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Compare Stability Management in Power System Using 48- Pulse Inverter, D-STATCOM and Space Vector Modulation Based STATCOM

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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.

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.

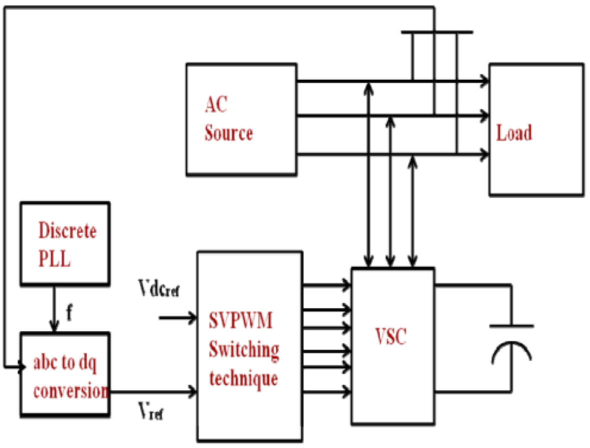

Fig. I. Block Diagram of Proposed Model

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.

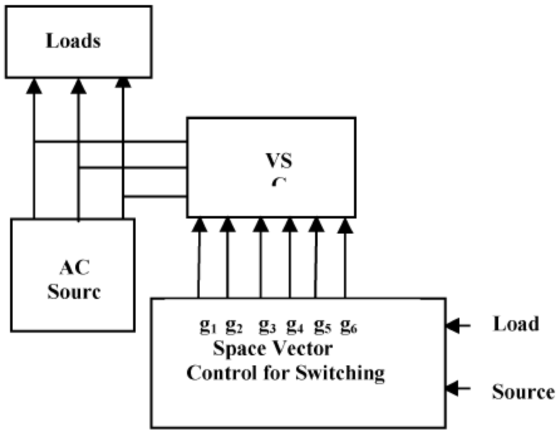

Fig.2. Control Circuit of Voltage Source Converter

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. 2.1. 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, 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.

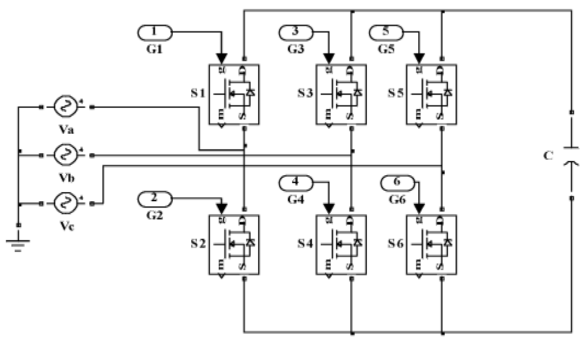

Fig.2.1 Simulation Model of Voltage Source Converter

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

$e_a + e_b + e_c = 0.$

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

We get,

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

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

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

CONTROL TECHNIQUE DESIGN

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 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.

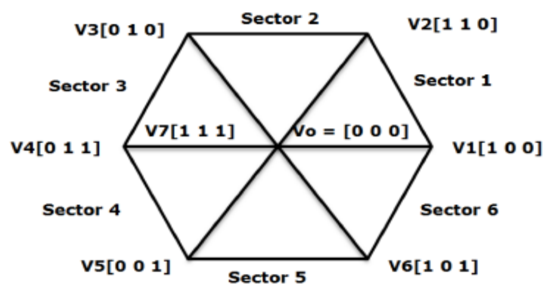

Fig.3. Principle of Space Vector used in VSC

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).

Results and Discussion

Results with 48 pulses VSC based STATCOM, D-STATCOM and SVPWM based STATCOM devices were taken for following cases:

- Case I: For normal operating condition the fluctuation in bus voltage at the initial time and the duration has been studied and compared.
- Case II: The performance of all the systems has been studied under fault condition and the amplitude and duration of the fluctuation has been compared.

Result obtained without fault while using 48-Pulse VSC based STATCOM

We studied the performance of 48-pulse STATCOM with a power system connected without fault condition in MATLAB the output waveform of the proposed method are as follow;

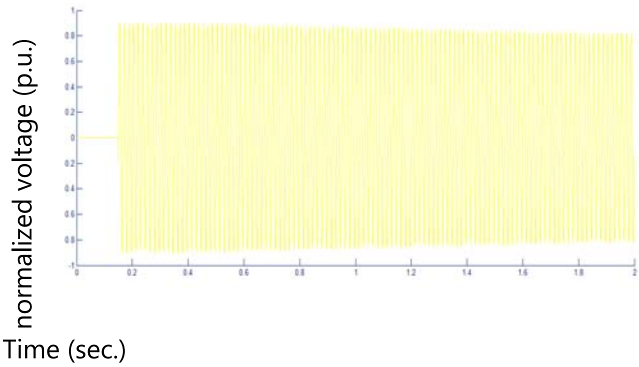

Fig. 4.1 Half cycle normalized voltage without fault (48-Pulse VSC based STATCOM)

