International Journal of Engineering & Technology, 7 (4.18) (2018) 455-460

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Control Strategy of Photovoltaic System to Regulate Active and Reactive Power during Unbalanced Grid Voltages by Using Fuzzy Logic Control

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Abstract

The advanced reactive power regulation is planned to direct the highest and the voltages at least point of regular pairing inside the cutoff points set up in grid codes for consistent operation. These work displays a regulating technique to which the grid associated PV system meaning to direct the power of both active and reactive infused to the electrical system amid the voltage faults that are uneven in nature. Fuzzy controller is propel controller which is for the most part appropriate for the personal fundamental guidance tool. which additionally gave the electronic system operation by the master choice. The reference of active power is acquired from a Maximum Power Point Tracking (MPPT) calculation. The advanced force methodology creates the necessary reference currents that forced by the grid-tied inverter from the coveted P and Q powers and the deliberate voltage supply. In unequal voltage sags, positive and negative sequence KVAr are consolidated to adaptable boost and even out the phase voltages; maximum phase voltage is controlled below as far as possible and the base phase voltage simply over as far as possible. The plan is approved to a solitary step PV system where the currents that are regulated by means of prescient control. By using the fuzzy controller for a nonlinear system which permit the decrease for the questionable impact in the system which control and impeccably enhance the effectiveness. Results demonstrating the execution of the procedure are introduced amid uneven sags and swells.

Keywords*—Solar power generation, MPPT, Fuzzy controller, Current control, Power generation control, unbalance voltage, Low-voltage ride through (LVRT)*

1. Introduction

The huge seepage balanced of RES and distributed generation (DG) plants has prompted an adjustment in the prerequisites for auxiliary administrations, especially amid grid faults. These days, grid-associated photovoltaic systems have turned out to be the quickest developing and much encouraging RES in the planet. The grid associated PV systems consists of 2 types: 1) Solitary stage: where just a single converter that shaft complete errands, i.e. both MPPT and also current grid control, 2) Multi arrange: which the expansion of at least one DC/DC converters is utilized to do tracking of maximum power.

Be that as it may, multi organize systems have a few downsides, for example, a less productivity, dependability, bigger cost, and bigger size in contrast with solitary stage network [2], [3]. Diverse controllers are recommended in these methods to infuse the coveted P and Q power amid an unstable voltage.

The common standard for the previously mentioned strategies is to quantify the three-phase grid voltage and break down it in sequence of both negative and positive; at that point the regulate system utilizes positive or two sequence elements to figure the present reference amid a fault voltage: (1) normal active-reactive regulate(AARC) creates that the reactive power consists of ripple, constant active power, zero THD and current are asymmetric (2) power generated by positive-negative sequence control(PNSC) produces zero THD, the Q power was constant and creates swell in active power and unstable currents (3) symmetrical positive sequence control(BPSC) produces invalid THD, ripple creates in both active-reactive power and also unequal voltages (4) immediate active reactive control (IARC) in this method during fault grid it creates constant active-reactive power with huge THD and currents are unequal These strategy displays a regulating methodology for solitary step PV systems intended to infuse the coveted P and Q power amid uneven voltage sags and swells, containing a technique to specify the current control. Zero, positive, negative sequences are the fault voltages. In this subject the faults that contains zero sequence is not issued in the method. The plan for the PV plant is a solitary stage which a prescient grid-current control is connected. And also demonstrated that these control conspire worked typical and unequal situations infusing the coveted references of power

2. Photovoltaic system

An expansive PV plant with incorporated configuration displays the plan appeared in Fig. 1.

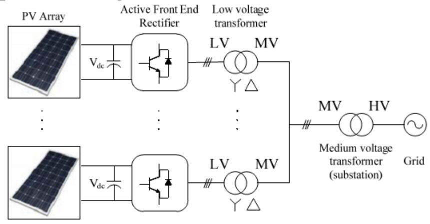


Fig. 1. PV plant connected with grid

The grid is connected with PV array by PV converters that takes MPPT and regulates the power flow of P and Q power. However some of the PV systems works underneath 1000volts subsequently a transformer utilizes to build lower voltage produced to a intermediate voltage; ordinarily in star delta association. The PV plant that generates power is send to the substations wherever a transformer raises the voltage from intermediate to huge power transmission voltage

The grid-associated PV system is displayed in Fig. 2, to regulate the system necessary variables are shown. To a solitary stage the PV array module is associated .where it must guarantee the infusion of active power computed by few technique to acquire MPPT. the Perturb and Observe (P&O) technique is employed in this work.

