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Neutral-Point Clamped Multilevel Inverter Based Transmission Statcom for Voltage Regulation

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ABSTRACT: *This paper deals with T-STATCOM used for voltage fluctuations with the help of multilevel VSI circuit A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end user equipments. This work describes the techniques of correcting the supply voltage sag, swell and interruption in transmission system. T-STATCOM works based on the VSI principle and injects a current into the system to correct the voltage sag, swell and interruption.*

Keywords **-** *Voltage source inverter,T-STATCOM , PWM..*

I. INTRODUCTION

Electrical energy is the backbone of the development of the society. With the industrial growth of a nation, there is always an increased consumption of electrical energy. In developed countries, the demand of electrical energy doubles every ten years. In developing countries, like India, this demand doubles every seven years. Due to this, transmission systems are being pushed closer to their stability and thermal limits while the focus on the quality of power delivered is greater than ever. But transmission systems have many forms of limitations, involving power transfer between areas, also referred as transmission bottlenecks, or within a single area or region that is referred as a regional constraint.

In the transmission system STATCOMs handle only fundamental reactive power and provide voltage support to buses. In addition STATCOMs in transmission system are also used to modulate bus voltages during transient and dynamic disturbances in order to improve transient stability margins and to damp dynamic oscillations.

II.THE BASIC PRINCIPLE OF SYNCHRONOUS LINK BASED STATCOM

In a synchronous link where two ac sources(V_{bus} , V_{vsc}) of same frequency are together by means of a link inductor X_L (Fig 1), active power flows from the leading bus to the lagging one and reactive power flows from the source with higher voltage magnitude to the one with lower voltage magnitude [8]. If the output voltage is equal to the AC system voltage, then the reactive power exchange is zero.

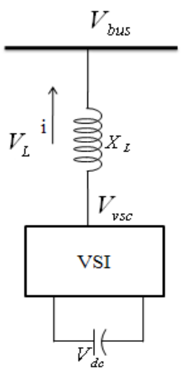

Fig .1 Static Synchronous Compensator.

III.THE THREE-LEVEL NPC VSI

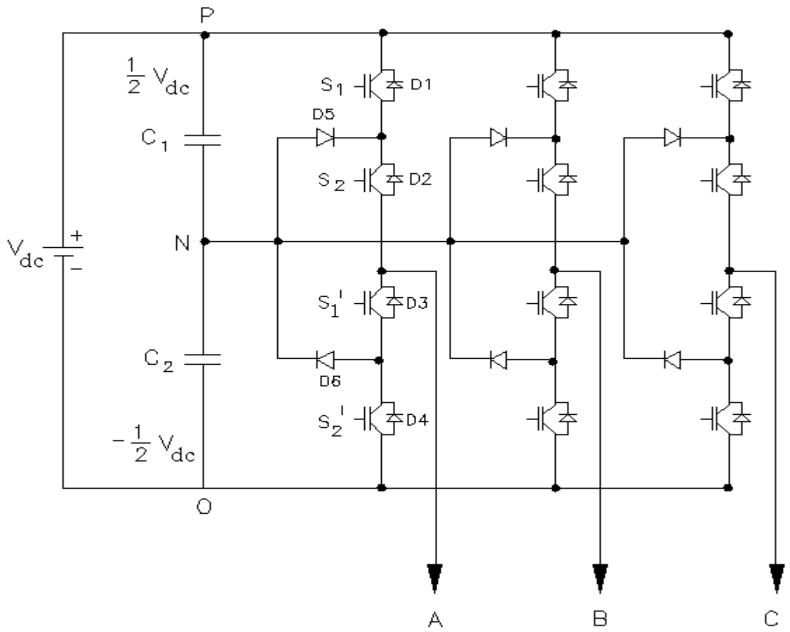

Fig.2 Diode ClampedThree-Level Inverter.

The diode-clamped inverter [5] was also called the neutral-point clamped (NPC) inverter because when it was first used in a three-level inverter the mid-voltage level was defined as the neutral point level.

A three-level diode-clamped inverter is shown in Fig. 2. In this circuit, the dc-bus voltage is split into three levels by two series-connected bulk capacitors, $C_1$and C_2. The middle point of the two capacitors N can be defined as the neutral point. The output voltage V_{AN} has three states: $V_{dc}/2$, 0, and $-V_{dc}/2$. For voltage level $V_{dc}/2$, switches S_1 and S_2 need to be turned on; for $-V_{dc}/2$, switches $S_1^{'}$ and $S_2^{'}$ need to be turned on; and for the 0 level, S_2 and $S_1^{'}$ need to be turned on. Table 3.1 shows the switch status and definition of state for phase A of diode clamped inverter. The two diodes D_5 and D_6 clamp the switch voltage to half the level of the dc-bus voltage. When both S_1 and S_2 turn on, the voltage across A and O is V_{dc}, i.e., $V_{AO} = V_{dc}$. In this case, D_6 balances out the voltage sharing between $S_1^{'}$ and $S_2^{'}$ with $S_1^{'}$ blocking the voltage across C_1 and $S_2^{'}$ blocking the voltage across C_2.

