

# Amalgamated Nine Switch Inverter with PV and Self Supported DVR System

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**Abstract**—This paper proposes a nine switch inverter (NSI) topology amalgamation of photovoltaic (PV) with self-supported dynamic voltage restorer (DVR) with the grid tied system. The proposed system configuration gets rid of the number of switches to less count to nine, which reduce cost and bi-directional power flow in domestic applications while robust against rapid increase sensitive loads. In addition to that mitigate the power quality issues such as voltage sag, swell, balanced/ unbalanced loads and symmetrical/ unsymmetrical faults. Furthermore, reducing the switching losses increases the system efficiency and reliability, a proper discontinuous modulation technique is studied and used. Performance comparison with reduced number of switches, analyses of the proposed inverter by overcoming the compensation of the DVR via simulation results, output waveforms validity under different operating modes.

**Keywords**—Nine switch inverter topology, solar power, Maximum Power Point Tracking (MPPT), power generation, quality power, dynamic voltage restorer.

## I. INTRODUCTION

Tremendous usage natural energy resources, overcoming the non-conventional energy resources because of environmental aspects a flexible power generation is obtained by photovoltaic to small and large power generation plants [1]. To obtain a natural green energy source with higher efficiency power through PV generation system of maximum power point control algorithm and the power output through a conversion system is used basically in an

individual voltage source inverter system [2], [3]. In domestic applications where increase in power electronic loads leads to critical load with major problems with power quality raises affecting the grid voltage by voltage sag, swell, balanced/unbalanced loads and symmetrical/unsymmetrical faults. In distribution system, it becomes more to maintain an uninterruptible power flow to the domestic loads [4], [5]. In order to avoid the power quality issues modern custom power (CP) devices fewer than two

groups are a network reconfiguring type and compensating type. The concept of the custom power is tools of application of power electronics controller devices into the power distribution system to supply a

quality of power, demanded by the sensitive users. For the generation of custom power devices voltage source inverter (VSI) is generally used, due to self-supporting of dc bus voltage with a large dc capacitor. In order to compensate the load problems, DVR a high-speed switching device is functional as also named static series compensator. Its applications over voltage regulation, flicker attenuation, voltage sag and swell protection, voltage balancing [6]. In a progress where a grid tied with PV plant with a six switch VSI makes advantages over injecting the active power instead of grid supply to the load terminals [7]. Another problem of sensitive loads makes the system unstable, to rectify that compensation of interrupted voltage during the certain conditions DVR performs it with another six switch VSI. Thus the self-supported DVR will maintain the load voltage to rated power [8]. By the system were a two separate VSI which makes switching losses and increasing the operational time problem cannot be solved [9]. In addition to that proper maintenance over battery is needed. The power rating of the PV depends on the solar panels in array of series and parallel strings towards the inverter output generation [10].

Instead of using the two separate VSI, we move towards nine switch inverter topology make the system dual functionality over various advantages. By using this method, we have reduced switches and computational losses. In addition to that the system with DVR makes more improvement in uninterruptible power supply [11], [12]. The system will make more efficiency over the loads with a quality power to the load centers. In order to achieve a high performance of the compensation takes place for the requirements of the problems in the grid. The proposed work is validated by nine switch inverter

system compensation from sensitive loads over voltage sag by the study over simulation study.

## II. PROPOSED SYSTEM

In this proposed system, the nine switch inverter topology is shown in Fig.1 consists of nine semiconductors; switches are accustomed to take in PV with DVR performances. The proposed topology gives six output lines are split off two three phase outputs. The grid side outputs are A, B, C terminals through the PCC ends and load side outputs are X, Y, Z terminals as shown in Fig 1. In this proposed system, nine switch inverter topology where the three semiconductor switches ( $T_4 - T_6$ ) are common for both PV and DVR performances over the grid tied system. According to that the proposed configuration consists of various modes of operation in that specifically the switching status for phase-a can be explained easily through the ON and OFF of semiconductor switches shown in TABLE I.