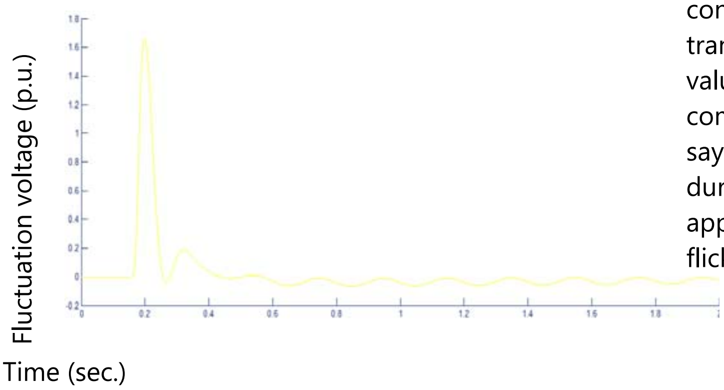

Fig. 4.2 Fluctuation voltage without fault (48-Pulse based STATCOM)

Figure 4.1 shows the transient voltage fluctuation of the 48 pulse VSC based STATCOM system connected with normal load under balance condition. As we see from the figure the value about 0.85 to 0.9 p.u. i.e. voltage sag up to 10-15% of supply voltage and the duration of fluctuation is approximately 0.2 seconds. Also the instantaneous flicker sensation wave is not smooth.

As shown in figure 4.2 under transient period fluctuation under normal condition the voltage fluctuation duration transient settling up to 0.2 to 0.4 seconds and at fault voltage fluctuation be increased. Instantaneous flicker sensation wave is increased to a very high value at the transient period (13).

Result obtained without fault while using D – STATCOM

We studied the performance of Distributed STATCOM with a power system connected without fault condition in MATLAB the output waveform of the proposed method are as follow;

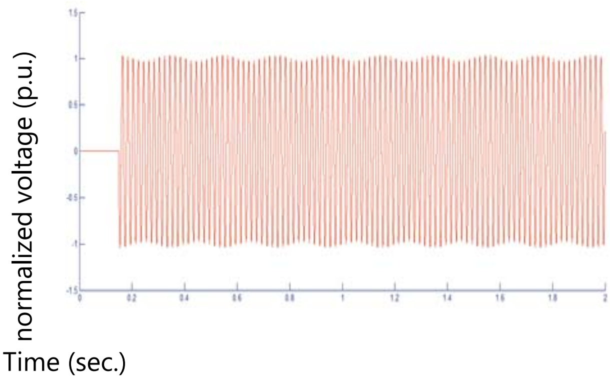

Fig. 4.3 Half cycle normalized voltage without fault (D-STATCOM)

Figure 4.3 shows the transient voltage fluctuation of the Distributed STATCOM (D- STATCOM) system connected with normal load under balance condition. As we see from the figure the value of transient voltage fluctuation varies up to 0.05 p.u. value which is the very negligible deviation as compare to 48-pulse VSC based STATCOM, finally says that it achieve its 95% supply voltage and the duration of fluctuation settling time is approximately 0.2 seconds. Also the instantaneous flicker sensation wave is smooth.

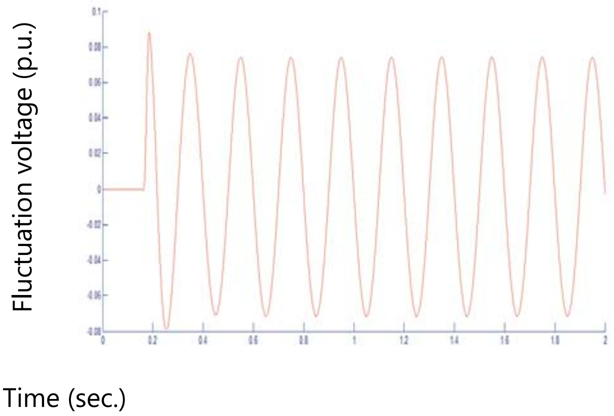

Fig. 4.4 Fluctuation voltage without fault (D-STATCOM)

As shown in figure 4.4 under transient period fluctuation under normal condition the voltage fluctuation duration settling up to 0.08 p.u. which is negligible and at fault voltage fluctuation is increased. Instantaneous flicker sensation wave is negligible deviation to a normal value at during transient period (10).

