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Grid-Connected Single Voltage Source Inverter With Power Quality Improvement Features

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Abstract – *This work concern about two tasks related to the working and performance of space vector pulse width modulation; understanding the principle of space vector modulation and investigating the harmonic performance of the two-level voltage source inverter. Space Vector Pulse Width Modulation (SVPWM) is basically a modulation technique based on modulation of input dc signal (constant value) into output pulses of different width and different, usually 5 or 7, amplitude levels thus generating an AC signal which could be smooth out by proper filtering or selecting a proper inductive load. Space vector modulation scheme is superior to Pulse Width Modulation (PWM) scheme because there are two main problems in PWM, harmonic distortion and switching speed, and both of these problems are overcome by implementation of the Space-Vector PWM (SVPWM) technique. Two level inverters are investigated by means of their harmonic distortion. This proposed work introduces an improved version of space vector modulation by using a modified two level voltage source inverter for eliminating the even-order harmonics.*

Keywords*: Grid-connected inverter, instantaneous symmetrical component theory (ISCT), microgrid, power quality, SVPWM, voltage source inverter,*

I. Introduction

The aim of this work is to improve the power quality for Distributed Generation (DG) with power storage system. Power quality is the combination of voltage quality and current quality. Power quality is the set of limits of electrical properties that allows electrical systems to function in their intended manner without significant loss of performance or life. Flexible operation of distributed generation (DG) units is a major objective in future smart power grid [1]–[4]. The majority of DG units are interfaced to grid/load via power electronics converters. Current-controlled voltage-sourced inverters (VSIs) are commonly used for grid connection [5]. Under the smart grid environment, DG units should be included in the system operational control framework, where they can be used to enhance system reliability by providing backup generation in isolated mode, and to provide ancillary services (e.g. voltage support and reactive power control) in the grid-connected mode. These operational control actions are dynamic in nature as they depend on the load/generatio profile, demand-side management control, and overall network optimization controllers (e.g., grid reconfiguration and supervisory control actions) [4]. To achieve this vision, the DG interface should offer high flexibility and robustness in meeting a wide range of control functions, such as seamless transfer between grid-connected operation and islanded mode; seamless transfer between active/reactive power (PQ) and active power/voltage (PV) modes of operation in the grid connected mode; robustness against islanding detection delays; offering minimal control-function switching during mode transition; and maintaining a hierarchical control structure.

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.

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..

II. Theory

Distributed Generation (DG) also called as site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy, generates electricity from the many small energy sources. In recent years, micro electric power systems such as photovoltaic generation systems, wind generators and micro gas turbines, etc., have increased with the deregulation and liberalization of the power market. Under such circumstances the environment surrounding the electric power industry has become ever more complicated and provides high-quality power in a stable manner which becomes an important topic. Here DG is assumed to include Wind power Generation (WG) and Fuel Cells (FC), etc.

Wind energy is the world‘s fastest-growing energy technology. It is a clean energy source that is reliable, efficient and reduces the cost of energy for homeowners, farmers and businesses. Wind turbines can be used to produce electricity for a single home or building, or they can be connected to an electricity grid for more widespread electricity distribution. They can even be combined with other renewable energy technologies. For utility-scale sources of wind energy, a large number of turbines are usually built close together to form a wind farm. Several electricity providers today use wind farms to supply power to their customers.

Fuel cell systems have high energy efficiency. The efficiency of low temperature proton exchange membrane (PEM) fuel cells is around 35-45%. High temperature solid oxide fuel cells (SOFC) can have efficiency as high as 65%. The overall efficiency of an SOFC based combined-cycle system can even reach 70%. Renewable energy and fuel cell systems are environmentally friendly. From these systems, there is zero or low emission (of pollutant gases) that causes acid rain, urban smog and other health problems; and, therefore, there is no environmental cleanup or waste disposal cost associated with them.

III. Method

Space vector modulation (SVM) is one of the ideal real-time modulation technique and is generally used for digital control of voltage source inverters. The working position of the switches in the two-level inverter in Fig.1 is able to be representing by switching state. As signify in Table 1, switch situation ‘P’ point out to facilitate the upper switch in an inverter leg is on and the inverter terminal voltage (VAN, VBN, or VCN) is positive (+Vd) while ‘O’ indicates that the inverter terminal voltage is zero due to the conduction of the lower switch.