TABLE I SWITCHING OPERATIONS OF PHASE-a

Output	Phase -a (ON)	Phase-a (OFF)
$+V_{dc}$	$(T_1, T_4)$	$(T_7)$
$0V$	$(T_4, T_7)$	$(T_1)$
Left $+V_{dc}$ & Right $0V$	$(T_1, T_7)$	$(T_4)$
Right $+V_{dc}$ & Left $0V$	$(T_1, T_4)$	$(T_7)$

status of nine switch inverter is shown in Fig. 2(a). The Pulse Width Modulation (PWM) technique generates gating signals for all switches. Each mode the switching operation are shown in table I. Likewise, in healthy grid mode six switches ( $T_1 - T_6$ ) are PWM operation and ( $T_7 - T_9$ ) are always ON beneficiary closed primary windings of DVR is made zero power.

### B. Fault Occurrence

Normally when a three phase fault occurs in grid, the switching operations change DVR to takes place to compensation of the faulted voltage towards supply. Here the PV remains calm. The requirement of voltage during fault is compensated by DVR towards the load side.

### C. Voltage Sag

At PCC, voltage sag occurs which behaves the compensation of sag voltage by NSI operation over PWM by reference signals as shown in Fig. 2(b). Such that achieve power in PV plants provided to certain limit to the highest current potential over the grid at the terminal by sending end side at PCC. In this mode, both PV and DVR are taking place in operation to share the power between grid and loads.

### D. Without PV

In this mode of operation where the PV plant in off status because there is no power generation. The PV side switches are backwards operated towards nominal voltage and illustrate the power. The power flow is backwards to the dc link capacitor from the

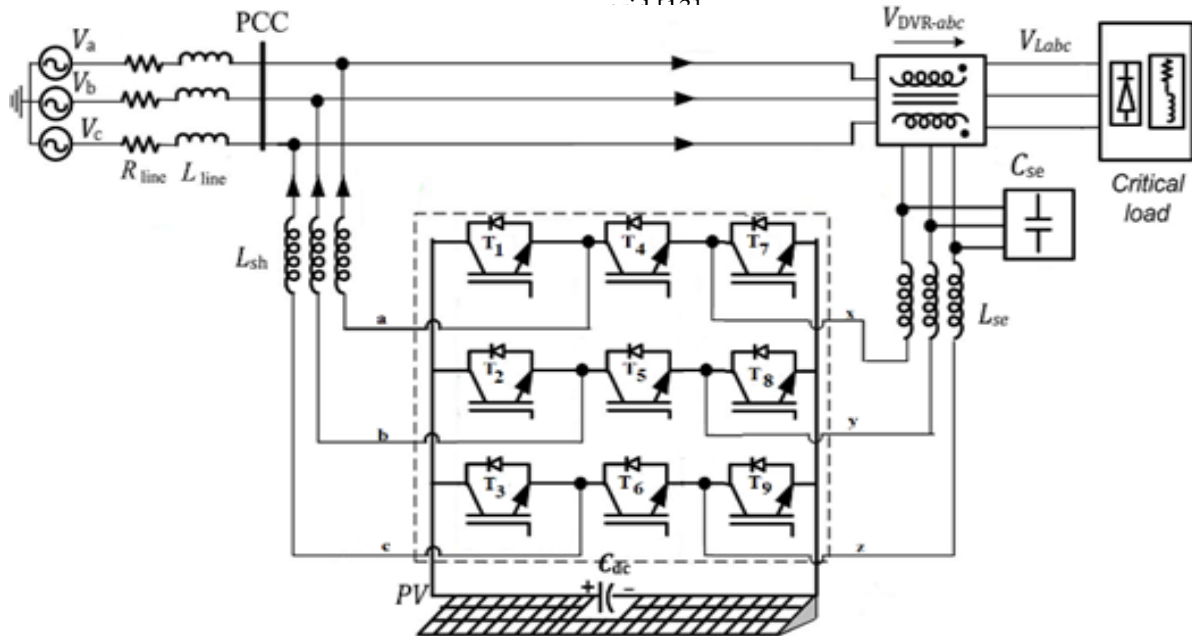


Fig.1. Proposed NSI with PV-DVR system configuration

#### A. Normal Grid Operation

This mode typically operates in an ostensible standards PV plant. Similarly, it shoots the active power engendered towards the grid side where the operation of the DVR is not needed. The switching

