ENHANCEMENT OF POWER QUALITY IN POWER GRID SYSTEM USING DVSI

[1]A.Narmada, [2]Shaik Abdul Razaq

[1]M.Tech Student, [2]Assistant Professor
Ashoka Womens Engineering College

***Abstract*: This project presents a dual voltage source inverter (DVSI) scheme to enhance the power quality and reliability of the microgrid system. The proposed scheme is comprised of two inverters, which enables the microgrid to exchange power generated by the distributed energy resources (DERs) and also to compensate the local unbalanced and nonlinear load. The control algorithms are developed based on instantaneous symmetrical component theory (ISCT) to operate DVSI in grid sharing and grid injecting modes. The proposed scheme has increased reliability, lower bandwidth requirement of the main inverter, lower cost due to reduction in filter size, and better utilization of microgrid power while using reduced dc-link voltage rating for the main inverter. These features make the DVSI scheme a promising option for microgrid supplying sensitive loads. The topology and control algorithm are validated through extensive simulation and experimental results.**

Index Terms: Grid-connected inverter, instantaneous symmetrical component theory (ISCT), microgrid, power quality.

I. INTRODUCTION

TECHNOLOGICAL progress and environmental concerns drive the power system to a paradigm shift with more renewable energy sources integrated to the network by means of distributed generation (DG). These DG units with coordinated control of local generation and storage facilities form a microgrid [1]. In a microgrid, power from different renewable energy sources such as fuel cells, photovoltaic (PV) systems, and wind energy systems are interfaced to grid and loads using power electronic converters. A grid interactive inverter plays an important role in exchanging power from the microgrid to the grid and the connected load [2], [3]. This microgrid inverter can either work in a grid sharing mode while supplying a part of local load or in grid injecting mode, by injecting power to the main grid. Maintaining power quality is another important aspect which has to be addressed while the microgrid system is connected to the main grid.

The proliferation of power electronics devices and electrical loads with unbalanced nonlinear currents has degraded the power quality in the power distribution network. Moreover, if there is a considerable amount of feederimpedance in the distribution systems, the propagation of these harmonic currents distorts the voltage at the point of common coupling (PCC). At the same instant, industry automation has reached to a very high level of sophistication, where plants like automobile manufacturing units, chemical factories, and semiconductor industries require clean power. For these applications, it is essential to compensate nonlinear and unbalanced load currents [4].

Load compensation and power injection using grid interactive inverters in microgrid have been presented in the literature [5], [6]. A single inverter system with power quality enhancement is discussed in [7]. The main focus of this work is to realize dual functionalities in an inverter that would provide the active power injection from a solar PV system and also works as an active power filter, compensating unbalances and the reactive power required by other loads connected to the system.In [8], a voltage regulation and power flow control scheme for a wind energy system (WES) is proposed. A distribution static compensator (DSTATCOM) is utilized for voltage regulation and also for active power injection. The control scheme maintains the power balance at the grid terminal during the wind variations using sliding mode control. A multifunctional power electronic converter for the DG power system is described in [9]. This scheme has the capability to inject power generated by WES and also to perform as a harmonic compensator. Most of the reported literature in this area discuss the topologies and control algorithms to provide load compensation capability in the same inverter in addition to their active power injection. When a grid-connected inverter is used for active power injection as well as for load compensation, the inverter capacity that can be utilized for achieving the second objective is decided by the available instantaneous microgrid real power [10]. Considering the case of a grid-connected PV inverter, the available capacity of the inverter to supply the reactive power becomes less during the maximum solar insolation periods [11]. At the same instant, the reactive power to regulate the PCC voltage is very much needed during this period [12]. It indicates that providing multifunctionalities in a single inverter degrades either the real power injection or the load compensation capabilities.

