Integrated Photovoltaic and Dynamic Voltage Restorer with Nine Switch Power Converter for Power Quality Enhancement

R.ArulPrakash[1] | R.Subramanian[2] | C.Ramakrishnan[3]
[1](Power System Eng, SNS College of Technology, Coimbatore, India, arulprakashreee@gmail.com)
[2](Dean (EEE Dept), SNS College of Technology, Coimbatore, India,rama.smani@gmail.com)
, [3](HOD (EEE Dept), SNS College of Technology, Coimbatore, India, , ramramki.krishna@gmail.com)

Abstract-*The paper presents the new system configuration of integrated PV system with the self-supported Dynamic Voltage Restorer. The "six-port converter" has nine semiconductor switches. It will decreasing the over all switch count from twelve to nine and also to improve the system ability against the symmetrical/asymmetrical faults and voltage sag. The six-port converter operational modes are presented. The control algorithm is developed with proposed configuration under different operating condition.*

Keywords-Bidirectional power flow, Photovoltaic(PV) System,Power Quality Enhancement,Voltage Sag,Faults.

1.INTRODUCTION

Energy is the primary measure of all kinds of work by human beings. Whatever happens in the world is the only expression of flow of energy of its forms. Energy is a crucial input in the process of economic, social and industrial development. Energy consumption in the developing countries is increasing at a faster rate. Conventional energy are depleting day to day, utilization of alternative energy sources is the only solution. India has made rapid strides towards economic self reliance over the last few years.

The power distribution from the load with on-site PV generation with custom power devices for critical load. Active power injects through grid connected PV plant through Voltage Source Inverter. Power quality enhancement through the self-supported DVR.In this existing system,not able to maintain the rated load voltage because of the dc-link capacitor's finite energy. One possible way for DVR is to add a shunt rectifier in the load side to maintain the dc-link capacitor at rated value. The other method to improve the DVR performance is to add a battery back-up. It is not affect the DVR rating but the maintenance of energy storage is added to the system.

The inverter VA rating depend upon the PV installed capacity of Solar Panels. PV panel id idle during early morning hours, evening hours, and night hours. The other part id DVR it's voltage rating is 20-40 percent of total load VA.

The proposed system with integration of two applications the new six-port converter configuration which integrates both PV generation unit and the DVR unit.Eliminates the separate inverter for both PV and DVR system. Under this consideration, the PV system's VA rating will take control of overall VA rating of converter, that isevenly rated DVR is ready for use load voltage.

It replaces two VSI to one combined converter which reduce overall semiconductor count, gate driver, and control circuit. The active power flow in six port converter protect sensitive load during voltage sag and take care of sensitive loads during Dip.

.

2. COMBINATION OF PV-DVR SYSTEM

Fig 2 shows the Proposed system. PV and DVR system are using the nine semiconductor switches in total. The main change between proposed system. Fig 1 shows the two dual output of the six-port converter where this six port converter.

A. Mode I (Healthy Grid)

Where the PV plant is operate at standard atmospheric condition (SAC). And normal value to the grid voltage for the six-port converter at Mode I. Active power injects by the PV-VSI and it generate by the PV plant. Where DVR-VSI remains not active as the healthy grid.The status of each switch by the six-port converter for equivalent operation.Generates the gating signal for all the switches by the carrier-based modulation. From Mode I where S1-S6 is operating in pulse width modulation control from the PV-VSI operation, the switch S7-S9 is ON. The primary winding of the series injection transformer is short circuit with the ON status of switch from S7-S9, here the DVR-VSI which injects the zero active power to the grid.

B. Mode II (Fault Mode)

Three phase fault at PCC is the condition of Mode II. During this mode PV-VSI is not active and DVR-VSI gives the higher compensating voltage. The left three switches have gating signal to the six-port converter with logic high. Where S1-S3 switches are "ON" during Mode II.The switch S4-S9 where six-port converter feeds a critical load with normal operating of SAC for PV plant.The operation of PV supported by DVR.The proposed PV and self-supported DVR not able to perform the 3 phase fault at PCC. Mode II cannot realize during the Fig 1. During this condition PV-VSI having neutral point to the series transformer adding the inductor with S1-S3 is ON. DVR which compensate the small voltage drop between the inductor.