The design of the capacitor is based on given equation:

$$C_{dc} = \frac{t_{c-max} * 2 * P_{dvr-vsi}}{\left[ V_{dc}^2 - \left( \frac{2 * V_{dvr-vsi}}{m_{i-max} * n_i} \right)^2 \right]} \quad (1)$$

### III. PWM TECHNIQUE

The PWM technique over the PV and DVR switches under the nine switch inverter through reference signals are given below shown in Fig.2.

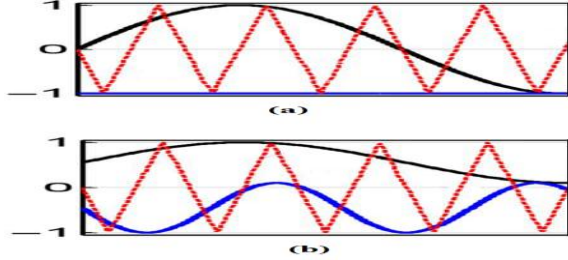


Fig. 2. PWM through reference signals

$$\begin{aligned} V_a &= M_{pv} \cos(w_{pv}t + \phi_{pv}) \\ V_b &= M_{pv} \cos(w_{pv}t - 120 + \phi_{pv}) \\ V_c &= M_{pv} \cos(w_{pv}t - 240 + \phi_{pv}) \end{aligned} \quad (2)$$

$$\begin{aligned} V_x &= M_{dvr} \cos(w_{dvr}t + \phi_{dvr}) \\ V_y &= M_{dvr} \cos(w_{dvr}t - 120 + \phi_{dvr}) \\ V_z &= M_{dvr} \cos(w_{dvr}t - 240 + \phi_{dvr}) \end{aligned} \quad (3)$$

where  $V_{a,b,c}^*$  and  $V_{x,y,z}^*$  are the voltage reference signals.  $M_{pv}$ ,  $\phi_{pv}$ ,  $w_{pv}$  are the modulation ratio, phase angle and angular frequency (2). It is similar towards the DVR equations for reference signals (3). In order to generate the gate signals as shown in Fig. 3 by using the control blocks for PV and DVR VSIs are obtained.

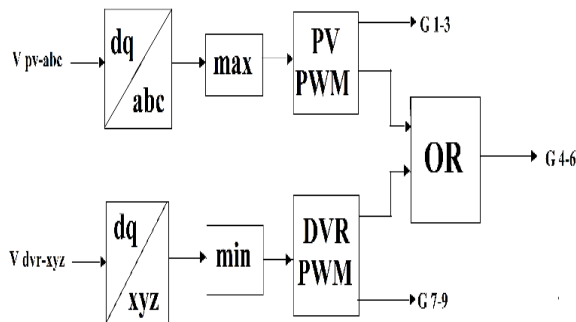


Fig. 3. Control block for PV and DVR representation

### IV. DISTRIBUTION DATA

TABLE IIDISTRIBUTION DATA PARAMETERS

PARAMTERS	VA LUE
GRID VOLTAGE(rms)	415v
LINE FREQUENCY	50Hz
PV POWER	10KVA
LOAD POWER	10KVA
DC LINK VOLTAGE	700 V
SERIES TRANSFORMER TURN RATIO	1:1
FILTER INDUCTOR AND CAPACITANCE	5mH & 50μF
GRID IMPEDANCE	0.5+j0.05Ω

### V. MATLAB SIMULINK MODEL

In this section, MATLAB/Simulink-based study is presented to illustrate the feasibility of system configuration. The parameters of simulated system are given in Table II.

