Modeling and Simulation of Fault Detection and Mitigation in Multilevel Converter STATCOM

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***Abstract*— In many countries all over the world last few decades are expanding and reconstructing power sector, but the most basic requirement of electrical power system is ability to consumer load demand and its very important. Now many transmission facilities confront one or more limiting network parameter and inability to direct power flow at will. In electrical AC power system given the insignificant electrical storage, the electrical generation and load must be balancing all the times. If the voltage is propped up with reactive power support, then load will go up and frequency will be dropping and system get collapse.**

STATCOM is FACT controlled device, it has been well accepted as an electrical power system for improving voltage regulation and improving reactive power compensation. In this paper deals with the development of simple and efficient method of fault detection and mitigation in multilevel converter STATCOM. The STATCOM employs a multilevel converter in order to reduce harmonics along the with DC source. This system will detect fault in multilevel converter and bypass the faulty module with healthy module to maintain efficiency and operation of STATCOM

Keywords—Fault Detection, Mitigation, Multilevel converter, Static Synchronous compensator.

I. INTRODUCTION

The Static Synchronous compensator has been well accepted as an electrical power system controller for improving voltage regulation and reactive power compensation. There are following reason to consider multilevel converter topology using for the STATCOM.

1) lower harmonic injection into the power system;

(2) decreased stress on the electronic components due to decreased voltages; and

(3) lower switching losses.

An eleven-level cascaded multilevel STATCOM is used in this paper. This multilevel converter uses many numbers of switches connected in series to synthesize staircase waveform and every full bridge can have three output voltages with different switching combinations, the number of output voltage levels is $2n + 1$. Where n is number of full bridges in every phase. The converter cells are identical. A large number of power switching devices has been used in this paper. Application is that the higher-level converters are used for high rating output power. This method proposed require that each phase be measured output DC- link voltage.

If in this system the fault is detect, the module get fault occurred is then isolate, and removed from the system. The multilevel converter system is work slightly decreased when fault is occurred, but still acceptable, performance until the module is replaced.

A. Static Synchronous compensator (STATCOM)

STATCOM is a switching converter type device. It is FACT device. VAR generator which is composed of two types converter. First is voltage source converter (VSC) and second one is Current source converter (CSC). This converter generates reactive power without using any reactive power storage like inductor or capacitor. It generating or absorbing reactive power proportional to the difference voltage between in the AC bus and the converter output terminal. STATCOMs are connected in shunt with the line via a coupling transformer

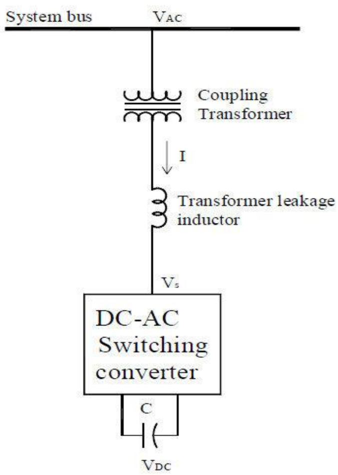

Fig 1. STATCOM connected to system-bus

- The possibility of generating a controllable reactive power directly, without the use of AC reactors or capacitor, by using switching power converters device.
- This device is functionally similar to an ideal synchronously rotating generator, and because of its similarities it is also called Static Synchronous Generators (SSGs). The purpose of providing reactive power compensation these SSGs are operated without an energy source and appropriately controlling similar to shunt connected condensers and they are hence called Static Synchronous condensers (STATCON) or Static Synchronous Compensators (STATCOM).
- In this paper using cascaded H- Bridge multilevel converter. These switches connected in series to synthesize staircase waveform. In eleven-level

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STATCOM, each leg has five H-bridges. each full bridge generates three different level voltages (V, 0, −V) under different switching states, the number of output voltage levels will be eleven. It has several advantages of cascade multilevel converter.