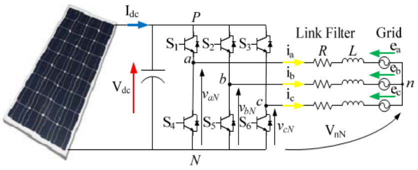


Fig. 2. Grid-connected PV system.

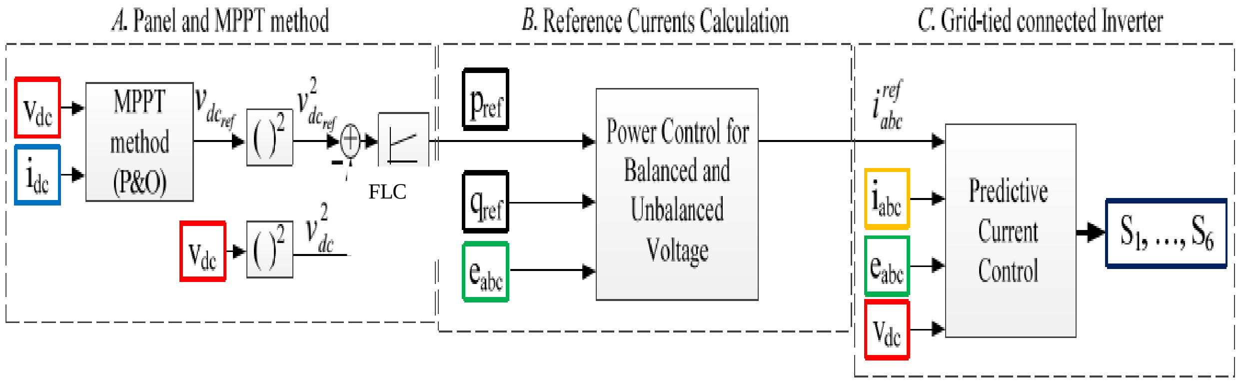


Fig. 3. Control Scheme of PV system by using FLC during balanced and unbalanced grid voltage conditions

Fig.3 demonstrates a plot that control to the grid-associated PV system. This regulation plan should be isolated in 3 steps: PV with Panel and MPPT technique, Reference Currents Calculation and Grid-tied electrical converter current control.

As beforehand said, the single phase converter should show the PV plant with MPPT. By these method, a classic P&O is been utilized [10]. The tracking of maximum power plan is finished each 1s and a 5V perturbation voltage is employed. When the Direct Current-link voltage reference was gotten, a Proportional Integration controller is employed to regulate the voltage of direct current by surrounding the ability infused into the grid. A control method of DC link is appeared in Fig. 4 where the power converter and the Direct Current capacitance worth.

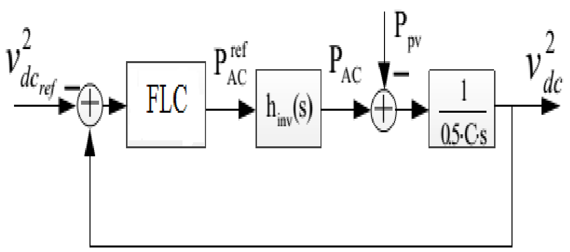


Fig. 4. Control method of DC link

The target of the projected technique is used to manage the P and Q provided by the grid to the ability inverter. The introduced strategy expect identified immediate P and Q reference power and voltage grid.

2.1. PV Panel and MPPT method:

A business array consists of so many cells that are connected in parallel and series, that are characterize power with maximum voltage (VMPPT) and maximum current (IMPPT), the electric system voltage (VOC) and the short circuit(ISC). The framework of business PV panel that contained in these method is appeared in Table I for a light of 1000 W/m2 and with temperature of 25°C

2.2 Reference current calculations:

The reference current calculations are shown below.

