

Improving Power System Stability using Matlab and Space-Vector-Modulation-Based Statcom

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Abstract

This study shows how to create power flow sharing in a power system utilising programmable AC sources that feed linear and nonlinear loads. SVPWM is a control technique used in a three-phase Voltage Source Converter (VSC) that serves as a Static Synchronous Compensator (STATCOM) to provide reactive power compensation. In addition to reactive power correction, a Voltage Source Converter utilised as a Static Synchronous Compensator provides effective damping for subsynchronous resonance, which improves the stability of renewable hybrid power systems [2]. The Voltage Source Converter with space vector control method is offered for correcting reactive power flow in order to rectify power factor, eliminate harmonics, and balance both linear and non-linear loads. Among the many PWM strategies, the space vector technique is recommended because it is simple to increase digital realisation and AC bus use. The suggested control technique is based on an approximation of the Voltage Source Converter's third-order nonlinear model, which compensates for uncertainty in three phase system parameters. The use of a Space Vector Pulse Width Modulation controller is recommended as a control approach for dependable power sharing between AC power sources in the grid and loads.

Keywords: - Voltage Source Converter (VSC), Space Vector Pulse Width Modulation (SVPWM), Static Compensator (STATCOM), AC power sources

INTRODUCTION

Power Electronics Circuit progress has led to the enhancement of Converter circuits, which find use in managing power sharing and achieving power stability difficulties. This work investigates a direct active and reactive power control strategy combined with a sliding mode approach. A vector control accomplishment is presented in which extra PI controllers are given to correct for undesirable negative sequence components from an imbalanced load [3]. The controller is built on a double synchronous reference frame. The authors developed a flatness-based technique [4], in which the power of VSC is a flat output and a Lyapunov function is employed to create the controller. For space vector modulation, an optimization-based multivariable PI controller is developed. In this study, an adaptive control of a VSC employed as a STATCOM for power factor adjustment is suggested. The Voltage Source Converter is provided in the proposed technique to operate as a STATCOM, providing efficient damping for subsynchronous reverberation and improving power flow stability in the power system. The approach employs indirect vector control in conjunction with a PI controller to generate PWM pulses for converter switches and to regulate the output voltage. An adaptive control

employs the Model Reference Adaptive Control Algorithm to control the output voltage, with a reference voltage serving as a basis and the control performed in accordance with the reference voltage [1]. The controller design with the Lyapunov function is presented to improve system stability. The PI controller is employed, which does not increase the speed of response and makes it impossible to forecast what will happen with the mistake; the controller's reaction time increases as the output voltage level increases, making accurate control over the PWM approach impossible [8]. A tiny amplitude of a high frequency harmonic exists due to an imbalanced load. To address the aforementioned shortcomings, the suggested solution employs the Space Vector Modulation switching mechanism. In the β frame, the SVPWM switching mechanism is used. There are several PWM approaches accessible, such as PWM, 48 pulse inverter, and SVPWM, among which SVPWM switching technique is recommended since it is simple to increase stability, as shown in Fig.1. In this paper, a coordination control technique for all converters is suggested to smooth power transfer between source and load links when the grid is converted from one operating state to another under varied load and resource situations, and it is validated using Matlab/Simulink.