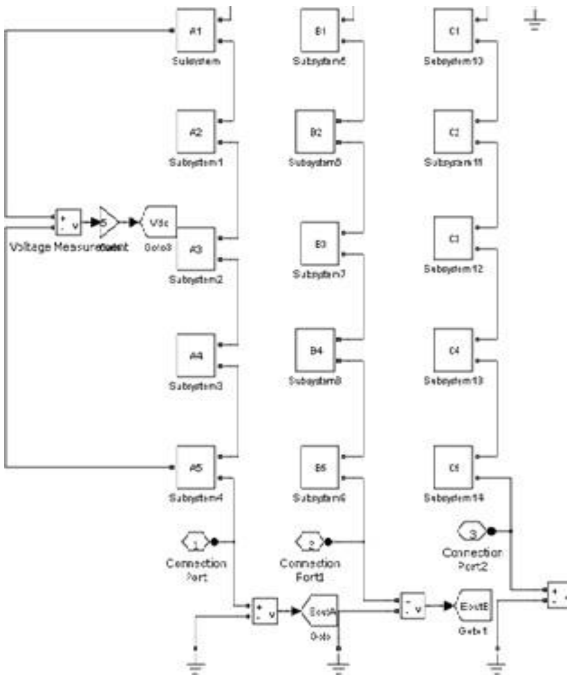

Fig 2. Eleven level Cascaded Multilevel STATCOM

II. INVERTER

Inverters are power electronic circuits which are capable of converting DC to AC voltages. Inverters do not produce any power; they use power provided by DC source. The output waveforms are generally sine wave, square wave or quasi square wave. Different types of inverters are given below

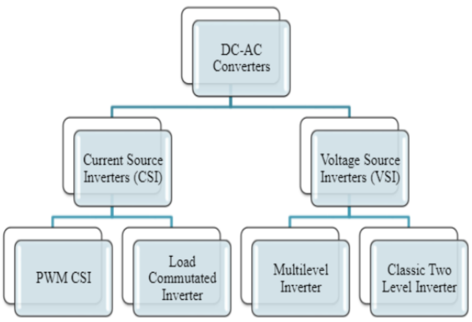

Fig 3. Multilevel Inverter

Inverters are two types current source inverter and voltage source inverter. The multilevel converters are the converters that are capable of higher power levels from various DC sources with lower voltage using power semiconductor devices. The multilevel converters are capable of interfacing renewable energy sources as DC sources on the DC side of the converter. The output result of multilevel converter is staircase waveform or quasi waveform.

B. Multilevel Converter STATCOM

(1) It is better suited for high-voltage, high-power applications than the conventional converters since the currents and voltages across the individual switching devices are smaller.

(2) It generates a multistep staircase voltage waveform it is a more sinusoidal output voltage by increasing the number of levels.

(3) It has better dc voltage balancing, since each bridge has its own dc source.

switching topology is chosen such that the capacitors with the lowest voltages are charged or conversely, the capacitors with the highest voltages are discharged. One common pulse width modulation (PWM) use is the phase shift PWM (PSPWM) switching concept. The PSPWM strategy causes cancellation of all carrier and associated sideband harmonics up to the $(N - 1)$ carrier group for an N-level converter.

Where N is the number of cells in each phase. the carrier frequency has been decreased for better clarity in fig no. 4.

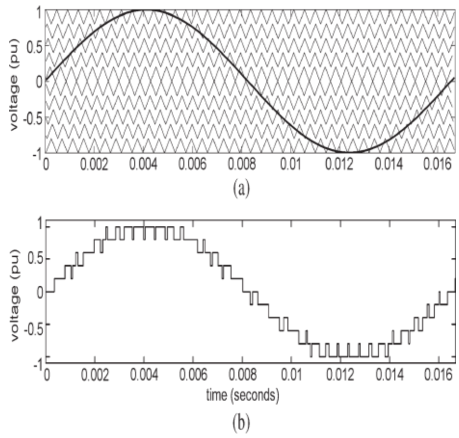

Fig. 4. (a) Carrier and reference waveform for PSPWM. (b) Output waveform.

C. Fault Analysis for Multilevel STATCOM

Fig..5. can experience several types of faults. Each switch in the cell can fail in an open or closed state. The closed state is the most severe failure since it may lead to shoot through and short circuit the entire cell. An open circuit can be avoided by using a proper gate circuit to control the gate current of the switch during the failure. If a short circuit failure occurs, the capacitors will rapidly discharge through the conducting switch pair if no protective action is taken. Hence, the counterpart switch to the failed switch must be quickly turned off to avoid system collapse due to a sharp current surge.

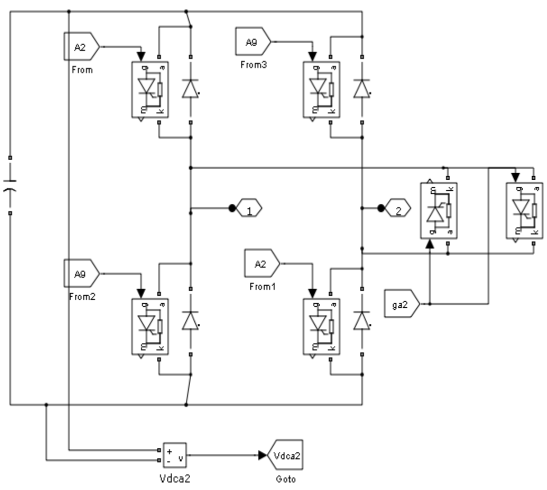

Fig. 5. Cell with fault switch.