#### A. NORMAL GRID OPERATION (MODE-1)

In this mode simulation results shown in Fig. 4 & 5 the PV is active and DVR is idle. The switches ( $T_1 - T_6$ ) operated through PWM technique and ( $T_7 - T_9$ ) are HIGH.

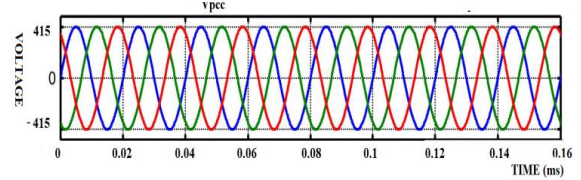


Fig. 4. Grid voltage in mode-1

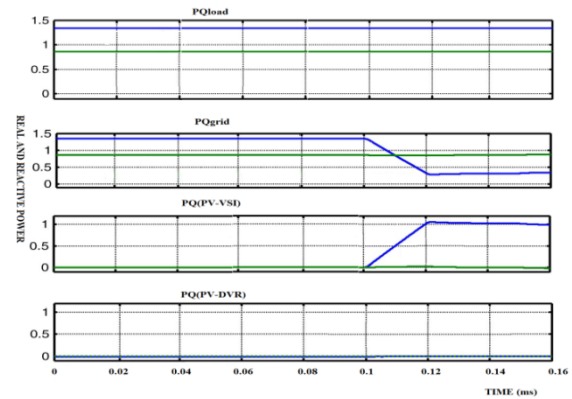


Fig. 5. Real and reactive power in mode-1

#### B. FAULT OCCURRENCE (MODE-2)

Assume that when a fault occurs in PCC, the nine switch inverter operates towards PV and DVR as shown in Fig. 6. The DVR is taking power to provide the compensation of fault voltage towards the grid at load side as shown Fig. 7.

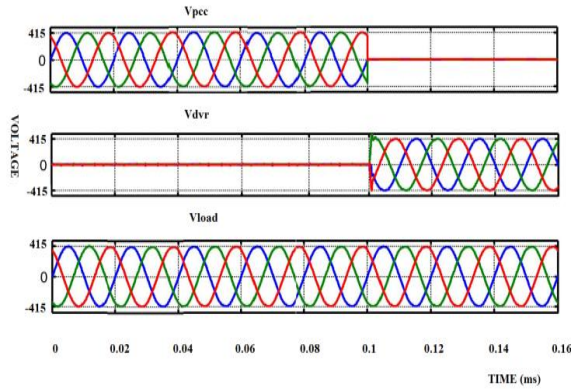


Fig. 6. Voltage across grid, DVR, Load in mode-2

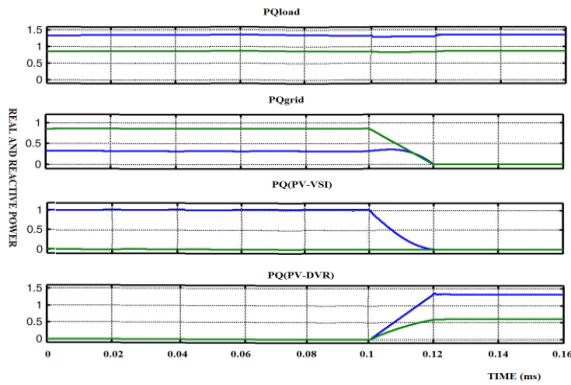


Fig. 7. Real and reactive power in mode-2

#### C. VOLTAGE SAG (MODE-3)

In grid when sag occurs a depth of 50% in sending end voltage as shown in Fig. 8. So that DVR compensation over the presag voltage is supplied to the load side. The power which generated by PV plant is supplied to the load by DVR as shown in Fig. 9.