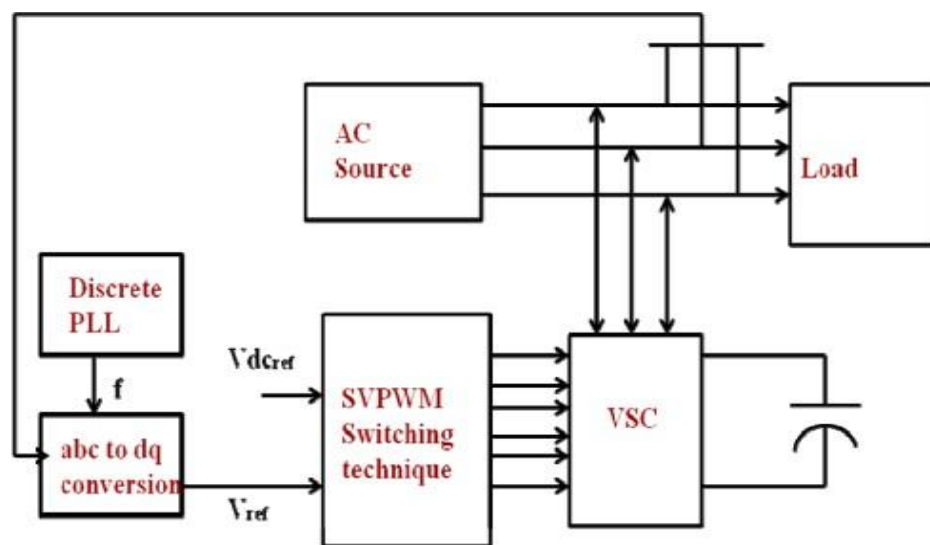


Fig. 1. Block Diagram of Proposed Model

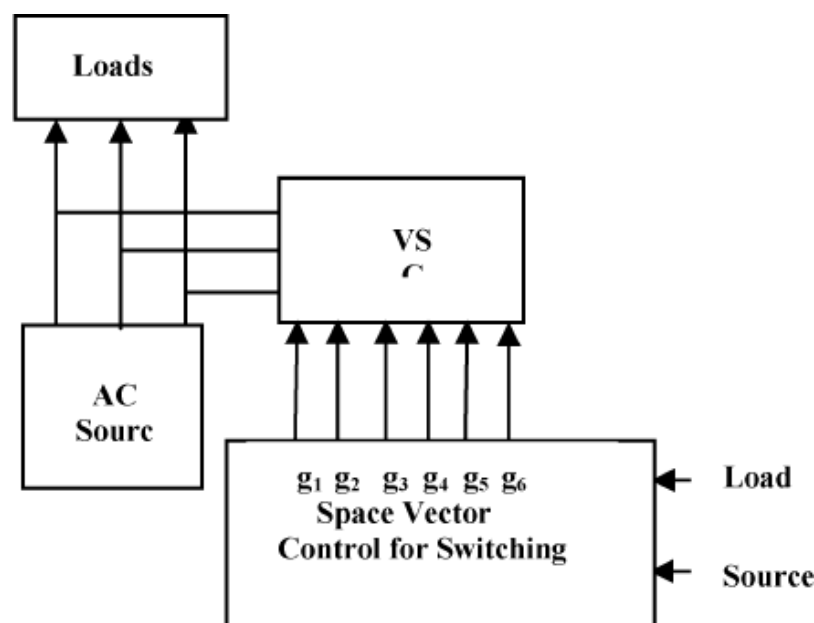


Fig.2. Control Circuit of Voltage Source Converter

CONVERTER DESIGN

Static Synchronous Compensator: A voltage source converter connects the converter to the power grid. The modelling of converters is necessary for developing control or assessing converter behaviour.

The VSC is designed to deliver power to the system and is disconnected over three phases of alternating current power supply. Capacitor equalisation occurs when the voltage source converter is linked across the supply theca. The voltage at the

converter's output supplies the capacitive reactive component, which cancels the inductive reactive component of the supply, resulting in an increased power factor, as seen in Fig. 2.

Voltage Source Converter Structure:

The three phase voltage source converter is built using six MOSFETs, each with an anti-parallel diode to provide a current route when the MOSFET switch is turned off, as shown in Fig. 3. Three-stage VSC has three legs with two switches in each leg that function in tandem. If both switches on the same leg direct, a dead

short out occurs in the DC join, and hence forward time is integrated in the switches on the same leg. Between the AC source and the information channel, the VSC has a point of basic coupling (PCC). The three-phase supply and load must be balanced using PCC. An inductive load can be linked to PCC. The voltages at the point of common coupling are represented as V_a , V_b , V_c , and the current flowing through it is i_a , i_b , i_c , whereas the voltages at the VSC terminal are e_a , e_b , e_c . The SVPWM method is used to create gate pulses to the voltage source converter switches.