Result obtained without fault while using SVPWM- STATCOM

We studied the performance of Space vector pulse width modulation STATCOM with a power system connected without fault condition in MATLAB the output waveform of the proposed method are as follow;

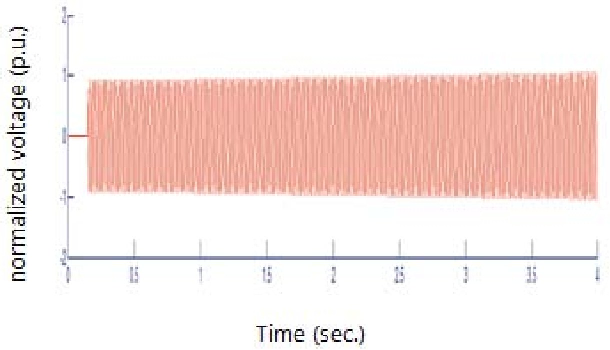

Fig. 4.5 Half cycle normalized voltage without fault (SVPWM STATCOM)

Figure 4.5 shows the transient voltage fluctuation of the SVPWM STATCOM (Space Vector Pulse Width Modulation STATCOM) system connected with normal load under balance condition. As we see from the figure the value of transient voltage fluctuation varies up to -0.2 p.u. value which is the very negligible deviation as compare to both D-STATCOM and 48-pulse VSC based STATCOM and the duration of fluctuation settling time is approximately within 0.5 seconds. Also the instantaneous flicker sensation wave is very smooth.

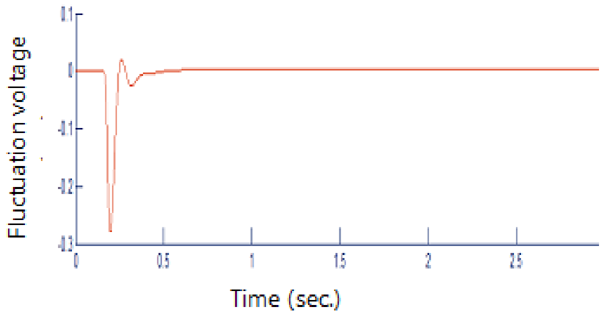

Fig. 4.6 Fluctuation voltage without fault (SVPWM STATCOM)

As shown in figure 4.6 under transient period fluctuation under normal condition the voltage fluctuation duration settling up to 0.3 to 0.5 seconds and at fault voltage fluctuation is very smooth i.e. no fluctuation. Instantaneous flicker sensation wave is negligible deviation to a normal value at during transient period.

Comparison of 48-pulse STATCOM, D-STATCOM and SVPWM-STATCOM under normal condition

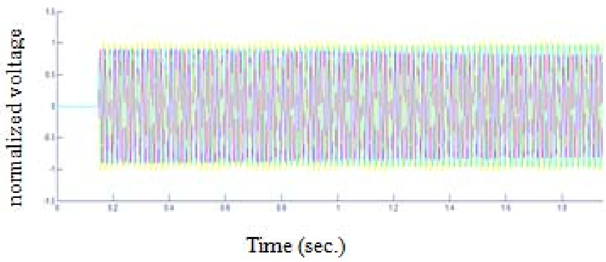

Fig. 4.7 Half cycle normalized voltage without fault (48 Pulse, D-STATCOM and SVPWM based STATCOM)

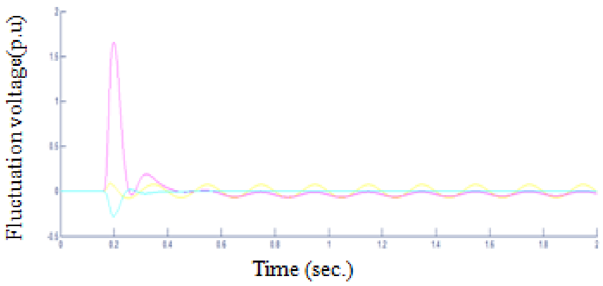

Fig. 4.8 Fluctuation voltage without fault (48 Pulse Vs D-STATCOM)

Table 4.1 Comparison of 48-pulse STATCOM, D-STATCOM and SVPWM-STATCOM under normal condition

STATCOM	Voltage Fluctuation	Settling Time	Flicker wave
48- Pulse VSC based STATCOM	1.2 p.u.	2.7 sec	High Deviation
D-STATCOM	0.01 p.u.	2.5 sec	Smooth
SVPWM STATCOM	-0.2 p.u.	0.5 sec	Very Smooth

