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APPLICATION OF CONTROL STRATEGIES TO RIDE THROUGH CAPABILITY OVER DIFFERENT TYPE FAULTS FOR SINGLE STAGE INVERTER BASED GRID CONNECTED PHOTO VOLTAIC POWER PLANT

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Abstract - *In this paper the issues of the inverter disconnection from a single stage gird connected photovoltaic power plant (GCPPP) are discussed and control strategies are specified to fault-ride-through the system. PI and Fuzzy control strategies are discussed. The main reasons for inverter disconnection are (i) excessive dc link voltage, (ii) excessive ac currents and (iii) loss of grid-voltage synchronization. By using inverter control the reactive power is controlled so that reactive power support during balanced voltage sag and to control reactive power injection to the non faulty phase during unbalanced voltage sag. These issues and ride through capability by controllers are discussed by considering 1-MVA GCPPP using MATLAB/Simulink.*

Key Words: photovoltaic systems, grid faults, fault ride through, reactive power.

1. INTRODUCTION:

In present scenario, solar power attains great importance because of its pollution free nature. So that grid connected photovoltaic system power plants are place important role. In grid connected photovoltaic power plants, the PV array is connected to the inverter by means of dc link. This inverter converts the dc power to ac power, and this power is connected to grid by a suitable power transformer. Because of large usage of photovoltaic systems, importance is given to the problems related with the PV system grid synchronization. To improve the reliability of the system, the fault analysis can be done.

2. STATEMENT OF PROBLEM:

The inverter in the system is became out of synchronization or disconnected from the grid because of some faults in the system, the system reliability is decreased. The problems where inverter disconnected from the system are

(i) Excessive dc-link voltage,
(ii) Over current at the ac side,
(iii) Loss of grid voltage synchronization. Moreover, in the case of asymmetrical faults,
(iv) The reactive current injected must not exceed values that cause voltages to increase above 110% of the nominal value in the non-faulty phases.

The above problems are addressed in this paper are studied by taking base diagram shown in fig-1.

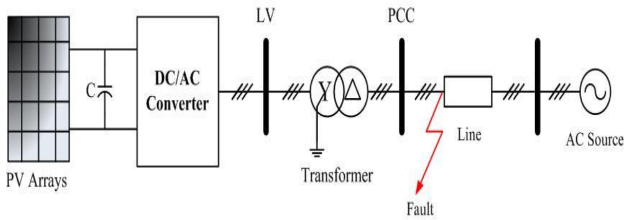

Fig -1: Schematic diagram of single stage GCPPP

The above stated problems are discussed and control strategies are given to limit those problems without disconnection of inverter from grid.

3. FAULT-RIDE-THROUGH CONTROL STRATEGIES:

The problems stated in this paper are explained by considering voltage sag with balanced and unbalanced faults. To meet the fault ride through, at first dq current references, namely i_{dref} and i_{qref} are calculated from dc-link voltage control and Droop control respectively, which is shown in fig-2. These reference values can be modified according to the FRT (fault-ride-through) for control the inverter.

3.1. Three phase voltage sag fault:

The voltage sag considered here is 40% balanced three phase fault. Because of this voltage sag the currents at the gird terminal or grid currents are increases as shown in fig-Every inverter has current limits, if those limits are exceeds because these excess currents inverter may disconnected from the grid.

Under grid voltage sag condition, the d component of the system increases so that the grid currents. Which may leads to exceeds the over current protection limits. so that the inverter may came out from grid synchronization.

The references provided to the system using current controllers are to be limited based on the inverter limits. But This would allow the inverter to keep on operating during some voltage sag processes without over passing the current protection limits and hence forcing it to be disconnected from the grid. For FRT, the limiter has to control active power as well as it has to inject reactive current. The reactive current injection is controlled by droop control. So the modified reference currents are given to the system according to the FRT requirement.

If the power generated in the dc side is more than the power given to the grid, because of voltage drop caused by high currents then it leads to increment of dc link voltage. If this voltage is out of limits, inverter disconnected from the system.