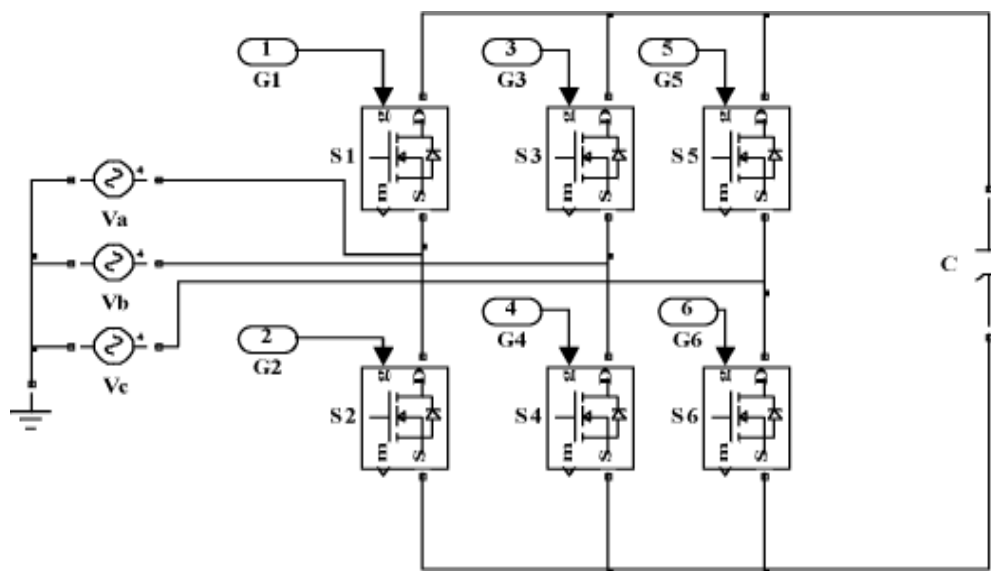


Fig.3. Simulation Model of Voltage Source Converter

Voltage Source Converter Modeling

Three phase input to the voltage source Converter is given as

$$V_a = V_m \sin(\omega t)$$

$$V_b = V_m \sin(\omega t - 2\pi/3)$$

$$V_c = V_m \sin(\omega t + 2\pi/3)$$

At the point when the driver circuit is designed with sinusoidal PWM method or with a SVPWM switching technique a modulation index factor is added with the each period of input voltage. Therefore the modulating signal is given as

$$V_{ma} = A_m \sin(\omega t + \delta)$$

$$V_{mb} = A_m \sin(\omega t - 2\pi/3 + \delta)$$

$$V_{mc} = A_m \sin(\omega t + 2\pi/3 + \delta)$$

The voltage source converter output voltage and their relation based on the modulation index and modulating angle is derived and analyzed as follows. Under Balanced Condition the VSC terminal voltages are given as

$$e_a + e_b + e_c = 0.$$

Substituting the value of V_{ma} , V_{mb} , V_{mc} from above equations

We get,

$$e_a = (1/2) V_{dc} * m_a \sin(\omega t + \delta)$$

$$e_b = (1/2) V_{dc} * m_b \sin(\omega t - 2\pi/3 + \delta)$$

$$e_c = (1/2) V_{dc} * m_c \sin(\omega t + 2\pi/3 + \delta)$$

Table 1. Voltage vector corresponding to switching conditions using SVPWM

Voltage Vector	a	b	c	V_α	V_β	Vector
V0	0	0	0	0	0	0
V1	1	0	0	$2V_{dc}/3$	0	V_{0°
V2	1	1	0	$V_{dc}/3$	$V_{dc}/\sqrt{3}$	V_{60°
V3	0	1	0	$-V_{dc}/3$	$V_{dc}/\sqrt{3}$	V_{120°
V4	0	1	1	$2V_{dc}/3$	0	V_{180°
V5	0	0	1	$-V_{dc}/3$	$-V_{dc}/\sqrt{3}$	V_{240°
V6	1	0	1	$V_{dc}/3$	$V_{dc}/\sqrt{3}$	V_{300°
V7	1	1	1	0	0	V_{0°

CONTROL TECHNIQUE DESIGN

Introduction: Switching Manage Method in Voltage Source Converter is used to control the output voltage of the converter circuit and also to increase overall system stability. Sinusoidal PWM, Third Harmonics injection PWM, and Space Vector PWM are three distinct PWM Switching Control approaches. The major goal of the pulse width modulation approach in the converter circuit is to control the output voltage as well as to detect and regulate the low frequency module of the converter output voltage through high frequency switching. Space vector modulation is a direct vector control approach that uses reference frame transformation theory as an indirect control technique. The immobile frame ABC reference quantity is changed to two axis orthogonal quantity β , which is a

rotating reference frame quantity, according to reference frame transformation theory. Despite comparing the modulating and carrier waves, the duty cycle was miscalculated in this sort of modulation.