Table 1. Pv panel parameters

P_{mppt}	325W
I_{mppt}	8.69A
V_{mppt}	37.4
I_{SC}	9.14V
V_{OC}	46V
Number of PV panels	570

Consider the currents and voltages of grid in abc coordinates $[v_{abc}] = [v_a \quad v_b \quad v_c]^t$ and $[i_{abc}] = [i_a \quad i_b \quad i_c]^t$ Then the P is assigned by using formula , Clarke's transformation, presented in (1) the immediate P and Q p(t) can also wrote in the form of αβγ coordinates

$$T_{ABC\to\alpha\beta\gamma} = T = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \quad (1)$$

Using $[v_{abc}] = T^{-1}[v_{\alpha\beta\gamma}]$ and $[i_{abc}] = T^{-1}[i_{\alpha\beta\gamma}]$,p(t) in $\alpha\beta\gamma$ coordinates is :

$$p(t) = \left(T^{-1}[v_{\alpha\beta\gamma}]\right)^t . \left(T^{-1}[i_{\alpha\beta\gamma}]\right)$$
$$p(t) = [v_{\alpha\beta\gamma}]^t (T^{-1})^t . (T^{-1})[i_{\alpha\beta\gamma}] \quad (2)$$

Since $i_a + i_b + i_c = 0, p(t) is$

$$p(t) = \frac{3}{2} v_\alpha i_\alpha + \frac{3}{2} v_\beta i_\beta$$

During fault conditions the eq 4 is still accurate to obtain p(t).

Developing (6), |[qabc]using alpha beta-gamma voltage and current is:

$$|[q_{abc}]| = \frac{3}{2}\sqrt{2v_\gamma^2(i_\alpha^2+i_\beta^2)+(v_\alpha i_\beta+v_\beta i_\alpha)^2} \quad (3)$$

The reference currents to supply an active power

$$i_{\alpha 1}^*, i_{\alpha 2}^* = \frac{Pv_\alpha \pm v_\beta\sqrt{\frac{-2P^2v_\gamma^2+Q^2(v_\alpha^2+v_\beta^2)}{2v_\gamma^2+v_\alpha^2+v_\beta^2}}}{v_\alpha^2+v_\beta^2} \quad (4)$$

$$i_{\beta 1}^*, i_{\beta 2}^* = \frac{Pv_\beta \pm v_\alpha\sqrt{\frac{-2P^2v_\gamma^2+Q^2(v_\alpha^2+v_\beta^2)}{2v_\gamma^2+v_\alpha^2+v_\beta^2}}}{v_\alpha^2+v_\beta^2} \quad (5)$$

The reference currents that are in eq (8) describes the lagging pf and from (9) compares to a leading pf. the currents in eq (8)and (9) must satisfy with

$$\frac{-2P^2v_\gamma^2+Q^2v_\alpha^2+Q^2v_\beta^2}{2v_\gamma^2+v_\alpha^2+v_\beta^2} \geq 0 \quad (6)$$

pref and qref should have to successive those condition to have the reasonable reference currents:

$$|q|_{ref} \geq \frac{\sqrt{2}v_\gamma}{\sqrt{v_\alpha^2+v_\beta^2}} p_{ref} \quad (7)$$

It outed to be that uneven voltage damage made between the electrical converters and also the electrical device produces voltage of zero sequence due to lower voltage side.

2.3. Grid-tied connected Inverter

Grid-tied connected inverter uses a predictive controller these controller gives accurate current and send to the switches these switches will operate on and off operation and gives exact output.

3. Fuzzy logic controller

In Fuzzy Logic Controller, by using linguistic rules the essential regulating action is dictated. The network is controlled by using those standards. The FC does not consider a model because the numerical factors are followed into linguistic factors.

