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STABILITY ENHANCEMENT IN POWER SYSTEM USING SPACE VECTOR MODULATION BASED STATCOM VIA MATLAB

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ABSTRACT

This paper demonstrates how the power flow sharing can be achieved in power system using programmable AC sources that is supplying linear and nonlinear loads. Space Vector Pulse Width Modulation (SVPWM) is used as a control algorithm in a three-phase Voltage Source Converter (VSC) which acts as a Static Synchronous Compensator (STATCOM) for providing reactive power compensation. Voltage Source Converter used as a Static Synchronous Compensator provides efficient damping for sub synchronous resonance that improves the renewable hybrid power system stability in addition to reactive power correction [2]. The Voltage Source Converter with space vector control algorithm is provided for compensating the reactive power flow to correct the power factor, eliminating harmonics and balancing both linear and non-linear loads. Among different Pulse Width Modulation (PWM) techniques space vector technique is proposed as it is easy to improve digital realization and AC bus utilization. The proposed control algorithm relies on an approximate third-order nonlinear model of the Voltage Source Converter that accounts for uncertainty in three phase system parameters. The control strategy for reliable power sharing between AC power sources in grid and loads is proposed by using Space Vector Pulse Width Modulation controller.

KEYWORDS: Static Compensator (STATCOM), Voltage Source Converter (VSC), Space Vector Pulse Width Modulation (SVPWM).

INTRODUCTION

The advancement in Power Electronics Circuits has led to the improvement of Converter circuits which finds application in controlling the power sharing and to achieve the power stability issues. In this paper a direct active and reactive power control technique added with a sliding mode approach is investigated. An achievement of vector control is proposed where additional PI controllers is provided to compensate undesired negative sequence components from an unbalanced load [3]. The controller is designed based on a double synchronous reference frame. The authors were proposed a flatness-based method where power of VSC is a flat output and a Lyapunov function is used to derive the controller [4]. An optimization-based multivariable PI controller is proposed for space vector modulation. This paper is proposed an adaptive control of a VSC used as a STATCOM for power factor compensation only. In the proposed method, the Voltage Source Converter is provided to act as a STATCOM which provides efficient damping for sub synchronous reverberation that improve the power flow stability in power system. The method incorporates indirect vector control with PI controller to produce PWM pulses for converter switches and to control the output voltage. An Adaptive control uses Model Reference Adaptive Control Algorithm to control the output voltage where a reference voltage is kept as a base and the control is done based on the reference voltage [1]. To make the stability of the system the controller design is proposed with Lyapunov function. PI controller is used which will not increase the speed of response and it is not possible to predict what will happen with the error, reaction time of the controller is more as the output voltage level improves it is not possible to have an accurate control over the PWM technique [8]. Due to imbalance load small amplitude of high frequency harmonic exists.

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To eliminate the above drawbacks Space Vector Modulation switching technique is implemented in the proposed method. The SVPWM switching technique is processed in αß frame. There are different types of PWM techniques available like PWM, 48 pulse inverter, and SVPWM among which SVPWM switching technique is suggested as it simple to improve stability as shown in Fig.1. In this Paper coordination control algorithm is proposed for all converters to smooth power transfer between source and load links when the grid is switched from one operating condition to another under various load and resource conditions which is verified by Matlab/Simulink.