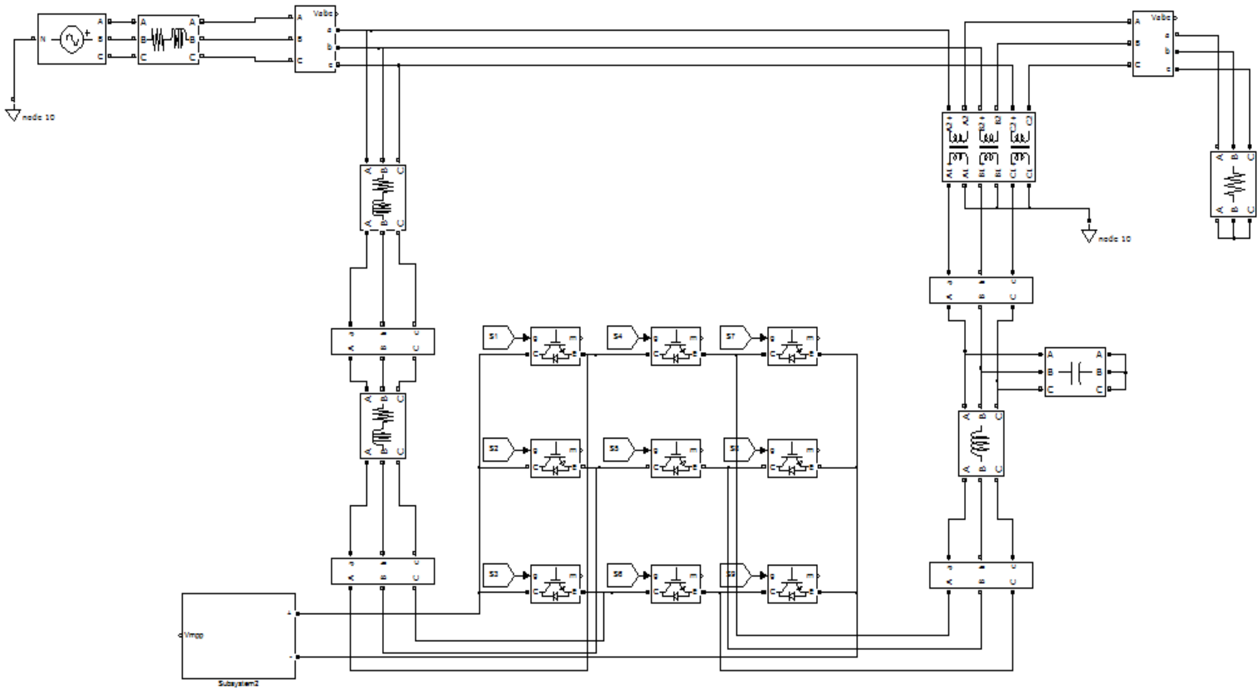

Fig 1 Self supported DVR and On-site PV generation

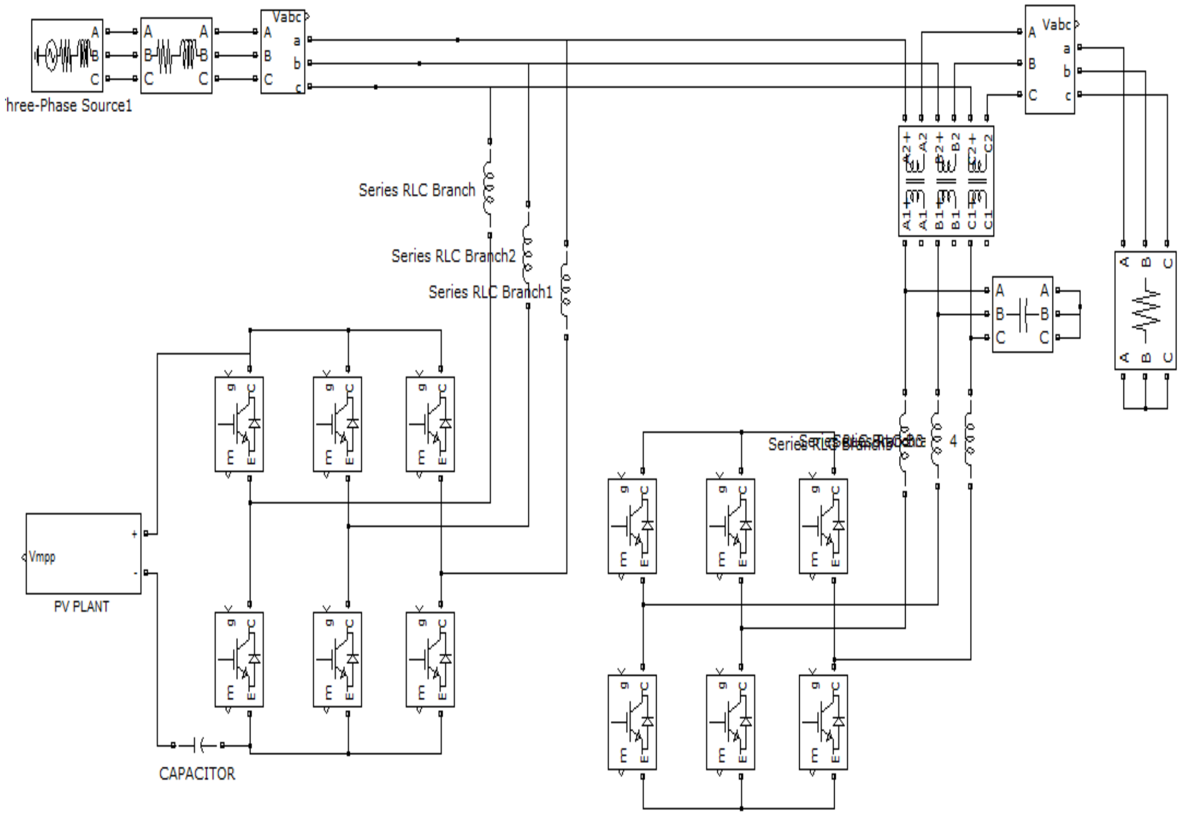

Fig 2 Integrated PV and DVR system

C. Mode III (Sag Mode)

Mode III describes the working of six-port converter during voltage dip at point of common coupling(PCC). Due to large phase increase and to avoid tripping during critical load, the presage compensation to the DVR-VSI.Based on maximum current capacity the injection of active power by the PV plant for grid voltage which is not zero. The nine switch both DVR and PV-VSI of nine switch is ON during Mode III given in Fig 5. The active power by the PV plant gives between load and grid based on magnitude of dip depth and LPF(Load Power Factor). The first priority is basically given to the sensitive load.