3.1.1 Application of PI control

These are reduced by implementing a PI control limiter into the system. The basic PI control is shown in fig-2.

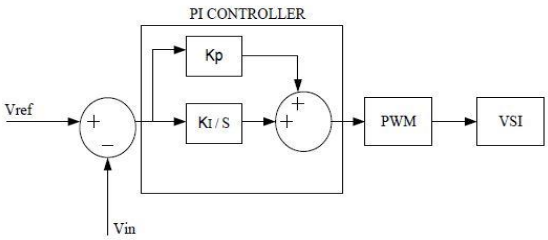

Fig-2: basic PI control structure.

The waveforms of the system after application of basic PI current limiter are shown in results.

3.1.2 PI control with anti-windup technique:

In case of anti-windup technique, the control technique same as PI control but taking of integral part into consideration is done according to the error in the system as shown in fig-3.

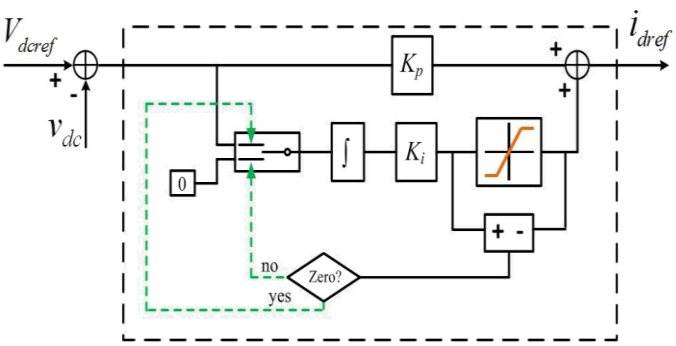

Fig -3: PI control with anti-windup technique

The resulted system waveforms because of anti windup technique are shown in results.

3.1.3 Application of fuzzy control technique:

Fuzzy is implemented to the system in place PI control strategy. The resulting system waveforms are shown in results. The fuzzy control strategy is shown in fig-4.

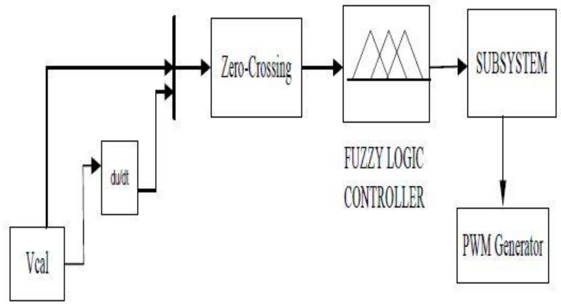

Fig-4: fuzzy control structure

3.2. LLG voltage sag fault:

In this unbalanced type of fault, 2LG fault with 35% is considered. Because of droop control, the reactive current is injected into the system, whenever the voltage drop is 10% of the nominal value. So based on the voltage drop the maybe activated and deactivated continuously, the distorted reference waveforms are observed after passing through PI based current limiter. These distorted reference currents produces distorted ac currents, sometimes this can causes overheating. The distorted wave forms are presented in results.

To reduce these distortions in the reference waveforms MAF (moving average filters) are introduced. Which are reduces the distortions i.e MAFs are calculates the average values of sampled system and given a point of average value. So that the distortions in references are reduces after passing through limiter, so be the grid currents. This is shown in results.

To improve the system or to reduce the distortions, fuzzy controllers are introduced into the system. The results obtained after implementation of fuzzy controller in current limiter in place of PI are shown in results. The comparison can be made between controllers with respect to peak values or Total Harmonic Distortion of grid currents.