Result obtained with fault while using 48-Pulse VSC based STATCOM

We studied the performance of 48-pulse STATCOM with a power system connected with fault condition in MATLAB the output waveforms of the proposed method are as follow;

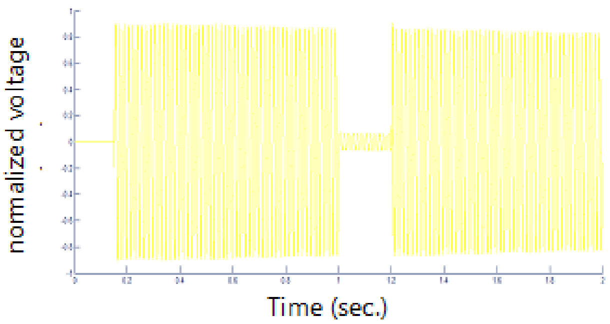

Fig. 4.9 Half cycle normalized voltage with fault (48-Pulse VSC based STATCOM)

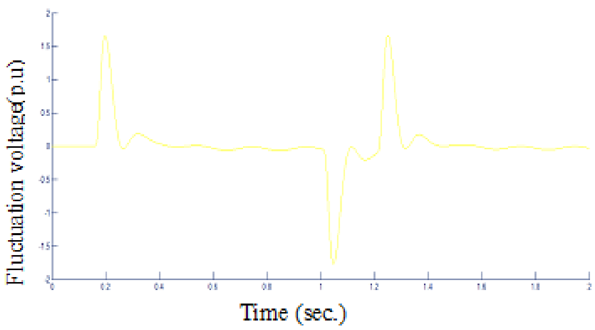

Fig. 4.10 Fluctuation voltage with fault (48-Pulse based STATCOM)

Figure 4.9 shows the voltage fluctuation of the system connected with fault or abnormal unbalance condition using 48-pulse STATCOM as the compensator. As we can see in the waveform, the value voltage fluctuation is up to 0.85 p.u. value which is very high reduction or voltage sag in power system and the instantaneous voltage fluctuation wave have spikes which is very dangerous.

Figure 4.10 shows the voltage fluctuation of the system connected under fault condition the voltage fluctuation duration is high is both cases transient and fault. And the instantaneous flicker sensation wave has been disturbed 1.5 times.

Result obtained with fault while using D – STATCOM

We studied the performance of Distributed STATCOM with a power system connected with fault condition in MATLAB the output waveform of the proposed method are as follow;

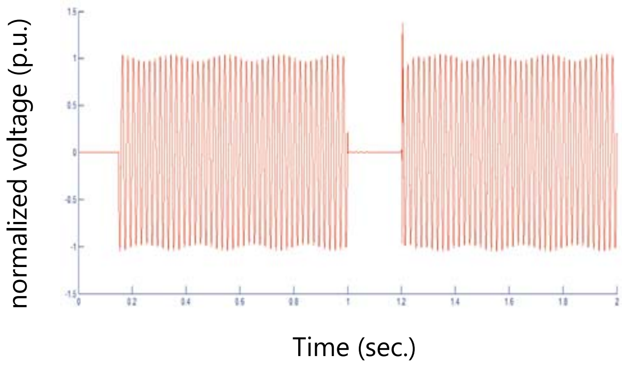

Fig. 4.11 Half cycle normalized voltage with fault (D-STATCOM)

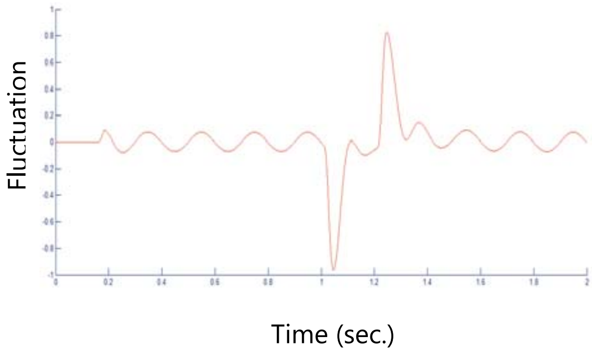

Fig. 4.12 Fluctuation voltage with fault (D-STATCOM)

Figure 4.11 shows the voltage fluctuation of the system connected with fault or abnormal unbalance condition using D-STATCOM as the compensator. As we can see in the waveform, the value voltage fluctuation is up to 0.05 p.u. reduction value which is very negligible and the instantaneous voltage fluctuation wave have negligible spikes which is smooth.

Figure 4.12 shows the voltage fluctuation of the system connected under fault condition the voltage fluctuation duration is smooth is both cases transient and fault. And the instantaneous flicker sensation wave has been disturbed with 20% increase.