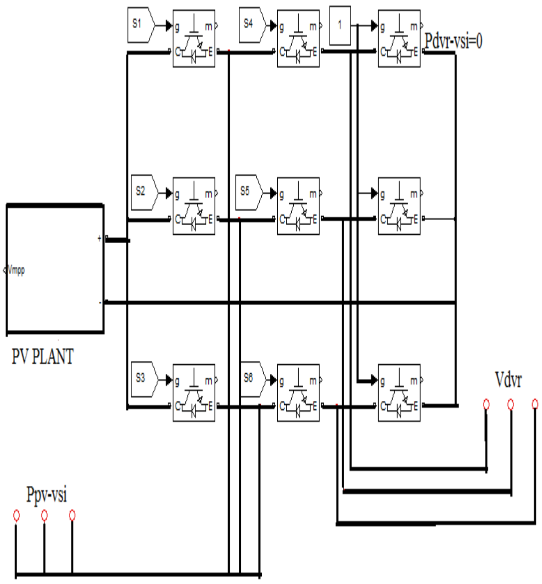

Fig 3 Mode I System Representation

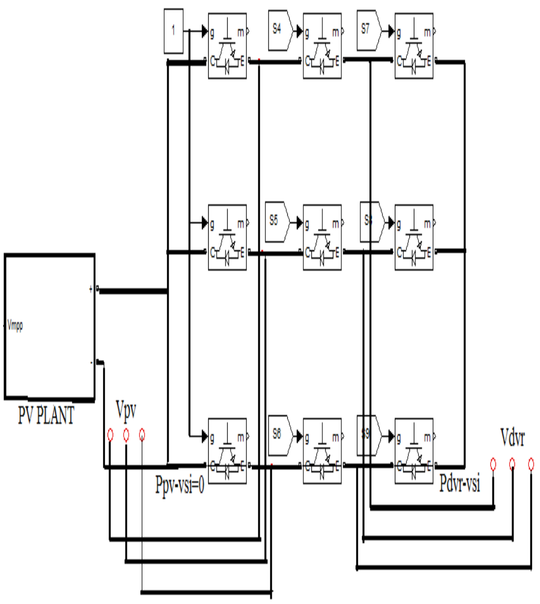

Fig 4 Mode II System Representation

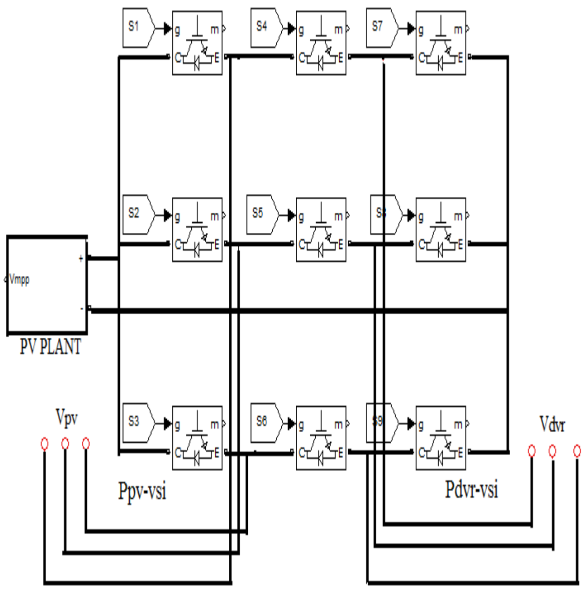

Fig 5 Mode III System Representation

3. Modulation Scheme for Six-port Converter

As given in Fig 2 the three switches is shared between both PV and DVR-VSI by the acceptable switching state. There are four possible connections with two output ports.

1) Both output with +Vdc for phase-a S1- ON S4-ON and S7-OFF

2) Both to 0V S1-OFF S4-ON and S7-ON

3) Left port to +Vdc and Right port to 0V phase-a S1-ON S4-OFF and S7-ON

4) Right port to +Vdc and Left port to 0V Phase-a S1-ON S4-ON and S7-ON.

The direct short-circuit of dc link cannot realized. The left port of the reference signal is used on third order harmonics injection method.

There are two mode of operation in six-port converter. 1) EF (Equal Frequency) operation, two set of output operate at equal frequency. 2) VF (Variable Frequency) for the two set of operation this frequency is used for harmonic compensation.

During the Mode 1, PV-VSI forced active power to the grid. Here the PV-VSI is unity and DVR-VSI goes to zero. During the Mode 3 is being most than Mode 1.where modulation index is reduced the PCC voltage dip is reduced. The increase in DVR-VSI is decreased to PV-VSI cross over does not occur.The reference signal of individual PWM is having six pulses with 120 degree operation PWMpv and PWMdvr

Gpv1-3= (Gpv4-6)'= $\begin{cases} 1, if \mid Mpv - a,b,c > Mc \\ 0, if \mid Mdvr - a,b,c < Mc \end{cases}$