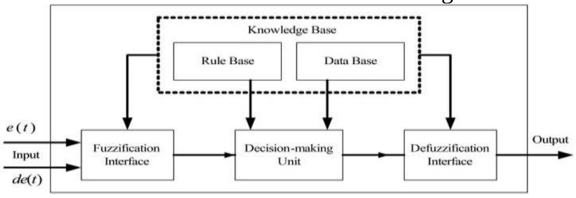


Fig.5. Fuzzy logic controller

The FLC involves three categories: fuzzification, obstruction motor and defuzzification. The FC is indicated by I. seven fluffy sets for each info and yield. ii. Triangular enrollment capacities for effortlessness. iii. Fuzzification iv. Suggestion utilizing Mamdani's, 'min' administrator. v. Defuzzification utilizing the tallness strategy.

Table 2: Fuzzy Rules

Error	Change in error						
	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

3.1. Fuzzification:

Enrollment strategy esteems are doled out to the linguistic factors, utilizing seven fluffy subsets: NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE, PS, PM, and PB. The Partition of fluffy subsets and the state of enrollment CE (k) E (k) work adjust the take care of business to fitting framework. The estimation of information mistake and alter in blunder are standardized by associate info scaling issue. The scaling input factor is arranged in a manner that the principles in the input are in placed among -1 and +1. There is only one fuzzy set in the input E(k) when the membership functions is placed in a shape of triangle.

$$E(k) = \frac{P_{ph(k)} - P_{ph(k-1)}}{V_{ph(k)} - V_{ph(k-1)}} \quad (8)$$

$$CE(k) = E(k) - E(k-1) \quad (9)$$

3.2. Inference Method:

There are many methods like Maximum-Dot and Maximum-Min are going to imposed in these article. Min method is proposed in these strategy. However the max operator or min operator for each rule is used in the output membership. Table 1 demonstrates control of the FLC.

3.3. Defuzzification:

As a plant additional usually need a non-fluffy to regulate, so we needed a defuzzification arrangement. The height strategy is utilized to figure out the FLC output. Later the FLC output may also manage the inverter switches. In UPQC, the P and Q power, terminal voltage and voltage capacitor are need to be well set. Keeping in mind top goal regulate those parameters, that are detected contrasted and the reference esteems. To accomplish this, the enrollment elements of FC are: change in error ,error and output.

The set of FC rules are derived from

$$u = -[\alpha E + (1-\alpha)*C] \quad (10)$$

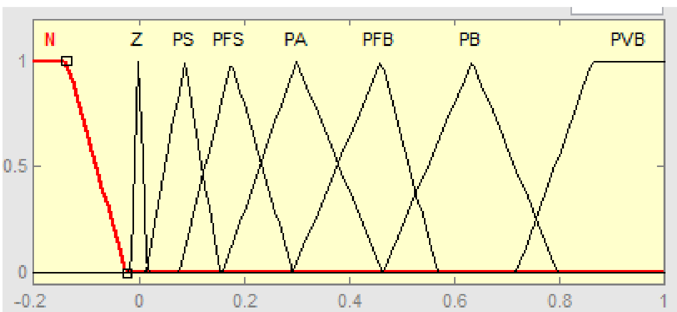


Fig .6. Input 1 as error asMF

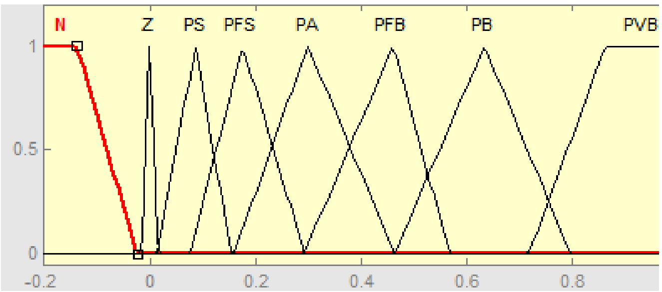


Fig.7. Input 2 as error MF

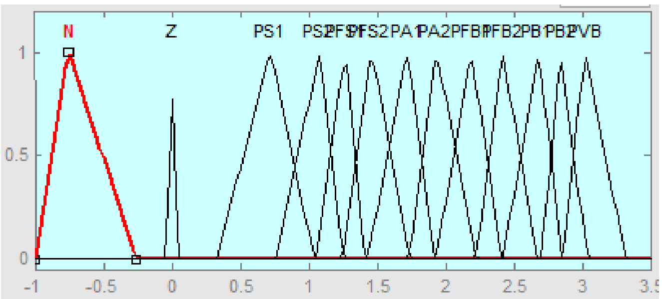


Fig.8. Output MF

Where α is self-adjustable issue that are control the full operation. E is the system error, C is the that modification in error and u is the variable that controls