Result obtained with fault while using SVPWM based STATCOM

We studied the performance of Space vector pulse width modulation STATCOM with a power system connected with fault condition in MATLAB the output waveform of the proposed method are as follow;

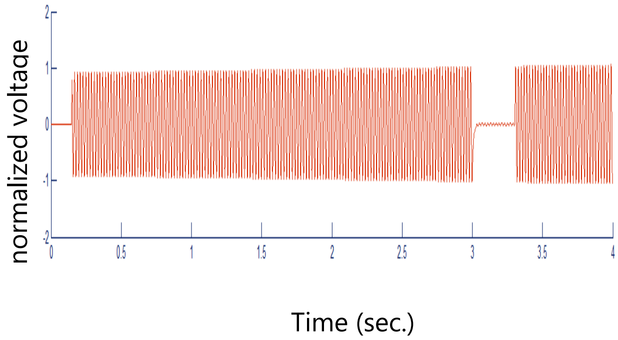

Fig. 4.13 Half cycle normalized voltage with fault (SVPWM STATCOM)

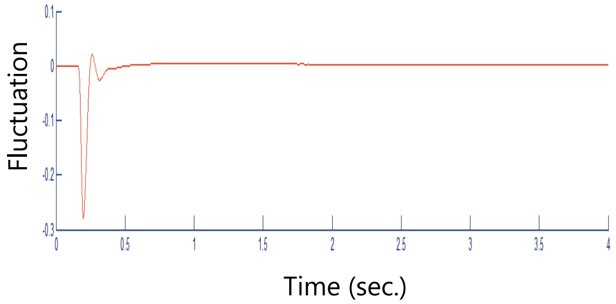

Fig. 4.14 Fluctuation voltage with fault (SVPWM STATCOM)

Figure 4.13 shows the voltage fluctuation of the system connected with fault or abnormal unbalance condition using SVPWM STATCOM as the compensator. As we can see in the waveform, the value voltage fluctuation is up to - 0.2 p.u. values which is very negligible and the instantaneous voltage fluctuation wave have negligible spikes which is very smooth.
Figure 4.14 shows the voltage fluctuation of the system connected under fault condition the voltage fluctuation duration is smooth is both cases transient and fault. And the instantaneous flicker sensation wave has been no disturbed within fault condition.

Comparison of 48-pulse STATCOM, D-STATCOM and SVPWM-STATCOM under Fault condition.

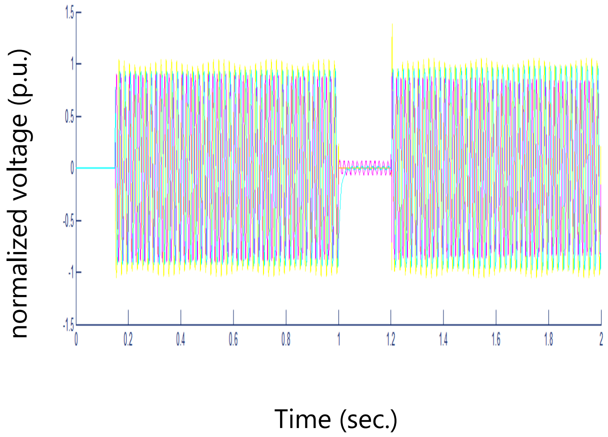

Fig. 4.15 Half cycle normalized voltage with fault (48 Pulse Vs D-STATCOM)

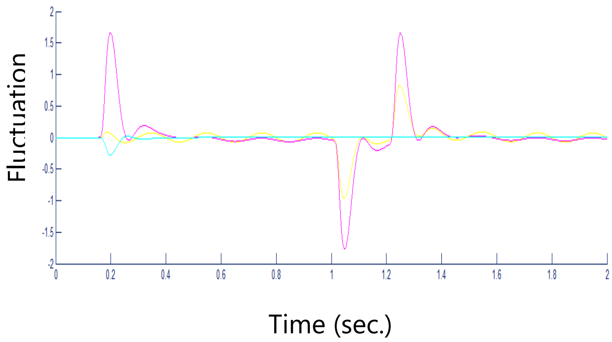

Fig. 4.16 Fluctuation voltage with fault (48 Pulse Vs D-STATCOM)

STATCOM	Voltage Fluctuation	Settling Time	Flicker wave
48- Pulse VSC based STATCOM	1.2 p.u.	2.7 sec	High Deviation
D-STATCOM	0.2 p.u.	2.5 sec	Smooth
SVPWM STATCOM	No fluctuation	-	Very Smooth

Table 4.2 Comparison of 48-pulse STATCOM, D-STATCOM and SVPWM-STATCOM under fault condition

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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