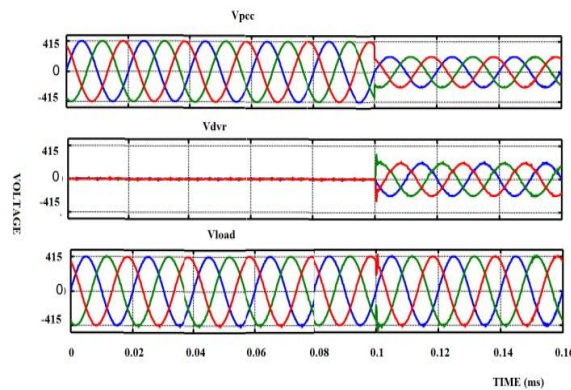


Fig.8. Voltage across grid, DVR, load in mode-3

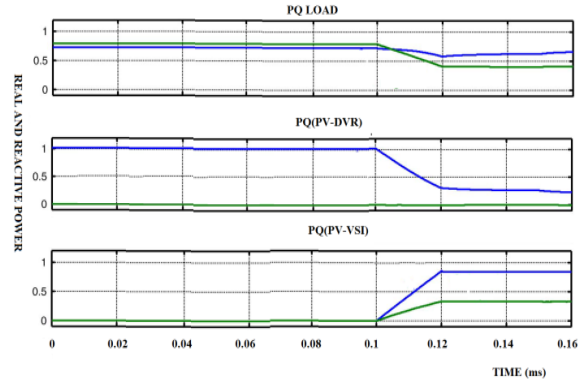


Fig. 9. Real and reactive power in mode-3

#### D. WITHOUT PV (MODE-4)

In proposed configuration when grid without PV supply doesn't have active power results the total power by DVR. The power required is taken from dc link. This mode corresponds to the intervals when PV plant is not producing any active power. The required load active power is provided by NSI system as shown in Fig 10 & 11.

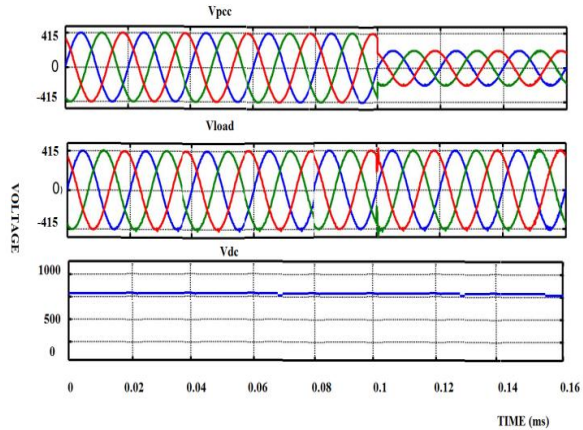


Fig. 10. Voltage across grid, DVR, load in mode-4

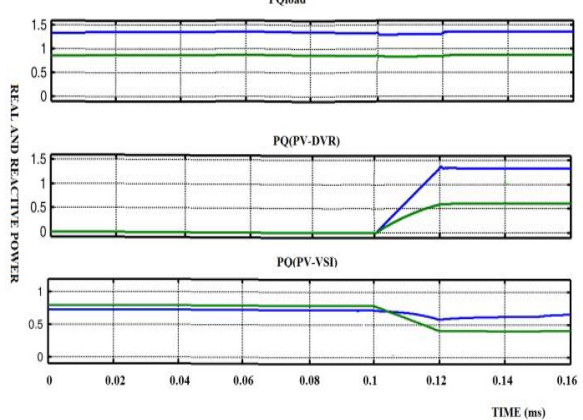


Fig.11. Real and reactive power in mode-4

#### VI. CONCLUSION

In this paper a nine switch inverter topology amalgamating of PV with a self-supported DVR system is proposed. In this configuration that unveils the utilitarian of surviving system provides power to the load side. It maintains the uninterrupted power supply through DVR compensation when voltage sag,



fault occurrence and no PV generation are observed through the simulation results. The proposed system configuration has various operations over the grid tied system are enhancing active power by PV and DVR at maximum compensation. It has more advantages over the upcoming load centers.

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