II. SIMULATION STUDIES

The simulation model of DVSI scheme shown in Fig. 1 is developed in PSCAD 4.2.1 to evaluate the performance. The simulation parameters of the system are given in Table I. The simulation study demonstrates the grid sharing and grid

TABLE I
SYSTEM PARAMETERS FOR SIMULATION STUDY

Parameters	Values
Grid voltage	400 V(L–L)
Fundamental frequency	50 Hz
Feeder impedance	$R_g = 0.5\ \Omega$, $L_g = 1.0$ mH
AVSI	$C_1 = C_2 = 2000\ \mu$F $V_{dcref} = 1040$ V Interfacing inductor, $L_{fx} = 20$ mH Inductor resistance, $R_{fx} = 0.25\ \Omega$ Hysteresis band ($\pm h_x$) = 0.1 A
MVSI	DC-link voltage, $V_{dcm} = 650$ V Interfacing inductor, $L_{fm} = 5$ mH Inductor resistance, $R_{fm} = 0.25\ \Omega$ Hysteresis band ($\pm h_m$) = 0.1 A
Unbalanced linear load	$Z_{la} = 35 + j19\ \Omega$ $Z_{lb} = 30 + j15\ \Omega$ $Z_{lc} = 23 + j12\ \Omega$
Nonlinear load	3 ϕ diode bridge rectifier with DC side current of 3.0 A
DC voltage controller gains	$K_{Pv} = 10$, $K_{Iv} = 0.05$

Injecting modes of operation of DVSI scheme in steady state as well as in transient conditions.The distorted PCC voltages due to the feeder impedance without DVSI scheme are shown in Fig. 5(a). If these distorted voltages are used for the reference current generation of AVSI, the current compensation will not be proper [14]. Therefore, the fundamental positive sequence of voltages is extracted from these distorted voltages using the algorithm explained in Section III-A. These extracted voltages are given in Fig. 5(b). These voltages are further used for the generation of inverter reference currents. Fig. 6(a)–(d) represents active power demanded by load (Pl), active power supplied by grid (Pg), active power supplied by MVSI (Pμg), and active power supplied by AVSI (Px), respectively. It can be observed that, from t = 0.1 to 0.4 s, MVSI is generating 4 kW power and the load demand is 6 kW. Therefore, the remaining load active power (2 kW) is drawn from the grid. During this period, the

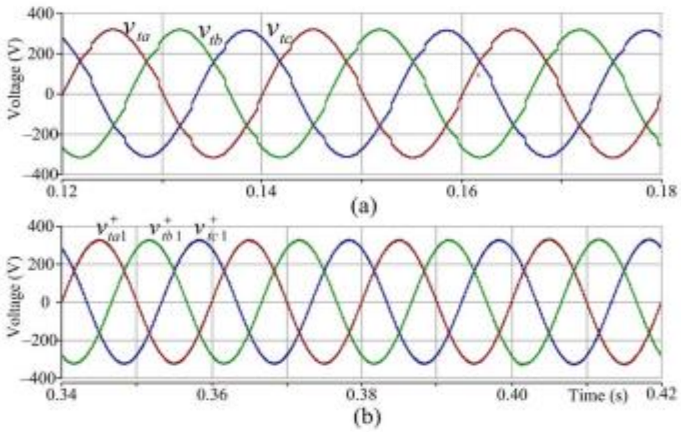

Fig 1: Without DVSI Scheme : (a) PCC Voltages (b) Fundamental positive sequence of PCC voltages.

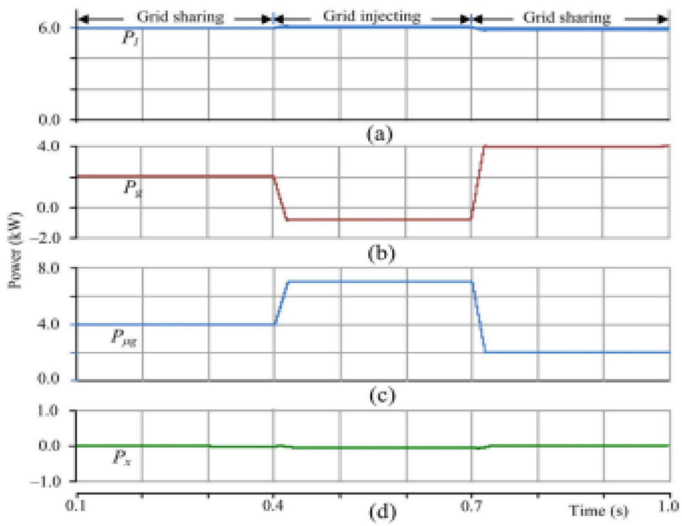

Fig 2: Active power sharing : (a) load active power ,(b) active power supplied by grid, (c) active power supplied by MVSI (d) Active power supplied by AVSI.