Gdvr1-3=(Gpv4- 6)’= $\begin{cases} 1, if\, |Mdvr - x,y,z > Mc \\ 0, if\, |Mdvr - x,y,z < Mc \end{cases}$ (1)

Carrier Signal amplitude is Mc. The PV and DVR VSIs are working in two set split of six switch inverter shown in Fig 1 and twelve gating signals directly sent to the corresponding inverter. The middle row shared between, the gating pulse produced by logic OR operation to the PWM signal for the right three switches of PV-VSI. The left three switch for DVR-VSI(Gpv4-6). Gdvr1-3. The final nine gating pulse Gn1-9 is follows as,

$$\left.\begin{array}{c} Gn1-3 = Gpv1-3 \\ Gn7-9 = Gdvr1-6 \\ Gn4,5,6 = Gpv4-6+Gdvr1-3 \end{array}\right\} (2)$$

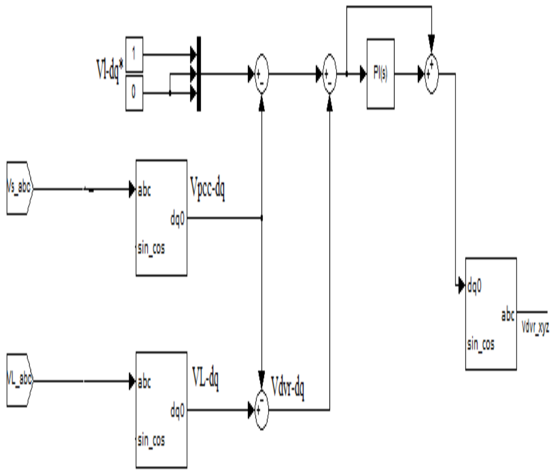

Fig 7 DVR-VSI

4. CONTROL SYSTEM

A. PV-VSI Control

The active and reactive power is occurring at PV-VSI frame,

$$\left.\begin{array}{c} P = 1.5 * [vdid + vqiq] \\ Q = 1.5 * [vdid - vqiq] \end{array}\right\} (3)$$

The positive sequence PCC voltage Vd=Vpcc. The PV power is expressed as

i* d-pv = $\frac{2}{3*Vd}$ Ppv (4)

The reference current iq* is zero. PV given current is changed based on sag dip and duration. Shunt current is change by limitation block.. The converter overloaded three times the rated current capacity(Imp) based on thermal rating of switches. By comparing both actual and reference values and error is processed through PI controller. The output signal is changed back to stationary output Vpva,b,c as shown in Fig 6.

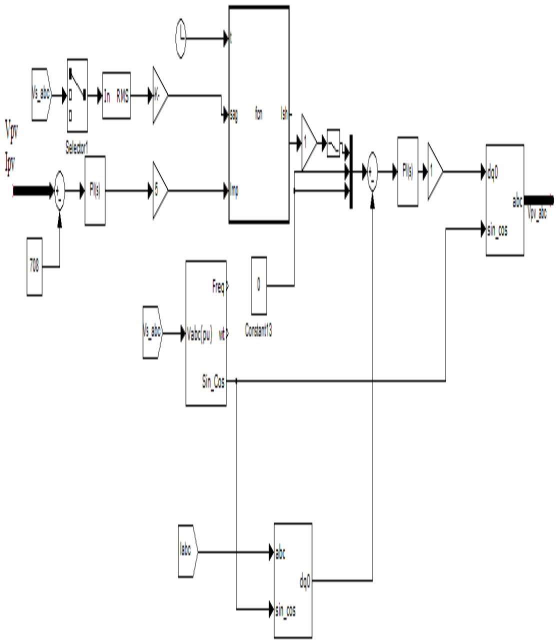

Fig 6 PV-VSI

B. DVR-VSI Control

Fig 7 shown the control block of DVR-VSI. The split between reference and DVR voltage is process by PI controller reference frame. Vdvr-dq directly used to control the open loop of the reference frame. The drop across the switches is not able to compensate, interfacing filter and series transformer. Feed forward signal is given to the PI to compensate the system losses.

