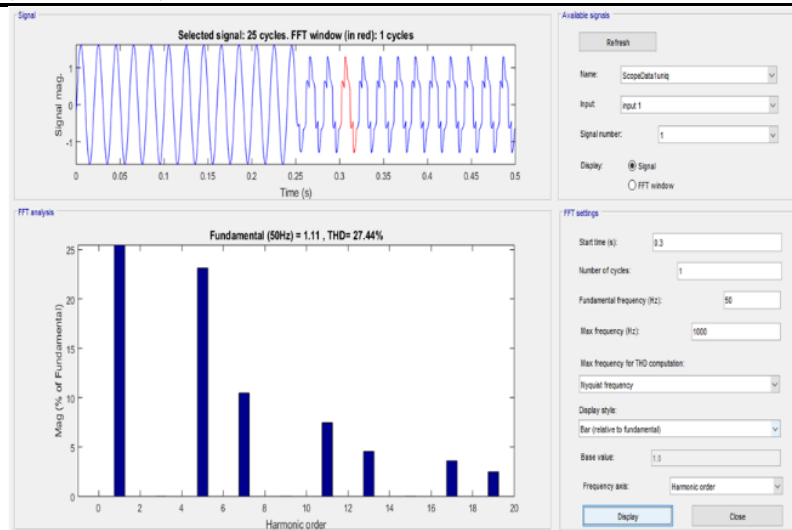


Fig.17. THD of FUZZY CONTROLLER

By comparing the THDs of PI and Fuzzy are shown. There the better performance is given by the FUZZY controller. With the lowest value of 0.01 percentage.

VII. CONCLUSION

In this undertaking, fuzzy indispensable choice combination technique is connected for issue examination. In view of different qualities of LG, LL and LLL shortcoming extricated by wavelet, this technique completely considers the dependability and versatility distinction of every nearby investigation measure incorporates numerous neighborhood examination results and gives an authoritative investigation end, which lessens the vulnerability impact brought about by experimental qualities and exceptionally builds the determination unwavering quality and flexibility. With grid voltage dip compensator channel, the dynamic execution is greatly improved as far as less oscillations and contortion in waveforms. Simulation results uncover demonstrates that, regardless of whether the nearby investigation results are reliable or not, this technique could generally find fault line precisely under different states of various PI controller establishing strategies, diverse starting fault voltage edge just as various change obstruction.

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