Some of the important features of diode clamped inverter are given below:

Low voltage power semiconductor devices: The m-level diode clamped inverter requires (m+1) active devices (GTO and IGBT's etc) per phase and each active device will see a blocking voltage of (V_{dc} / (m-1)). Duty cycle of switching devices: The duty cycle of the power switches is different. So switches of different current rating have to be used for optimal design.

(a) Rating for clamping diodes: For five and higher level inverters, the voltage blocking capability of the diodes are different. So the diodes will have different voltage ratings. Assuming that the characteristics of diodes are identical, then multiple diodes of same voltage rating have to be used to achieve required voltage-blocking capacity. Hence, for a sufficiently large number of levels, the number of diodes required will become too large and will make the circuit less reliable. Also power circuit layout and packaging becomes difficult.

(b) Capacitor voltage unbalance: The mid point voltage is derived using capacitors and these carry load current. Unequal loading of the capacitors leads to imbalance in the dc bus capacitor voltages and this will cause the dc mid pint voltage to drift. This is not a serious problem for utility applications such as, static VAR generators (SVG), active power filters, etc., where the inverters need to supply only the reactive power.

(c) High voltage surge: During turn off, the devices will experience a high transient over voltage and also snubbers are required to distribute the voltage across clamping diodes in a uniform fashion. The design of snubbers is complicated, as the current through these snubbers is bi-directional.

When the number of output levels is sufficiently high, the inverter system required a huge number of clamping devices due to the series connection of clamping diodes and capacitors. These not only increase the cost of the system, but also controlling the inverter output and capacitor voltage balance becomes more complex when the number of levels is higher than five. Thus diode clamped inverters are usually limited to three or (maximum).

IV.CONTROL STRATEGY.

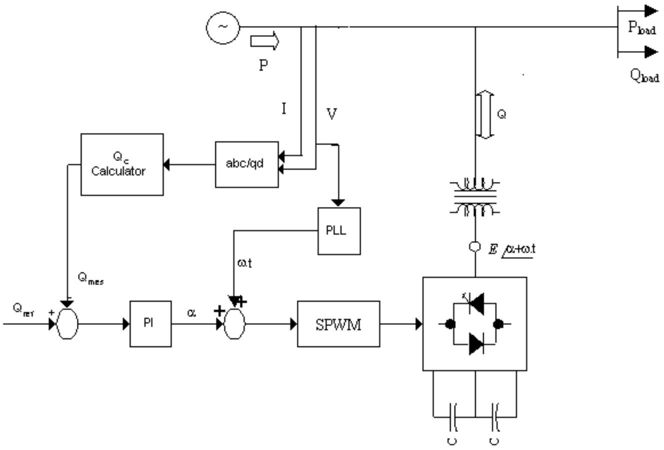

Fig.3 Main circuit and control block diagram of T-STATCOM.

The main objective of this control method is to control the phase angle of the inverter output [9] with respect to the changes in the system reactive power. The quantities obtained from above algorithms are used to calculate the system reactive power and phase angle (ωt). The measured reactive power is then compared with reference value to produce error signal, which is then passed through a PI controller to obtain the required phase angle α. Pulses required for the inverter are generated from SWPM block. By controlling the phase angle α of inverter output voltage, the DC capacitor voltage can be changed. Thus, the amplitude of the inverter output voltage can be controlled. Schematic representation of the control circuit as shown in fig (3).

V.SPWM Technique

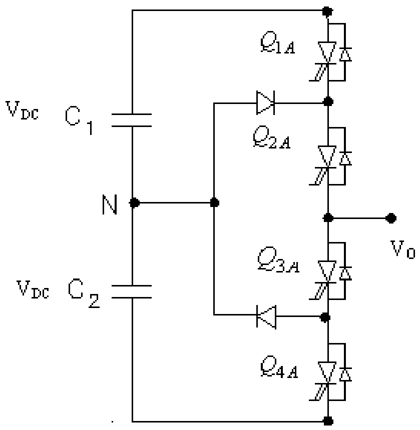

Fig 4. Phase A of three-level inverter.

Table 1: Switching pattern.