The input to the detection algorithm is $\hat{E}_{out}$ for each phase, where $\hat{E}_{out}$ is the STATCOM filtered RMS output voltage. If the STATCOM RMS output voltage drops below a preset threshold value (E´), then, a fault is known to have occurred. Once a fault has been detected to have occurred, then the next step is to identify the faulty cell. By utilizing the switching signals in each converter cell, (i.e., S_1 and S_2), it is possible to calculate all of the possible voltages that can be produced as show in table 1

Table -1: Switching state and output voltage of a H-bridge

S_1	S_2	V^+_{ax}	V^-_{ax}	V_{ax}
0	0	0	0	0
0	1	0	V_{dc}	$-V_{dc}$
1	0	V_{dc}	0	V_{dc}
1	1	V_{dc}	V_{dc}	0

Thus, the output voltage of a cell is

$$V_{ax} = V_{ax}^{+} + (-V_{ax}^{-}) \quad \text{--------------------(1)}$$

at any given instant as illustrated in Table 1

And since the cells of the STATCOM are serially connected, the total output voltage per phase is

$$V_{yo} = \sum_{X=1}^{n} v_{yx} \qquad y\square[a,b,c] \qquad (2)$$

Where n is the number of blocks.

By utilizing the switching signals in each converter cell, (i.e., $Sj1$ and $Sj2$, j is the cell number), it is possible to calculate all of the possible voltages that can be produced at any given instant. When there is a fault in the multilevel converter, the capacitor at the faulty block will rapidly discharge. This discharge results in a phase shift in the output ac voltage as well as a change in amplitude of voltage. The set of all possible phase fault voltages for an eleven-level converter is given by

$$f_1 = V_{dco} (S_{21} - S_{22} + S_{31} - S_{32} + S_{41} - S_{42} + S_{51} - S_{52}) \quad \text{(Cell 1 faulted)}$$
$$f_2 = V_{dco} (S_{11} - S_{12} + S_{31} - S_{32} + S_{41} - S_{42} + S_{51} - S_{52}) \quad \text{(Cell 2 faulted)}$$
-
-
$$f_5 = V_{dco} (S_{11} - S_{12} + S_{21} - S_{22} + S_{31} - S_{32} + S_{41} - S_{42}) \quad \text{(Cell 5 faulted)}$$

Or more succinctly as

$$F_i = V_{dco} \sum^{n} (S_{j1} - S_{j2}),\ I = 1, ...,n \text{ --------(3)}$$

Where V_{dc0} is the ideal voltage across a single cell block. If there is a faulted cell, only one f_i will be near the actual STATCOM output phase voltage E_{out}; all of the others will be too high. Therefore, to determine the location of the fault cell, each f_i is compared against E_{out} to yield

$$X_i = E_{out} - f_i\ , \qquad i = 1, \ldots, n \qquad \text{-------------------- (4)}$$

The smallest xi indicates the location of the faulted block because this indicates the f_i which most closely predicts the actual E_{out}.

The choice of threshold voltage E' depends on the number of cells in the converter. The ideal output voltage is

$$\hat{E}_{out,\,0} = \frac{n\ Vdco}{\sqrt{2}} \qquad \text{----------------------------- (5)}$$

During a fault, E_{out} will decrease by V_{dc0} yielding

$$\hat{E}_{out,\ fault} = \frac{(n-1)\ V_{dc0}}{\sqrt{2}} = \frac{n-1}{n}\ \hat{E}_{out},0. \text{ ------------- (6)}$$

Therefore, the threshold voltage E' should be chosen such that $(n - 1/n)\ E_{out,\ 0} \leq E' \leq E_{out,\ 0}$. In an eleven- level converter, $n = 5$ and the faulted RMS voltage will decrease by roughly 20%. Therefore, a good choice for E' is 85% of the rated output STATCOM voltage will decrease by roughly 20%. Therefore, a good choice for E' is 85% of the rated output STATCOM voltage.

III. EXAMPLE AND RESULT

The single line diagram of the electrical distribution system feeding an arc furnace is shown in Fig. 6. The STATCOM has been shown to be an efficient controller to mitigate arc furnace flicker.