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4. RESULTS:

4.1 Three Phase fault with 40% Voltage sag:

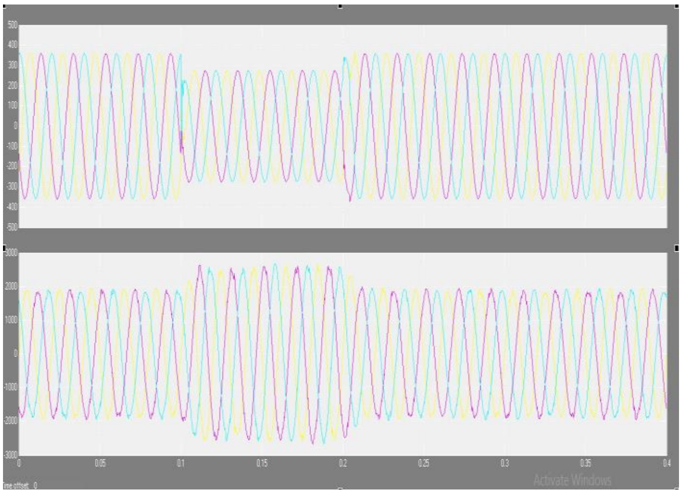

Fig-5: Grid (a) voltages at the power plant terminal (b) grid currents.

Because of of the fault on the grid, from the figure it can be observed that the currents of the grid are increases.

4.1.1 After Application of Current Limiter(PI control):

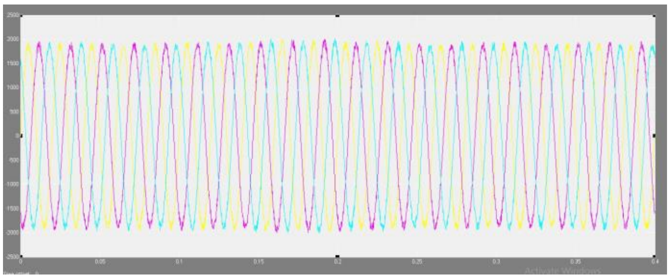

Fig-6: grid currents

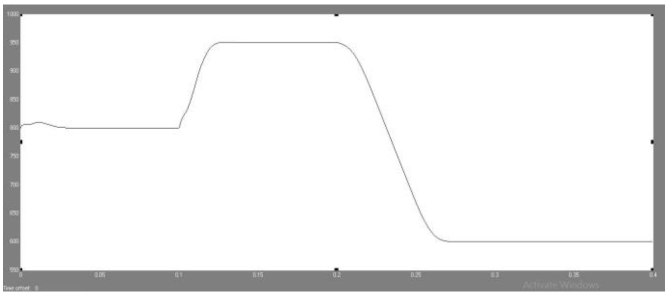

Fig-7: dc-link voltage

From the above figure it can be said that the excess grid currents are reduced after application of current Limiter and the dc link voltage is increased during the fault.