Switches on	Switches off	Output voltage
Q_{1A}, Q_{2A}	Q_{3A}, Q_{4A}	$+V_{DC}$
Q_{2A}, Q_{3A}	Q_{1A}, Q_{4A}	0
Q_{3A}, Q_{4A}	Q_{1A}, Q_{2A}	$-V_{DC}$

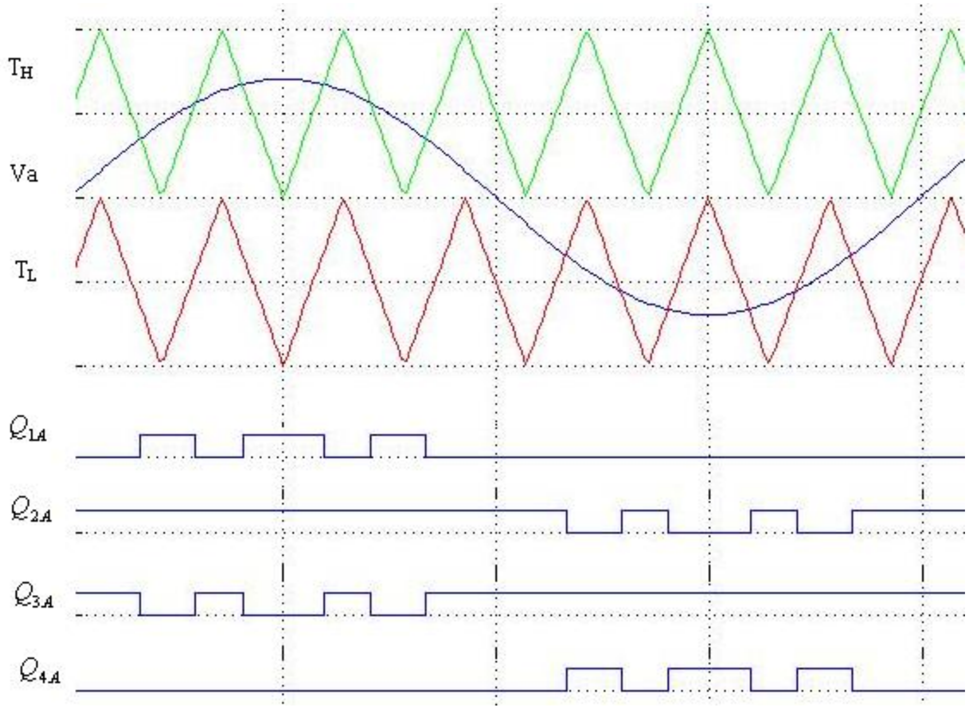

Fig.5 Triangular-Sinusoidal PWM Control for Three-Level NPC Inverter

Here a single reference sine wave (Va) is compared with two carriers waves (T_H, higher carrier wave and T_L, lower carrier wave) to generate pulses. The pulses generated by comparing Va with T_H and Va with T_L. The switch Q_{1A} is on when Va> T_H , Q_{4A} is on when Va> T_L , Q_{3A} is on when Q_{1A} is off and Q_{2A} is on when Q_{4A} off. When the compensator current is controlled indirectly varying the converter output voltage, it is called indirect current controlled [11]. By controlling the phase angle of the inverter output voltage, the dc capacitor voltage V_{dc} can be changed. Thus, the amplitude inverter output can be controlled. Phase angle control method is an example for indirect control.

VI. PHASE ANGLE CONTROL METHOD

The three phase AC signals are transformed into the stationary two phase quantities using Clarke's transformation and then the stationary quantities are transformed to the rotating synchronous reference frame (SRF). If the system voltages are balanced the SRF quantities will be dc quantities and if there is any unbalance in the system the transformed quantities will not be DC. Consider the following three phasors.

$$V_a = 1\angle 0^0 \quad (4.1)$$

$$V_b = 1\angle -120^0 \quad (4.2)$$

$$V_c = 1\angle 120^0 \qquad (4.3)$$

These three phasors are converted to the two phase form using Clarke's transformation the Clarke's transformation matrix is given below

$$\begin{bmatrix} V_\alpha \\ V_\beta \\ V_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \qquad (4.4)$$

Now these two phase stationary quantities are converted to rotating form using the Park's transformation as

$$\begin{bmatrix} V_d \\ V_q \\ V_0 \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} V_\alpha \\ V_\beta \\ V_0 \end{bmatrix} \qquad (4.5)$$

The phase angle θ used in the above transformation is obtained from phase locked loop (PLL) which is described in next section.

VII.CONCLUSION

A new Voltage source inverter based T STATCOM using three-level inverter is proposed for high voltage and high power applications. Using the model, a new control method which control sthe phase angle gives fast response . Voltage source inverter is used to compensate the voltage fluctuations at the receiving end voltage.

STATCOM can provide both capacitive and inductive compensation and is able to control its output current over the rated maximum capacitive or inductive range independently of the ac system voltage. voltage dips mainly have their origin in the higher voltagr levels, are removed by usingthis technique. If the economical losses due to voltage dips are significant, mitigation actions can be profitable for the customer

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