Micro grid is operating in grid sharing mode. At t = 0.4 s, the micro grid power is increased to 7 kW, which is more than the load demand of 6 kW. This micro grid power change is considered to show the change of operation of MVSI from grid sharing to grid injecting mode. Now, the excess power of 1 kW is injected to the grid and hence, the power drawn from grid is shown as negative. Fig. 7(a)–(c) shows the load reactive power (Ql), reactive power supplied by AVSI (Qx), and reactive power supplied by MVSI (Qμg), respectively. It shows that total load reactive power is supplied by AVSI, as expected. Fig. 8(a)–(d) shows the plots of load currents (il(abc)), currents drawn from grid (ig(abc)), currents drawn from MVSI (iμg(abc)), and currents drawn from the AVSI (iμx(abc)), respectively. The load currents are unbalanced and distorted. The MVSI supplies a balanced and sinusoidal currents during grid supporting and grid injecting modes. The currents drawn from grid are also perfectly balanced and sinusoidal, as the auxiliary inverter compensates the unbalance and harmonics

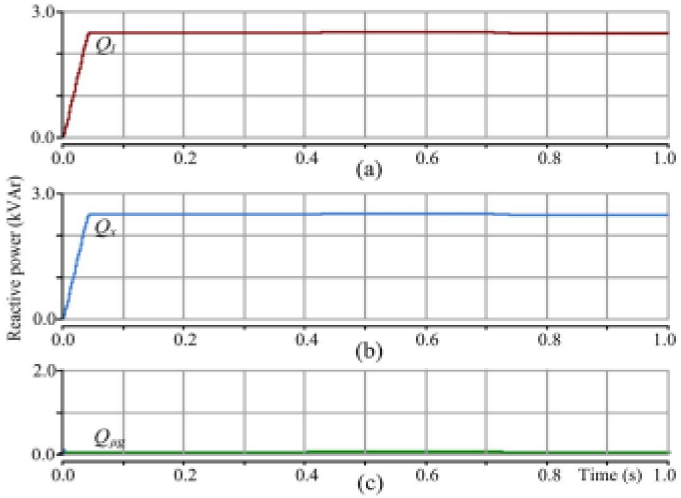

Fig 3: Reactive power sharing : (a) load reactive power (b) reactive power supplied by AVSI (c) reactive power supplied by MVSI.