4.1.2 Application of an anti- windup strategy to current Limiter:

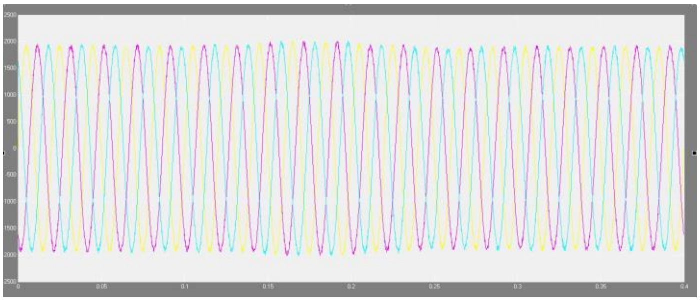

Fig-8: Grid currents

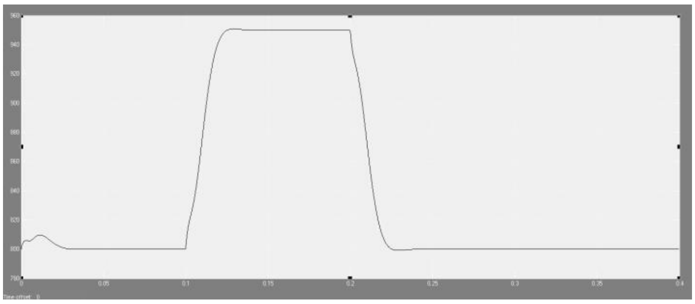

Fig-9: dc link voltage

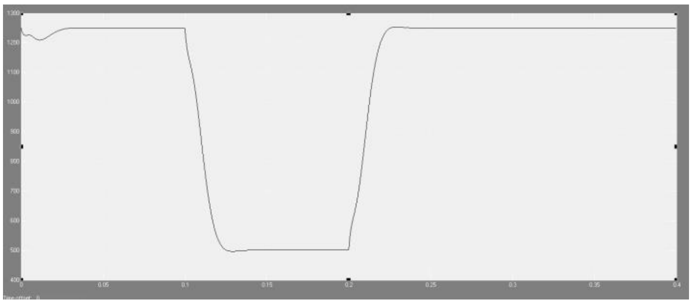

Fig-10: PV currents

After application of anti-wind up strategy, from the figures it can be said that the grid currents disturbance decreases and in case of dc link voltage, it came to normal with in small time.

Application of fuzzy control strategy:

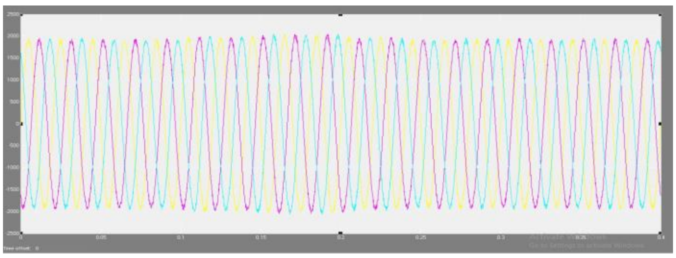

Fig-10: Grid currents

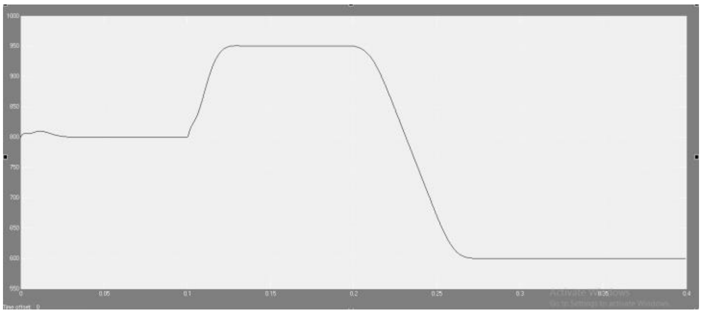

Fig-11: dc link voltage

From the above figures it can be said that the disturbance or harmonics in the gird currents are reduced furthermore.

4.2 Unbalanced 2LG fault with 35% voltage sag:

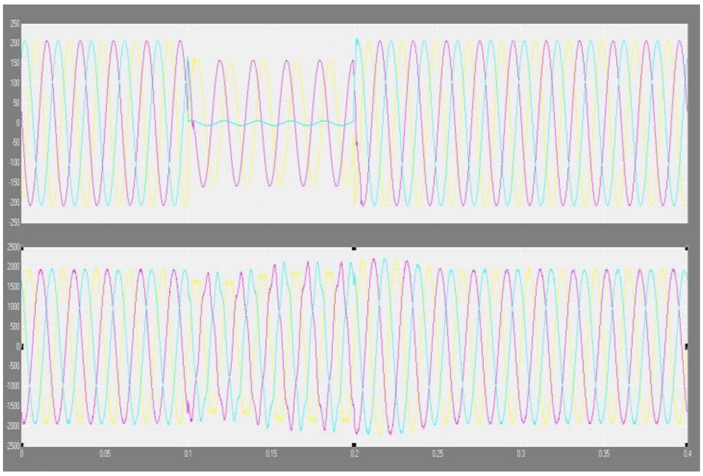

Fig-12: (a) PV terminal voltages (b) Grid currents

Because of the 2LG fault, voltage sags are seen in the terminal voltages and in grid currents observed that ripples during fault in the system.

Distorted reference currents:

The distored waveforms are produced because of the unbalanced voltage sag in the system.