For dip/fault detection erroe between reference PCC voltage and actual PCC voltage is calculated as,

Verror = $1 - \sqrt{V2pcc - d - V2pcc - q}$(5)

Verror exceeds the threshold 0.05 sag is detected and fault signal change the logic from 0 to 1. PV and DVR VSIs modulation signals V*pv-abc and V*dvr-xyz processed by nine gate signals.

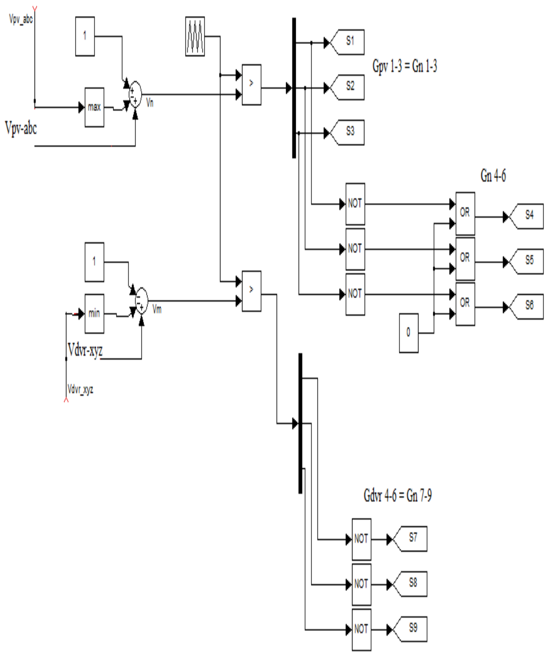

Fig 8 DVR-VSI

5. SIMULATION STUDY

The MATLAB study produced the reliability of proposed system configuration.

A. Mode I (Healthy Grid)

Grid is operating at normal condition during Mode-1. Fig 8(a)-(d) tells the simulation result foe Mode-1. All results can be expressed in p.u with base value of 10 kVA and 415 V. PV plant works in range of about 60%-100% of SAC. The MPPT loop is set as 20A with reference value of d-axis current i*d-pv The PV active power injects into the grid in Fig 8(d). Grid active power is decreased in same amount in Fig 8(b). During this mode DVR-VSI is not active during this mode of operation.

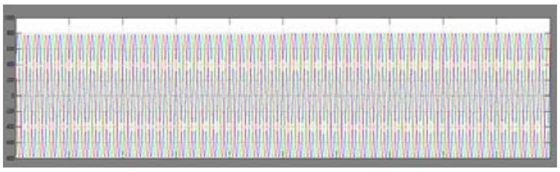

Figure 8 (a) Output Waveform at Vpcc

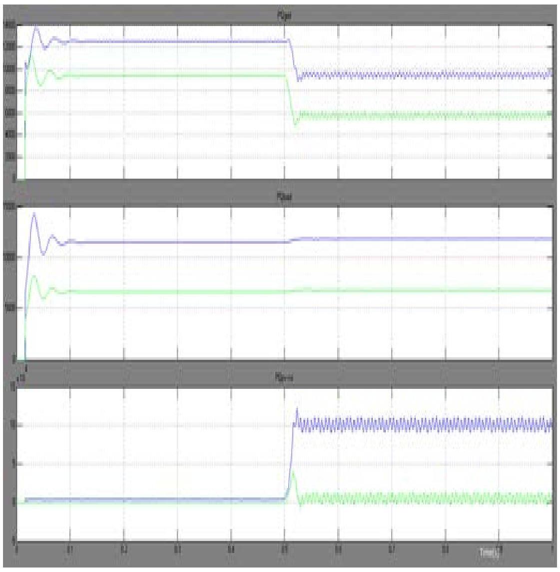

Figure 8(b-d) Output Waveform of PQload, PQgrid, $PQ_{PV\text{-}VSI}$

B. Mode II (Fault Grid)

PV plant supports the critical load by six-port converter has the operation of DVR giving full load active and reactive power. Given in Fig 9 (e)-(g), fault occurs at t = 0.1 s , the PV is not active and the power generated by PV plant is fully handled by DVR-VSI. Which increase the PV plant efficiency to optimize its power feed to critical load to deliver the grid. In this mode the supplies reactive power to the grid take part through fault ride through enhancement.