Space Vector Pulse Width Modulation Technique:

The topology of a three stage VSC is seen in Fig.4. Due to the requirement that the data lines never be shorted and the yield current remain consistently constant, a VSC can accept only eight distinct topologies. Six of these eight topologies produce nonzero yield voltage and are referred to as nonzero exchanging states, whereas the remaining two topologies produce zero yield voltage and are referred to as zero exchanging states.

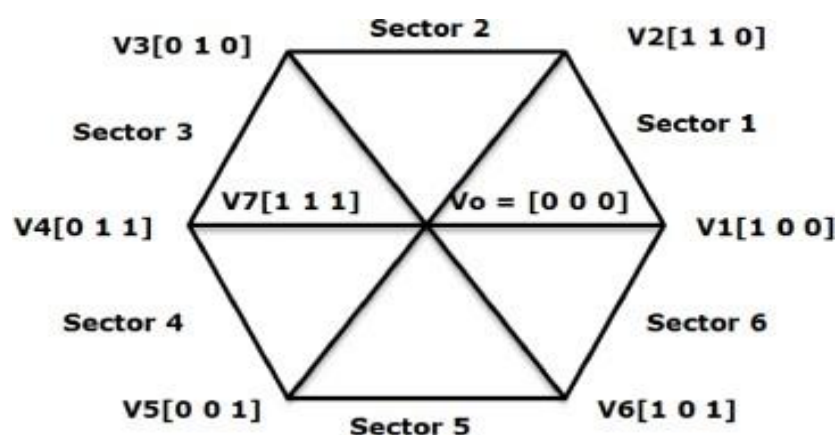


Fig.4. Principle of Space Vector used in VSC

The Gate Pulse to Voltage Source Converter is designed using Space Vector PWM technique where the fundamental Component of Output voltage can be increased up to 27.39% in which the modulation index could be reached up to Unity. SVPWM technique is accomplished by the rotating reference vector around the state diagram consisting of six basic non-zero vector forming an Hexagon. The angle made by d-q quantity

is compared with the reference angle which lies between 0° to 360° . This concept is implemented to find the angle of reference voltage vector which frames the different sector of the reference voltage. With this the reference voltage is made to work in different sectors with different angle which covers throughout the entire 360° of operation. This frames the Continuous Mode of Operation (CCM).