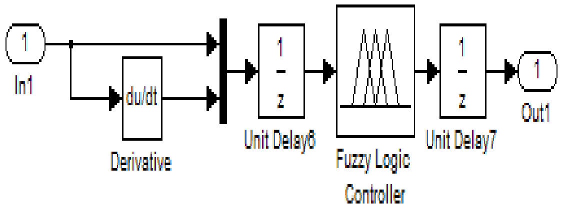


Fig.9. Fuzzy logic controller in simulation

4. Simulations results

The advanced methodology consists of PV plant with 186 KW are resembled by using Matlab. For high frequency switching the sample of 56μs is to be used for upcoming work by using a power converter with lower value and PV emulator The system parameters utilized as a part of the simulation are portrayed in Table 2.

Table 3. Set-up system parameters

R	1[mΩ]
L	0.2[mH]
C	2400[μF]
V_{rms}	220V
$N_s panel$	19
$N_{pp} panel$	30
T_s	56[μs]
F	50Hz

During regular operation the simulation results are appeared without fault voltages with illumination and profile outlined temperature in Fig.10.

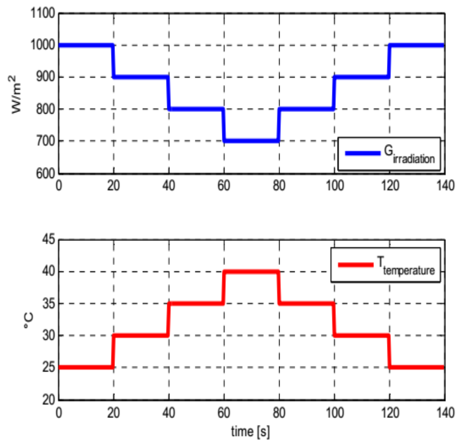


Fig. 10. Simulation results with temperature profile and irradiation

The Q power is kept to zero that is infused in the grid and the P infused relies upon the light and the panel of the temperature profile. The reactive and active power presented in the grid are appeared in Fig.11.during normal condition from 185kW to 123.5kW variation in active power beneath the MPPT situations and from 480A to 325A change in grid current.

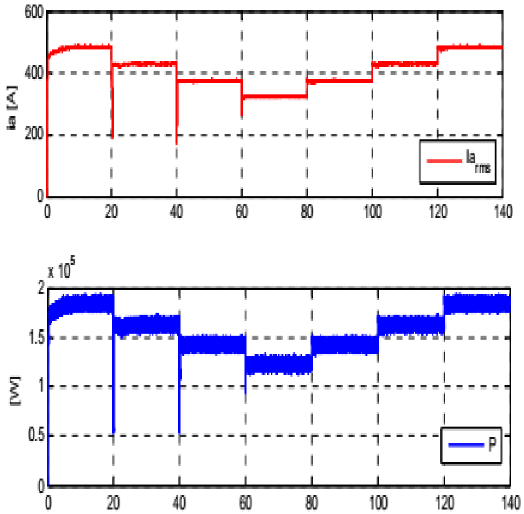
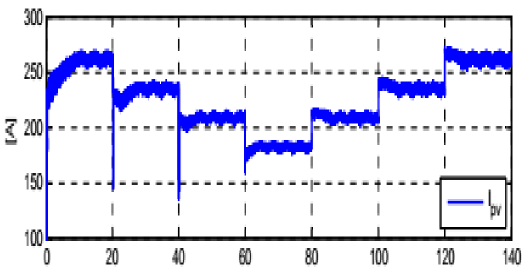


Fig. 11. P and Q, Grid Currents during normal operation.