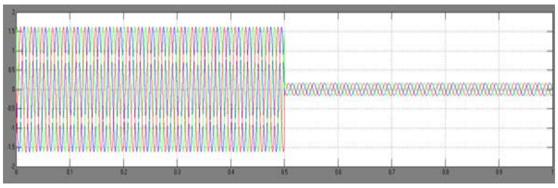

Figure 9 (a) Output Waveform of Vpcc

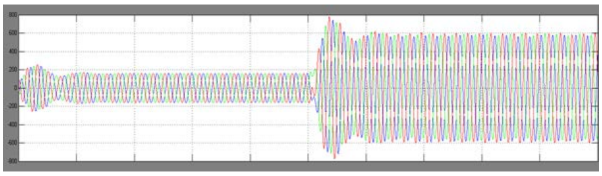

Figure 9 (b) Output Waveform of Vdvr

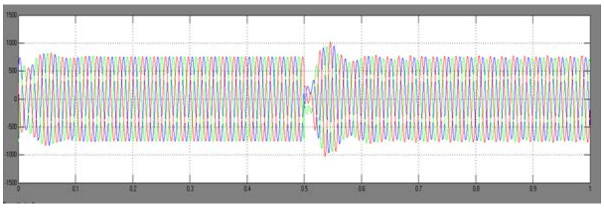

Figure 9 (c) Output Waveform of Vload

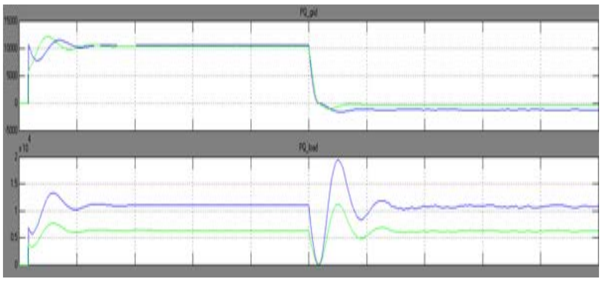

Figure 9(d)-(e) Output Waveform of $PQ_{PV\text{-}VSI}$,$PQ_{DVR\text{-}VSI}$

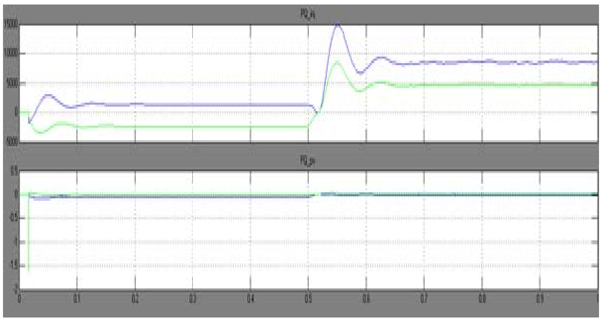

Figure 9(f)-(g) Output Waveform of $PQ_{PV\text{-}VSI}$,$PQ_{DVR\text{-}VSI}$

C. Mode III (Dip Grid)

1) Balanced Three Phase Voltage Sag:

The symmetrical sag depth is 50% of grid voltage. PCC voltage reduced to 0.5 p.u. the dip occurs at t = 0.1 s as soon as sag is identified. Fig 10 (a)-(e) shows the simulation results in Mode III. This configuration tells the presage load voltage by giving the fundamental voltage through series transformer. Sag depth is 50% due to presage restoration, 80% of PV plant active power delivered to the DVR-VSI, remaining 20% goes to grid by PV-VSI.

2) Unbalanced Three Phase Voltage Sag:

The six port converter of unbalanced sag with positive sequence voltage drop 40% and negative sequence voltage at 30%. Sag occurs at t = 0.1 s and DVR-VSI perform pre sag compensation. Proposed configuration operate on (0.1<Vpcc-p.u.<0.95). In case Vpcc-p.u.< 0.1, controller takes as fault and transition from Mode 3 to Mode 2.