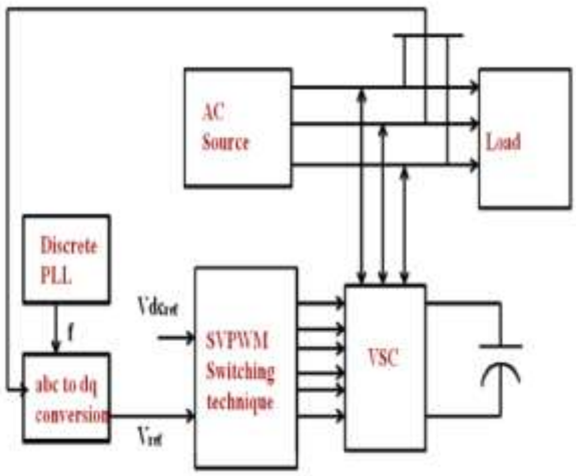

Fig. l. Block Diagram of Proposed Model

CONVERTER DESIGN

Static Synchronous Compensator: The converter is interfaced with power system through voltage source converter. The modeling of converter is important for deriving its control or analyzing the behavior of the converters. The VSC is made to provide for power system and is connected across three phase AC power supply. When the voltage source converter is connected across the supply the DC Capacitor equalization Voltage at the output of the converter supplies the capacitive reactive component which cancels the inductive reactive component of the supply so that the power factor is improved which is proved by using Fig. 2.

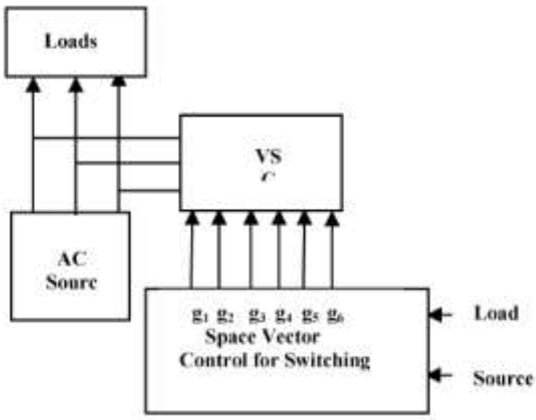

Fig.2. Control Circuit of Voltage Source Converter

Voltage Source Converter Structure: The three phase voltage source converter is designed with Six MOSFET's, each having an anti-parallel diode to provide the path for the current when the MOSFET switch is in OFF condition as shown in Fig. 3. Three stages VSC have three leg with two switch in every leg working in integral manner. In the event that both the switch on the same leg directs then a dead short out happens in the DC join and along these lines a dead time is incorporated in the switches of the same leg. The VSC has Point of basic coupling (PCC) between the AC source and the information channel. PCC is required to balance the three phase source and load. To PCC an inductive load can be connected. The point of common coupling voltages are represented as Va, Vb,

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Ve and the current flowing through it is ia, ib, ie and the VSC terminal voltages are ea, eb, ee. The gate pulses to the voltage source converter switches are generated by using SVPWM technique.

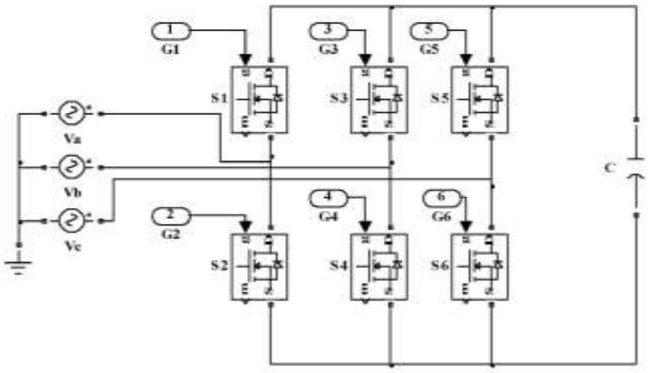

Fig.3. Simulation Model of Voltage Source Converter

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

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

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

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

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	2Vdc/3	0	$V_{0°}$
V2	1	1	0	Vdc/3	Vdc/√3	$V_{60°}$
V3	0	1	0	-Vdc/3	Vdc/√3	$V_{120°}$
V4	0	1	1	2Vdc/3	0	$V_{180°}$
V5	0	0	1	-Vdc/3	-Vdc/√3	$V_{240°}$
V6	1	0	1	Vdc/3	Vdc/√3	$V_{300°}$
V7	1	1	1	0	0	$V_{0°}$

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 ea + eb+ ec= 0.