There are 8 feasible combinations of switch states in the 2-level inverter as listed in Table2. The switching state [POO], for example, corresponds to the conduction of S1, S6, and S2 in the inverter legs A, B, and C, respectively. Among the eight switching states, [PPP] and [OOO] are zero states and the others are active states.

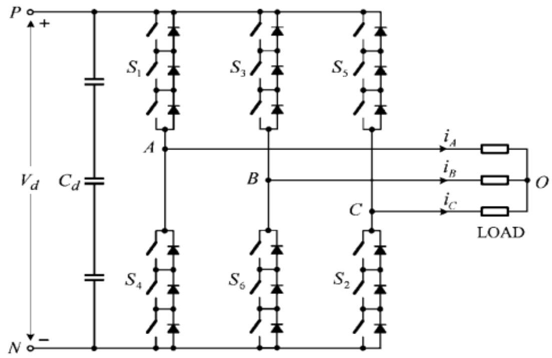

Fig.1 Simplified two-level inverter for high-power applications

Table 1 Definition of Switching States

Switching State	Leg A			Leg B			Leg C		
	S_1	S_4	v_{AN}	S_3	S_6	v_{BN}	S_5	S_2	v_{CN}
P	On	Off	V_d	On	Off	V_d	On	Off	V_d
O	Off	On	0	Off	On	0	Off	On	0

Table 2 Space Vectors, Switching States, and On-State Switches

Space Vector		Switching State (Three Phases)	On-State Switch	Vector Definition
Zero Vector	$\vec{V}_0$	[PPP] [OOO]	S_1, S_3, S_5 S_4, S_6, S_2	$\vec{V}_0 = 0$
Active Vector	$\vec{V}_1$	[POO]	S_1, S_6, S_2	$\vec{V}_1 = \frac{2}{3} V_d e^{j0}$
	$\vec{V}_2$	[PPO]	S_1, S_3, S_2	$\vec{V}_2 = \frac{2}{3} V_d e^{j\frac{\pi}{3}}$
	$\vec{V}_3$	[OPO]	S_4, S_3, S_2	$\vec{V}_3 = \frac{2}{3} V_d e^{j\frac{2\pi}{3}}$
	$\vec{V}_4$	[OPP]	S_4, S_3, S_5	$\vec{V}_4 = \frac{2}{3} V_d e^{j\frac{3\pi}{3}}$
	$\vec{V}_5$	[OOP]	S_4, S_6, S_5	$\vec{V}_5 = \frac{2}{3} V_d e^{j\frac{4\pi}{3}}$
	$\vec{V}_6$	[POP]	S_1, S_6, S_5	$\vec{V}_6 = \frac{2}{3} V_d e^{j\frac{5\pi}{3}}$

III.1. Theoretical Analysis

The active and zero switch states can be signify by active and zero space vectors, in that order. A representative space vector diagram for the two-level inverter is shown in Fig. 2, where the six active vectors V 1 to V 6 form a regular hexagon with six equal sectors (I

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to VI). The zero vectors V 0 lie on the center of the hexagon.

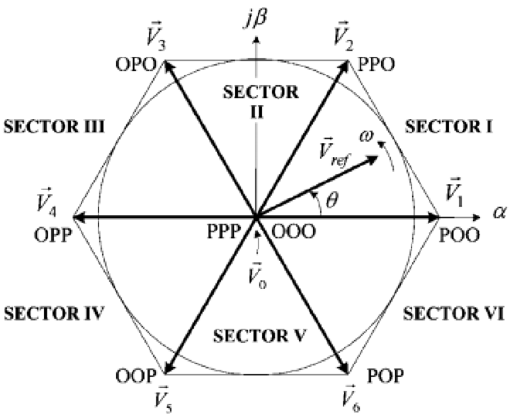

Fig.2 Space vector diagram for the two-level inverter

IV. Result

A simulation program for the conventional SVM scheme using the seven-segment switching sequence is given in Table 2. Then run simulation program for the tasks given in the Table 3. For each of the above tasks, draw waveforms (two cycles each) for the inverter line-to-line voltage vAB (V) and inverter output current iA (A).