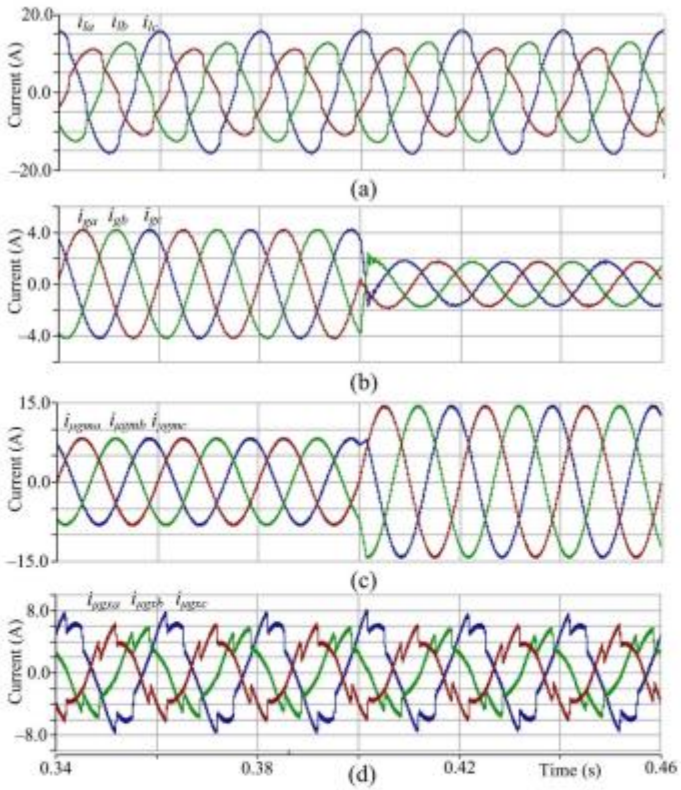

Fig 4 : Simulated performance of DVSI scheme: (a) load currents (b) grid currents (c) MVSI currents (d) AVSI currents

The Fig. (a) shows the plot of fundamental positive sequence of PCC voltage (v+ ta1) and grid current in phase-a (iga) during grid sharing and grid injecting modes. During grid sharing mode, this PCC voltage and grid current are in phase and during grid injecting mode, they are out of phase. Fig. 9(b) establishes that MVSI current in phase-a is always in phase with fundamental positive sequence of phase-a PCC voltage. The same is true for other two phases. Thus the compensation capability of AVSI makes the source current and MVSI current at unity power factor operation.

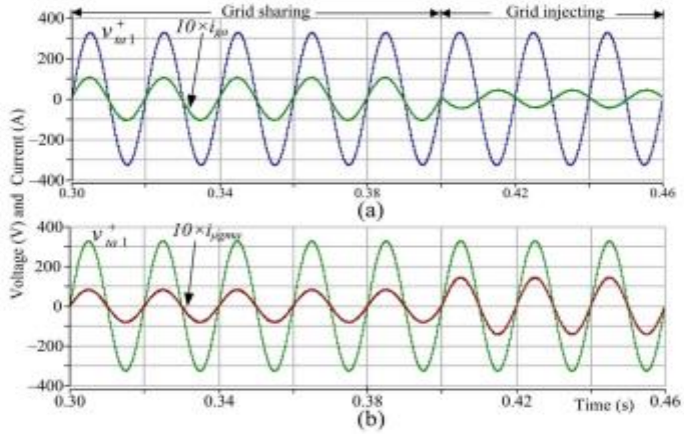

Fig 5 : Grid sharing and grid injucted modes of operation: (a) PCC voltages and grid current (phase-a) and (b) PCC voltage and MVSI current (phase-a)

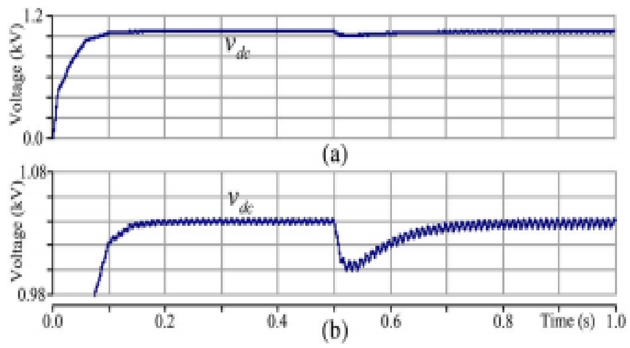

Fig 6 : (a) DC link voltage of AVSI (b) Zoomed view od dc link voltage dynamics during load condition

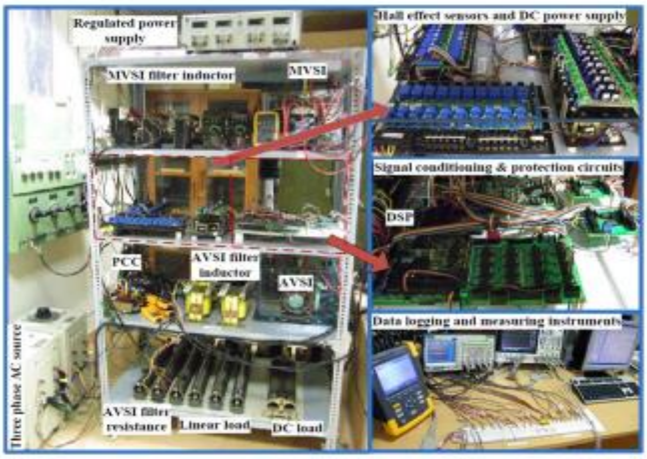

Fig 7 : Experimental setup of DVSI

These figures indicate that the voltage is maintained constant at a reference voltage (Vdcref) of 1040 V by the PI controller. All these simulation results presented above demonstrate the feasibility of DVSI for the load compensation as well as power injection from DG units in a microgrid.