SIMULATION TEST RESULTS

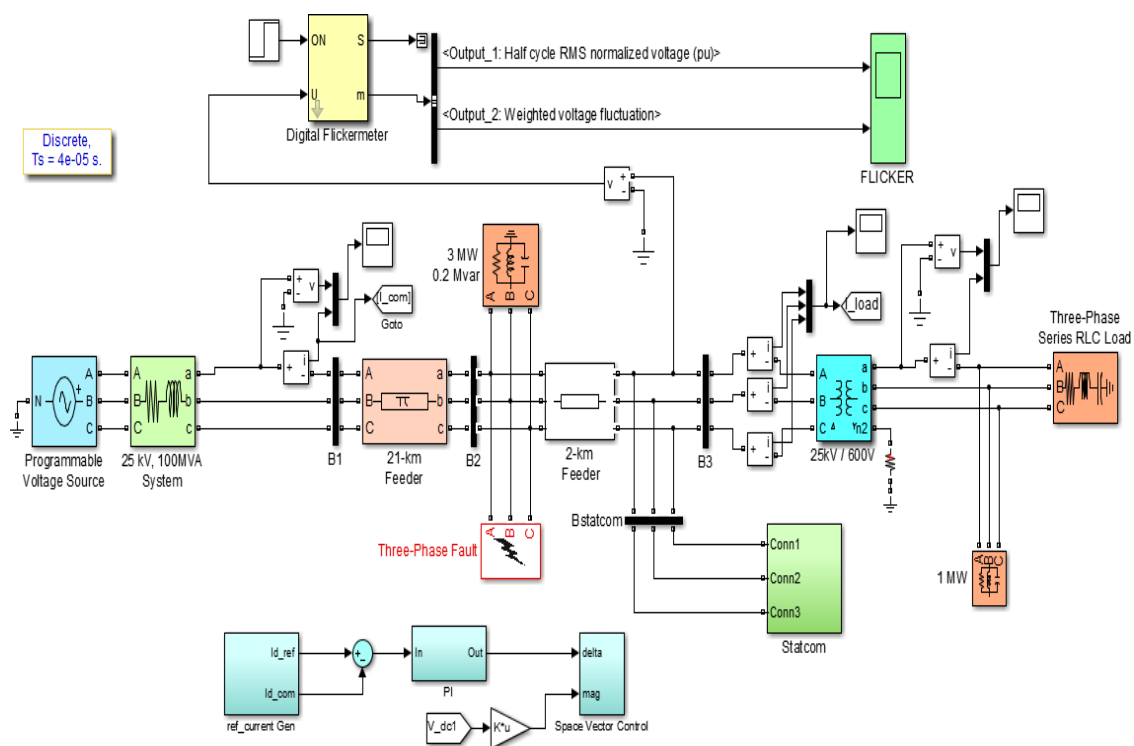


Fig.5. Simulation Model for SVPWM Controller

The three phase abs quantity is converted to two phase $\alpha\beta$ Voltages which is represented in "equations"

$$V_{\alpha} = (2/3)V_a - (1/3)V_b - (1/3)V_c$$

$$V_{\beta} = (1/\sqrt{3}) V_b - (1/\sqrt{3}) V_c$$

The Sector Phase angle which is represented in "below equation"

$$\theta = \tan^{-1}(V_{\beta} / V_{\alpha})$$

$$\theta \in [0.2\pi]$$

The timing of reference voltage vector is calculated and its active and zero vectors are calculated by using below equations.

The Value of T_a & T_b is fixed for each TPWM Period.

$$\begin{bmatrix} T_a \\ T_b \end{bmatrix} = \frac{MI\sqrt{3}Ts}{\pi} \begin{bmatrix} \sin \frac{K\pi}{3} & -\cos \frac{K\pi}{3} \\ -\sin \frac{(K-1)\pi}{3} & \cos \frac{(K-1)\pi}{3} \end{bmatrix} \begin{bmatrix} \cos n\omega Ts \\ \sin n\omega Ts \end{bmatrix}$$

The following assumptions have been considered in simulation:

- Unity power factor and power sharing at point of common coupling bus
- Real and reactive powers transfer is supported by batteries and super capacitor to load.

The Case Study

Case 1: For normal load without vulnerable condition, the variation of voltage analyzed for STATCOM using Space Vector Method PWM.

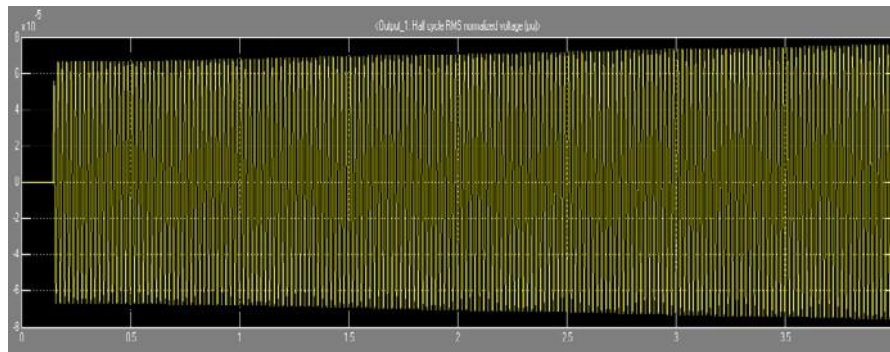


Fig.6 (a) half cycle RMS normalized voltage under normal condition (p.u.)