Table 3: Simulation tasks for the conventional SVM scheme

Simulation Task	F1 (Hz)	m_a	THD (%) v_{AB}	THD (%) i_{AB}
T.1	30	0.4	149.39	20.30
T.2	30	0.8	76.73	15.43
T.3	60	0.4	148.16	23.01
T.4	60	0.8	77.37	19.89

T.2 (f1 = 30 Hz, ma = 0.8)

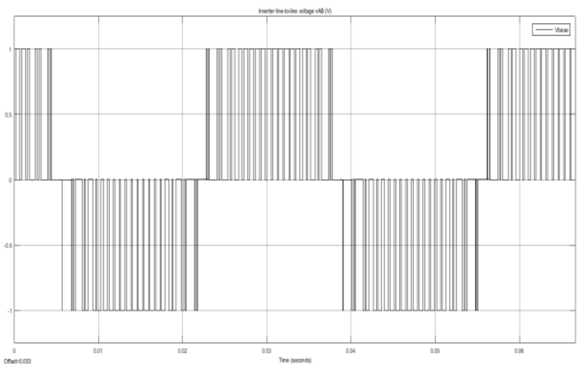

Fig.3 Inverter line-to-line voltage vAB (V)

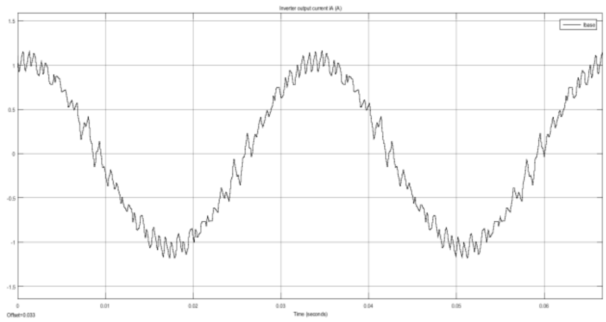

Fig.4 Inverter output current iA (A)

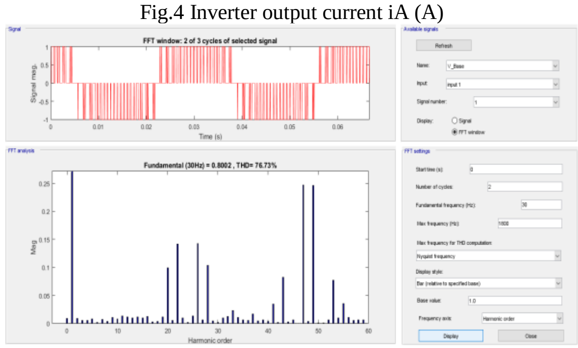

Fig.5 Harmonic distortion of v_{AB} normalized to the dc voltage V_d

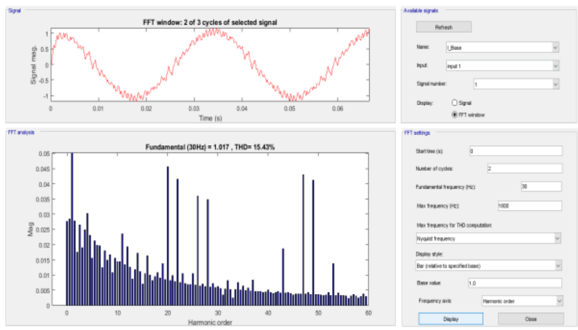

Fig.6 Harmonic distortion of i_A normalized to its rated fundamental component $I_{A1,RTD}$

V. Conclusion

A SVSI scheme is proposed for microgrid systems with enhanced power quality. Control algorithms are designed to produce reference currents for SVSI using ISCT. The projected methodology has the power to exchange power from distributed generators (DGs) and additionally to compensate the local unbalanced and nonlinear load. The performance of the projected scheme has been valid through simulation and experimental studies. Two level inverters are investigated by means of their harmonic distortion. Then we introduce an improved version of space vector modulation by using a modified two level voltage source inverter for eliminating the even-order harmonics. As compared to one inverter with multifunctional capabilities, a SVSI has several benefits like, increased reliableness, lower price because of the reduction in filter size, and additional utilization of inverter capability to inject real power from DGs to microgrid. Moreover, the utilization of 3-phase, three wire topology for the main inverter reduce the dc-link voltage requirement. Thus, a SVSI scheme could be a suitable interfacing choice for microgrid supply sensitive loads.

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