TABLE II
SYSTEM PARAMETERS FOR EXPERIMENTAL STUDY

Parameters	Values
Source voltage	50 V L–N (rms), 50 Hz
Feeder impedance	$R_g = 0.5\,\Omega,\ L_g = 1.0$ mH
Reference DC-link voltage of AVSI	$V_{dcref} = 220$ V
DC-link capacitance of AVSI	$C_1 = C_2 = 4700$ μF
DC-link voltage of MVSI	$V_{dcm} = 150$ V
PI gains of DC-link voltage controller	$K_{Pv} = 80,\quad K_{Iv} = 0.08$
Hysterisis band (h)	$\pm\ 0.15\ A$
Interfacing inductor (AVSI)	$R_{fx} = 0.5\ \Omega, L_{fx} = 10$ mH
Interfacing inductor (MVSI)	$R_{fm} = 0.5\ \Omega, L_{fm} = 5$ mH
Unbalanced linear load	$Z_{la} = 24 + j16\ \Omega$ $Z_{lb} = 36 + j16\ \Omega$ $Z_{lc} = 64 + j21\ \Omega$
Nonlinear load	3 ϕ diode bridge rectifier with a dc current of 2.4 A

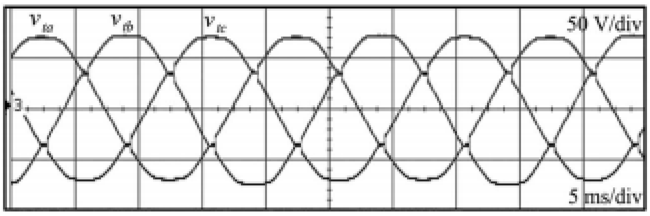

Fig 8 : Experimental results : PCC voltages before compensation

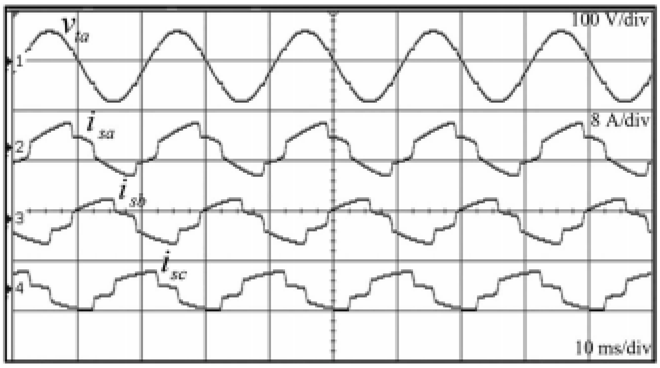

Fig 9 : Experimental results: PCC voltages (phase-a) and grid currents before compensation

III. CONCLUSION

A DVSI scheme is proposed for microgrid systems with enhanced power quality. Control algorithms are developed to generate reference currents for DVSI using ISCT. The proposedscheme has the capability to exchange power from distributed generators (DGs) and also to compensate the local unbalanced and nonlinear load.

The performance of the proposed scheme has been validated through simulation and experimental studies. As compared to a single inverter with multifunctional capabilities, a DVSI has many advantages such as, increased reliability, lower cost due to the reduction in filter size, and more utilization of inverter capacity to inject real power from DGs to microgrid. Moreover, the use of three-phase, threewire topology for the main inverter reduces the dc-link voltage requirement. Thus, a DVSI scheme is a suitable interfacing option for microgrid supplying sensitive loads.

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