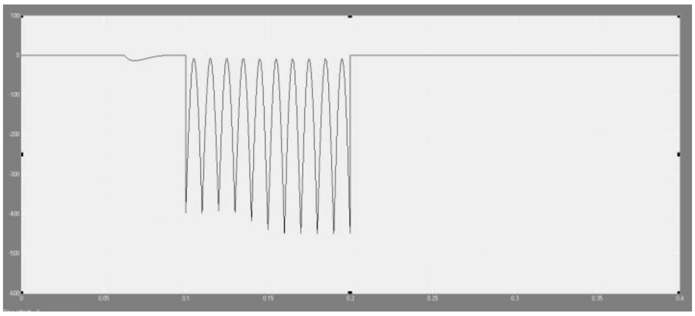

Fig-13: voltage drop

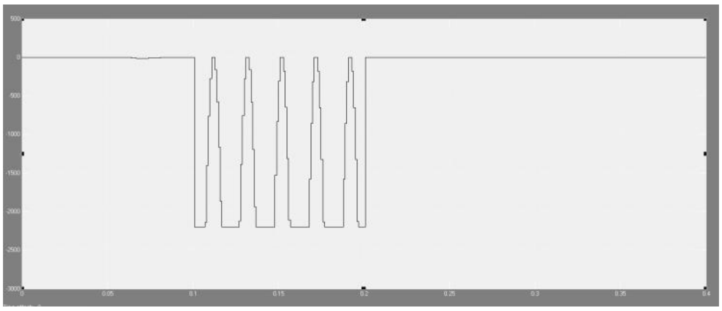

Fig-14: Reactive current reference

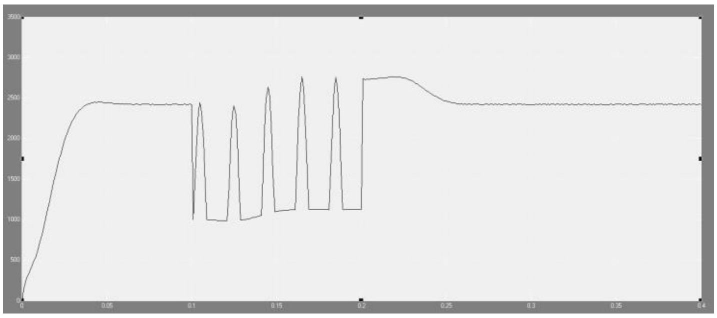

Fig-15: Active current reference

After Including MAF in the control:

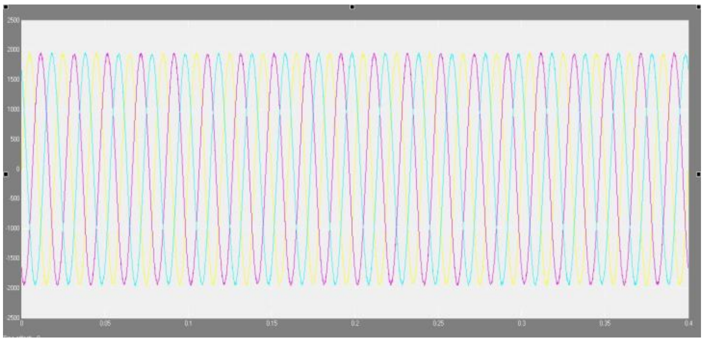

Fig-16: output currents

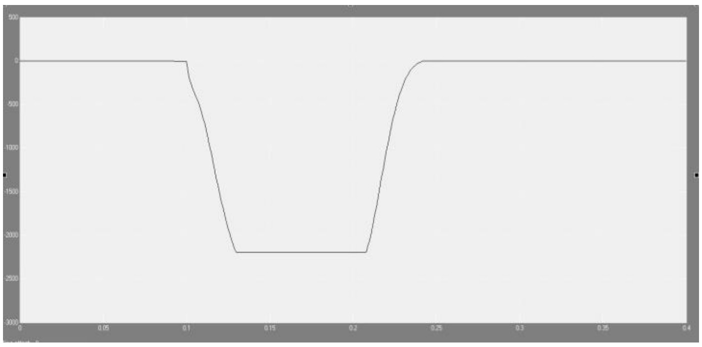

Fig-17: reactive reference current

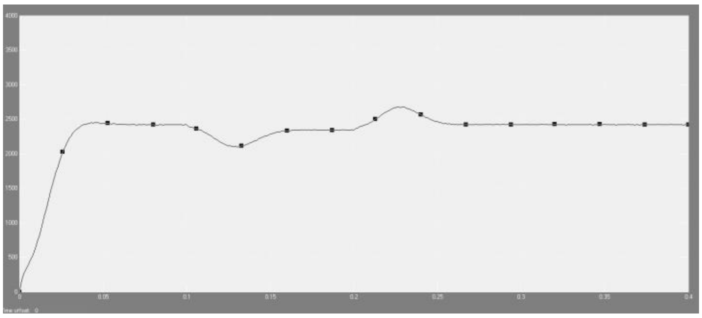

Fig-18: Active reference current

From the above it can be said that after including the MAF (moving average filters) the reference waveforms distortions are reduced so that the output currents.

After application fuzzy controller without MAF:

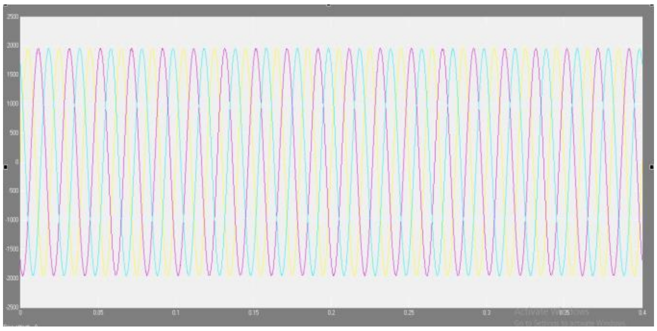

Fig-18: output grid currents

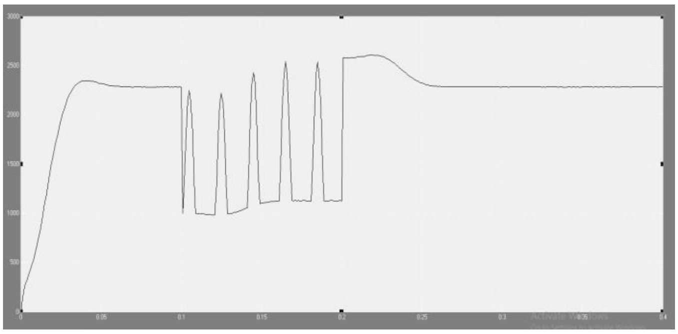

Fig-19: Active current reference

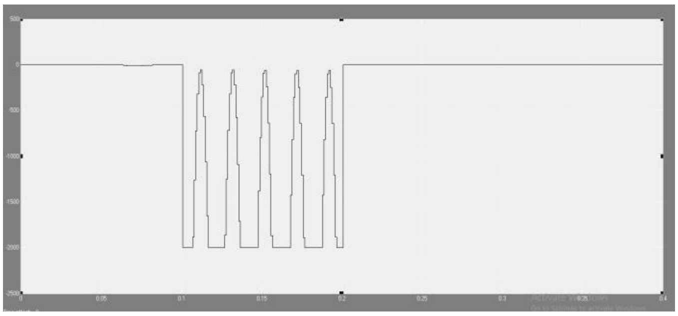

Fig-20: Reactive current reference

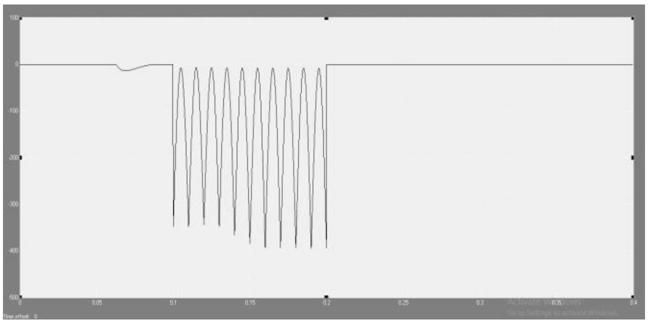

Fig-21: voltage drop

Because of employing fuzzy controller in place of PI control the distortions in the system are reduced compare to the PI control.