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

$e_a = (1/2)\,Vdc * m_a \sin(\omega t + \delta)$

$e_b = (1/2)\,Vdc * m_b \sin(\omega t - 2\pi/3 + \delta)$

$e_c = (1/2)\,Vdc * m_c \sin(\omega t + 2\pi/3 + \delta)$

CONTROL TECHNIQUE DESIGN

A. Introduction: Switching Control method in Voltage Source Converter is used to control the output voltage of the converter circuit and also this is used to improve the stability of the overall system. There are three dissimilar PWM Switching Control techniques that involve Sinusoidal PWM, Third Harmonics injection PWM and Space

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Vector PWM. The main objective of pulse width modulation technique in the converter circuit is to control the output voltage and to identify and control the low frequency module of Converter output voltage via high frequency switching. The Space vector modulation is a direct vector Control method in which the control technique is directly adopted by Reference frame transformation theory. Reference frame transformation theory means the motionless frame ABC reference quantity is converted to two axes orthogonal quantity αß which is a rotating reference frame quantity. In this type of modulation the duty cycle is computed in spite of comparing the modulating and carrier wave.

Space Vector Pulse Width Modulation Technique: The topology of a three stage VSC is shown in Fig.4 because of imperative that the data lines should never be shorted and the yield current must dependably be constant a VSC can accept just eight unmistakable topologies. Six out of these eight topologies create a nonzero yield voltage and are known as nonzero exchanging states and the staying two topologies deliver zero yield voltage and are known as zero exchanging states.

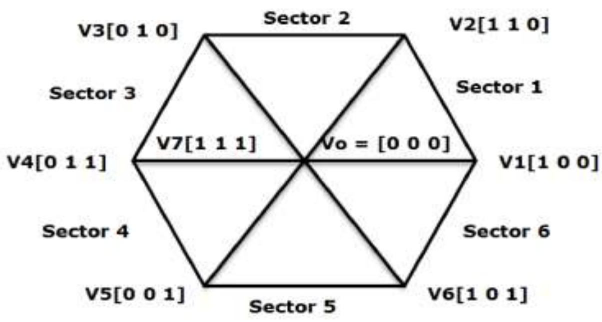

Fig.4. Principle of Space Vector used in VSC

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

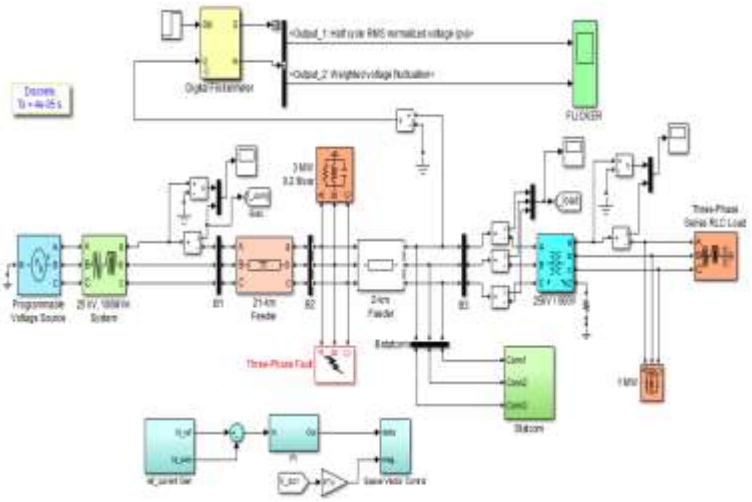

Fig.5. Simulation Model for SVPWM Controller

The three phase abc quantity is converted to two phase αß Voltages which is represented in "equations"

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$V\alpha = (2/3)Va - (1/3)Vb - (1/3)Vc$
$V\beta = (1/\sqrt{3})\ Vb - (1/\sqrt{3})\ Vc$

The Sector Phase angle which is represented in "below equation"
$\theta = \tan^{-1}(V\beta / V\alpha)$
$\theta\ \varepsilon\ [0.2\Pi]$