Fig. 7 demonstrates from the PV plant the power and voltage are present. 750V of reference voltage is kept at DC side originally but due to ripple of 10V the voltage oscillates in between 715V to 675V. from 260A to 181A change in DC currents . from the PV array the power is distributed to 175Kw later it will progress to 185kW to around 124kW. Due to loss in the system the active power values are different in both Fig.11 and Fig.12.



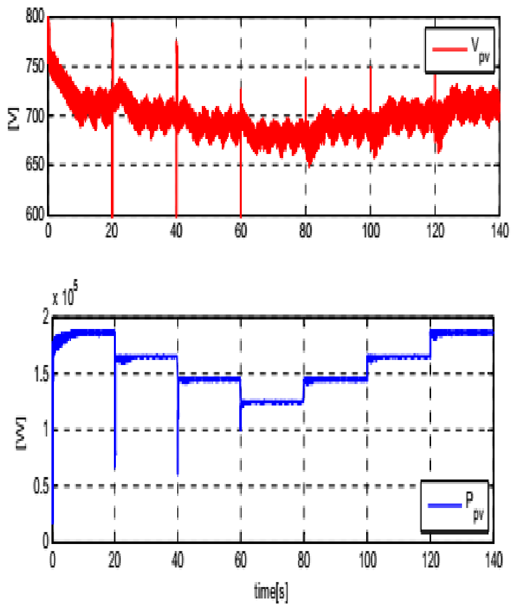


Fig.12. Current, Voltage, Power when the system contains grid faults

4.1. Voltage Sag: 20% va, 40% vb and 30% vc

Three Voltage sag are connected with in the system, see Fig. 13 (top). A voltage of 40% diminishment for part B that is connected in between the time intervals of t=0.05s to t=0.2s, and voltage of 30% decrease in part C is connected with the time intervals of t=0.1s to t=0.2s, lastly a voltage of 20% is diminished in part A between the time intervals of t=0.15(s) to t=0.2(s).The Q reference power is kept in null position and the network is function by MPPT method. The reference Q is about to zero, and also the system is function at MPPT with 1000W/m2 and 25°C producing 185kW. The grid is infused with the current appeared in Fig.13.

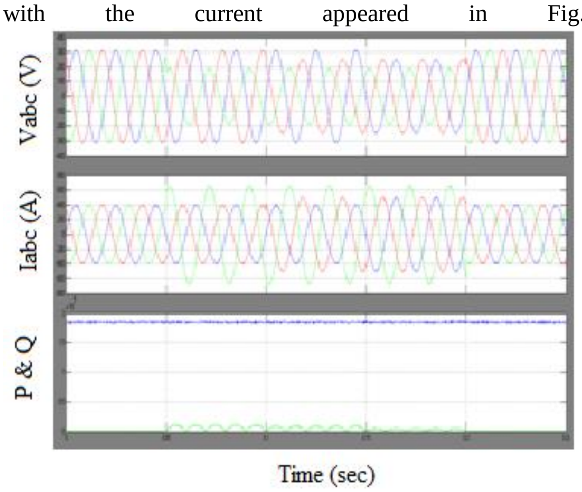


Fig. 13. During voltage sag simulation results when P and Q power ,V and I are injected

The Q power reference is kept with 50kVAr and the simulation results are shown in Fig.14 during the same voltage sag.

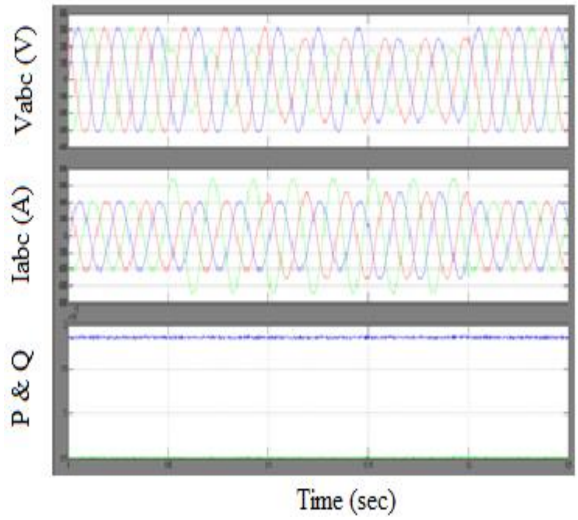


Fig. 14. Simulation results for P and Q power, V and I .