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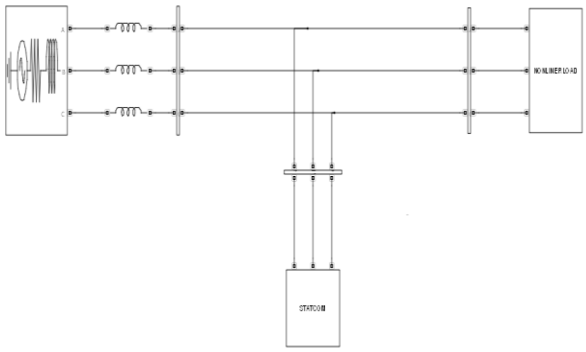

Fig.6. Single line dig of arc furrnace

The electrical arc furnace load is not sinusoidal, unbalanced, and randomly fluctuating. Electric arc furnaces are typically used to melt steel and will produce current harmonics and that harmonics are random. In this study a STATCOM composed of an eleven-level multilevel converter is connected to an 11kV line for the purpose of lire compensation. The proposed model is used to study the effect of occurrence of continued and different types of loads on the system in presence and absence of STATCOM. The proposed model is also used for studying the effect of occurrence of various types of faults in VSC of STATCOM and operation of detection and mitigation circuit during occurrence of fault.

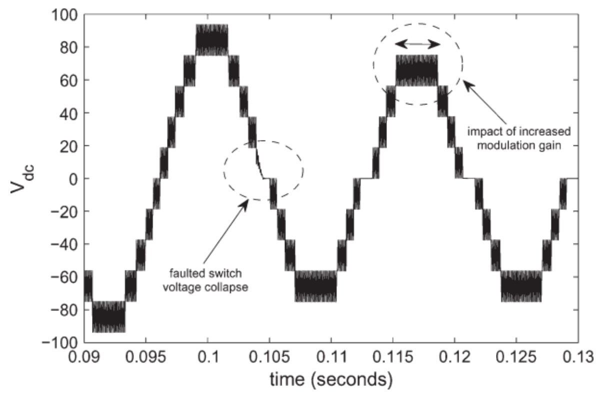

Fig. 7. Converter output with faulted cell

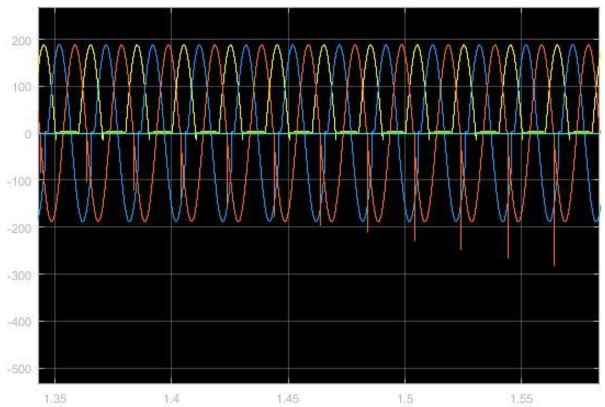

Fig.8. Output of multilevel inverter

IV. CONCLUSION

In this project a fault detection and mitigation technique for static synchronous compensator (STATCOM) has been developed in MATLAB SIMULINK. A STATCOM which consists of an eleven-level cascaded H-Bridge multilevel inverter is also developed using SIMULINK MATLAB. A controlling circuit was also developed to control the operation of STATCOM under various system conditions. The performance of system is investigated under various conditions and following points can be concluded from it

1. A static synchronous compensator based on cascaded H-Bridge multilevel the inverter was developed in MATLAB SIMULINK.
2. The simulations carried out on STATCOM for various system conditions like voltage sag or swell with and without STACOM, and from these simulations it can be concluded that when voltage sag occurs the system.
3.The fault detection and mitigation circuit of multilevel inverters was also examined for various faults like single and double cell short circuit and single and double cell open circuits. In all the cases the faults were detected below 0.01s, i.e., within the first half cycle of output waveform. 5. The multilevel inverter used does not need any transformer as it can be directly connected to high voltage sources. This reduces the size and cost of the inverter.

V. FUTURE SCOPE

In consideration with the literature reviewed and present scope of thesis, following areas can be worked and applied to existing model:

1. The efficiency of STATCOM can be improved by designing the VSC of STATCOM for a higher number of output levels.
2. To make system more reliable and cost-effective number of me itching devices needed must be reduced.

3. Different types of artificial intelligence-based techniques can be used to identify fault type and reconfigure circuit more quickly.

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