After application fuzzy controller with MAF:

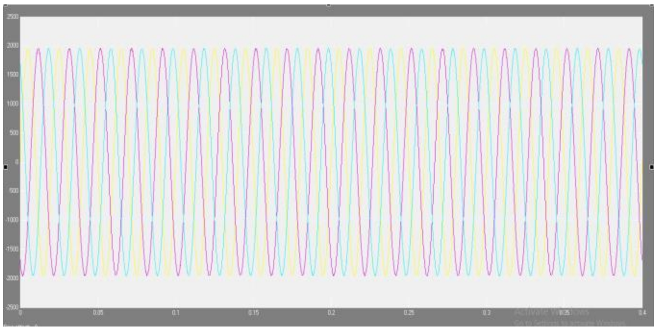

Fig-22: grid currents

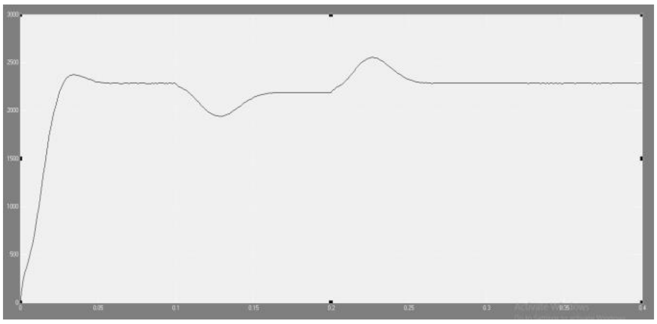

Fig-23: active reference current

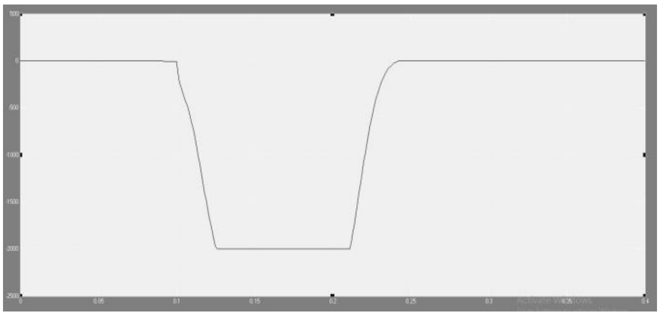

Fig-24: reactive current reference

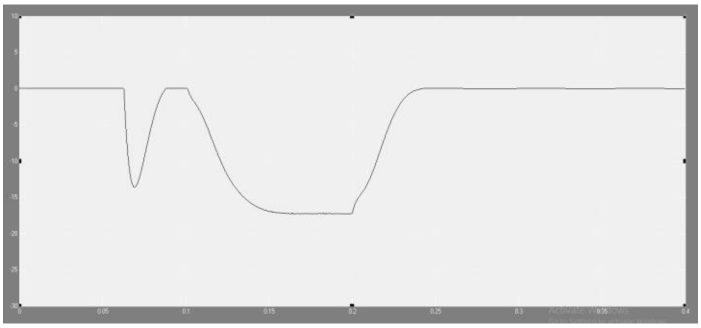

Fig-25: voltage drop

From the above figures it can be said that the ripples in the system or pulses are reduced because of the MAF in the control compare to only a fuzzy control.

5. CONCLUSION

In this paper, the issues of Grid Connected Photo Voltaic Power Plant are specified and control strategies are given to make the system ride through for those issues without disconnection of inverter from the grid. From the specified controllers, by observing graphs and FFT analysis, it can be said that fuzzy controller with MAF reduces the ripples in output grid currents at most.

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