During normal condition the current in the grid is 545A but during the losses in the system the current in the grid increases to a 714A.To satisfy the conditions in the eq 10 the P and Q powers during the fault in the grid must control with the references.

4.2. Voltage Swell: 30% vc, 20% va and 40% vb

Three voltage swells are applied with in the system, see Fig. 15. A voltage with 40% increment in part B is connected amid t=0.05s to 0.2s, a voltage with 30% increment in part C is connected amid t=0.1s to t=0.2s, lastly a voltage with 20% voltage increment is caused in part A.

Due to fault in the grid the system will have a null sequence therefore the Q power cannot control with the reference value, the current in the grid is 486A in ordinary operation and the Q power is kept with invalid value.

But the current in the grid drastically decreases to 360A because of fault conditions, due to voltage swell yhe Q power will have a ripple with 100Hz so to satisfy the conditions in the Eq (10) the Q reference power must be kept to 32.5kVAr

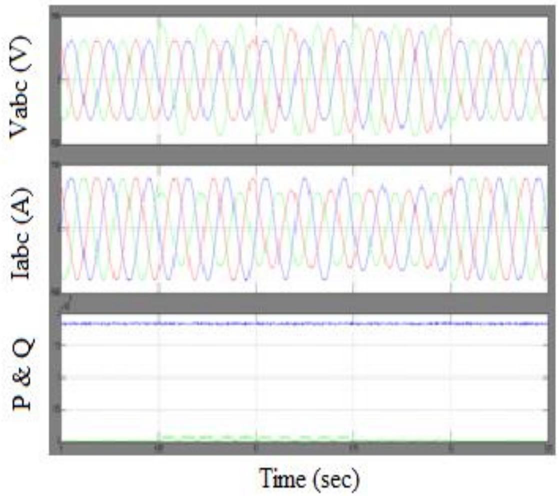


Fig. 15. During voltage swell simulation results for V, I, P and Q

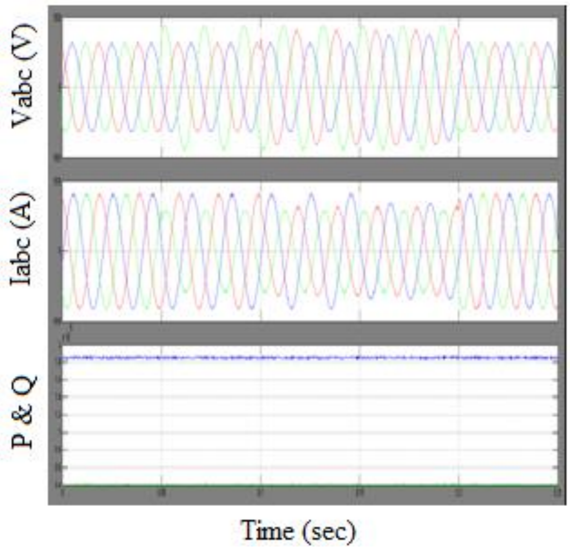


Fig. 16. During voltage swell simulation results when V, I,P and Q are injected.

5. Conclusion

This paper shows a generator with a proficient to achieve those 2 destinations: to keep the infused currents inside wellbeing esteems, and to figure references power to a superior usage of the inverter power limit. This work demonstrated during the fault conditions in the grid the active power also control that is provided to supply power in PV power systems. Fuzzy controller is propel controller that is for the most part appropriate for the human basic leadership instrument which likewise gave the operation of an electronic system with the master choice. In these methodology for various illumination and from profile temperature; amid grid voltage sags and swells maximum power can be extracted from the PV plant. By using the fuzzy controller for a nonlinear system which permit the decrease for the indeterminate impact in the system which control and consummately enhance the proficiency.

Acknowledgement

I am grateful to my guide M. Rama sekhara Reddy,M.tech.,ph.D., Assistant professor,Department Of Electrical Engineering for his indispensable encouragement to complete the project

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