The timing of reference voltage vector is calculated and its active and zero vectors are calculated by using below equations.
The Value of Ta & Tb is fixed for each T_{PWM} Period.

$$\begin{bmatrix} Ta \\ Tb \end{bmatrix} = \frac{MI\sqrt{3}Ts}{\pi} \begin{bmatrix} Sin\frac{K\pi}{3} & -Cos\frac{K\pi}{3} \\ -Sin\frac{(K-1)\pi}{3} & Cos\frac{(K-1)\pi}{3} \end{bmatrix} \begin{bmatrix} Cosn\omega Ts \\ Sinn\omega Ts \end{bmatrix}$$

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

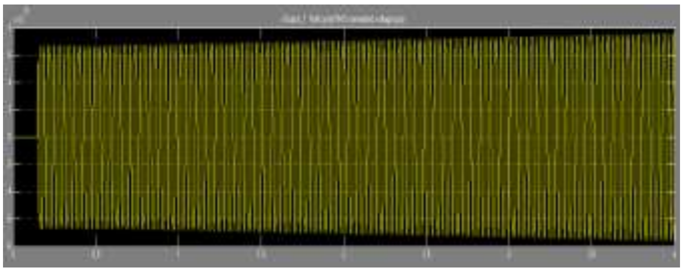

Fig.6 (a) half cycle RMS normalized voltage under normal condition (p.u.)

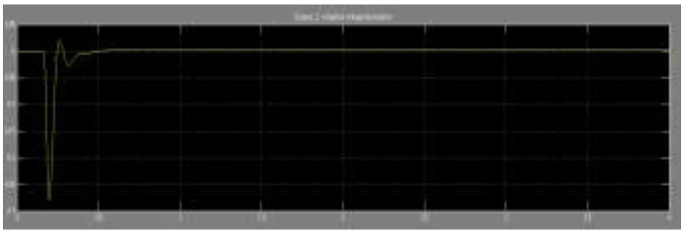

Fig.6 (b) weighted voltage fluctuation under normal condition (p.u.)

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

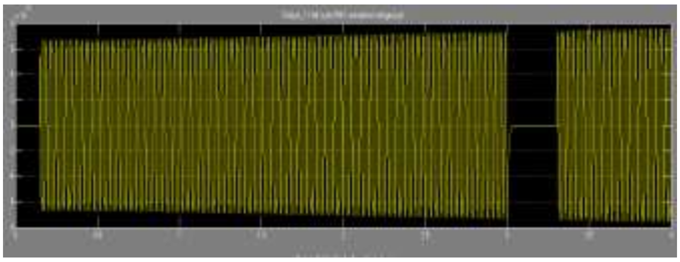

Fig.7 (a) half cycle RMS normalized voltage during fault condition (p.u.)

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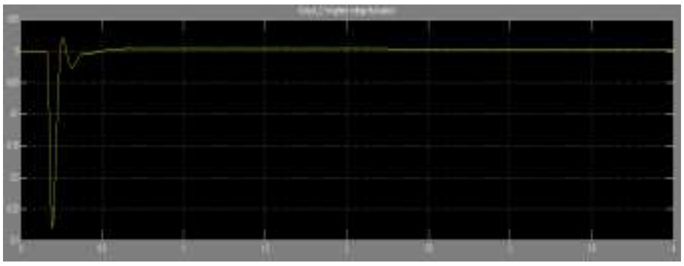

Fig.7 (b) weighted voltage fluctuation during fault condition (p.u.)

CONCLUSION

This paper has evaluated SVPWM technique which can only be applied to a three phase VSC. It increases the overall efficiency. The SVPWM is utilized for controlling the exchanging of the VSC. The framework containing the sources has been demonstrated and recreated utilizing MATLAB. The simulation results demonstrate that the framework can keep up stable operation under the proposed control plan. The model and coordination control calculation is proposed for every one of the converters to keep up stable framework operation under different burden and AC resources conditions. The power is transferred smoothly, when load condition changes.

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