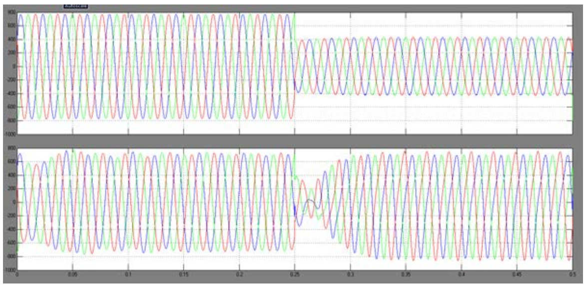

Figure 10(a-b) Output Waveform of Vpcc,Vload

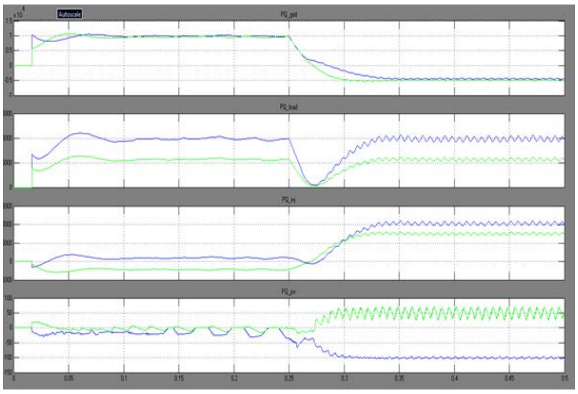

Figure 10 (c)-(f) Output Waveform of Pqgrid, PQload,PQ_{PV-VSI},$PQ_{DVR-VSI}$

6. CONCLUSION

In this paper, the combination of grid-connected PV system and self supportedDVR, It also exhibits the DVR operating range. It allows the DVR to utilize active power to PV plant improve robustness against severe fault. The different modes based on grid and PV generation. The discussed modes are healthy mode, grid mode, sag mode. The simulation study is feasibility to perform under different operating condition. This system is very useful for modern load centres on-site PV generation and restrict voltage regulation.

REFERENCES

[1] L. Zhang, P. C. Loh, and F. Gao, “Anintegrated nine-switch power conditionerfor power quality enhancement and voltagesag mitigation,” IEEETrans. PowerElectron., vol. 27, no. 3, pp. 1177–1190,Mar.2011.

[2] J. A. Martinez and J. M. Arnedo, “Voltagesag studies in distribution networks—PartI: System modeling,” IEEE Trans. PowerDel., vol. 21, no. 3, pp. 338–345, Jul. 2006.

[3] S. S. Choi, J. D. Li, and D. M.Vilathgamuwa, “A generalized voltage compensation strategy for mitigating the impacts of voltage sags/swells,” IEEETrans. Power Del., vol. 20, no. 3, pp.2289–2297, Jul. 2005.

[4] M. Azizi, A. Fatemi, M. Mohamadian, and A. Y. Varjani, “Integrated solution for microgrid power quality assurance,” IEEE Trans. Energy Convers., vol. 27, no. 4, pp. 992–1001, Dec. 2012.

[5] H. K. Al-Hadidi, A. M. Gole, and D. A.Jacobson, “Minimum power Operationof cascade inverter-based dynamic voltage restorer,” IEEE Trans.Power Del., vol. 23, no. 2, pp. 889–898, Apr. 2008.

[6] J. D. Li, S. S. Choi, and D. M. Vilathgamuwa, “Impact of voltage phase jump on loads and its mitigation,” in Proc. 4th Int. Power Electron. Motion Control Conf., Xian, China, Aug. 14–16, 2004, vol. 3, pp. 1762– 1766.

[7] IEEE Recommended Practices and Requirements for Harmonic Control In Electrical Power Systems, IEEE Standard 519-1992, Apr. 1993, pp. 1–112.