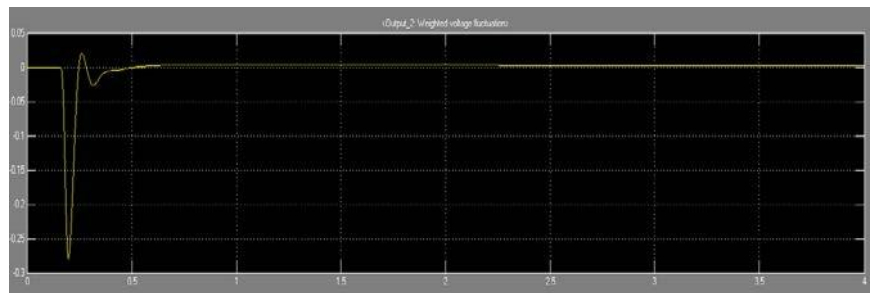


Fig.6 (b) weighted voltage fluctuation under normal condition (p.u.)

Case 2: System was subjected to vulnerable (fault) condition, the variation of above mentioned cases were analyzed.

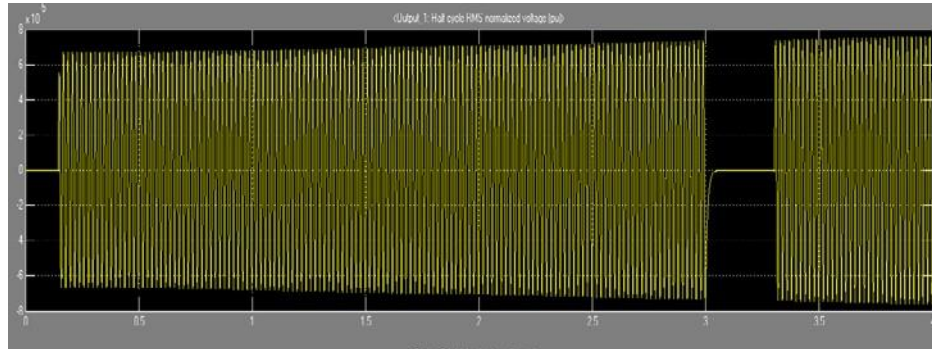


Fig.7 (a) half cycle RMS normalized voltage during fault condition (p.u.)

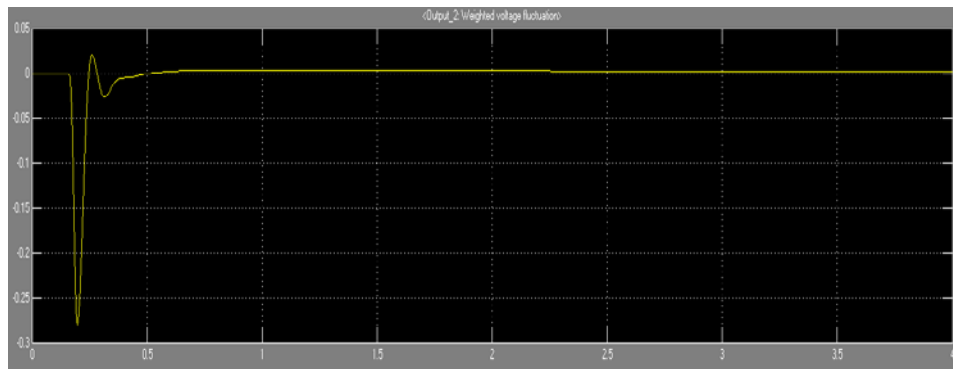


Fig.7 (b) weighted voltage fluctuation during fault condition (p.u.)

CONCLUSION

This article examined the SVPWM approach, which can only be used with a three-phase VSC. It improves overall efficiency. The SVPWM is used to govern the exchange of the VSC. MATLAB was used to show and rebuild the framework comprising the sources. The simulation results show that the framework can maintain stable operation under the suggested control strategy. The model and coordination control calculation are

presented for each converter to maintain stable framework operation under various load and AC resource circumstances. When the load condition changes, the power is transmitted smoothly.

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