Fault Detection in Multilevel Converter STATCOM Using Voltage Magnitude Method

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Abstract— Static synchronous compensators (STATCOMs) with multilevel converters are being used extensively now-a-days in power system for line compensation. The main advantages of using STATCOMs with multilevel converter are (i) lower harmonic generation, (ii) production of higher voltages due to reduced stress on power electronic devices and (iii) reduced switching losses. But one major drawback of multilevel converters is that due to higher number of components the reliability of device decreases because with increase in number of devices the probability of occurrence of fault also increases. If fault occurs in any one switch then its fast detection is extremely necessary for maintaining system stability which is largely affected by line compensation by STATCOM. The aim of this paper is to detect occurrence of fault in multilevel converter STATCOM and identify the faulty switch. The proposed idea is exemplified by an eleven-level cascaded H - Bridge multilevel converter STATCOM.

Key words: Fault detection, MATLAB, multilevel converter, reliability, static synchronous compensator (STATCOM)

I. INTRODUCTION

THIS In past few years, electricity has become basic necessity all over the world and as a result of that the power industry is expanding very rapidly. Hence, power generated has increased with increase in power demand. But with increase in production of power the need of a reliable and stable power system has occurred. One of the most pronounced issues in power system is maintaining power system stability. For this purpose power controllers are used. Static synchronous compensator (STATCOM) is one such power controller which is widely used for obtaining flat voltage profile and for reactive power compensation of line. The STATCOMs with multilevel converters are currently more prominent in power system due to following advantages:

(i) lower harmonic generation, (ii) production of higher voltages due to reduced stress on power electronic devices and (iii) reduced switching losses [1]. Various topologies of multilevel converters are used along with PWM technique for their control. Some topologies of multilevel converter are also called classical topologies, these include- cascaded H-bridge, diode clamped and flying capacitor. Among these cascaded H-bridge is most suitable for designing a STATCOM from the point of view of fault detection and mitigation due to its modular structure. Fig. 1 [1] shows an eleven level cascaded H- bridge converter STATCOM. The circuit consists of five full wave bridge converter each of which are connected to a DC source. The number of bridges (n) required can be calculated from equation: n=2s+1. Here, s is number of DC sources used.

Fig. 1: Eleven level cascaded STATCOM

As the number of output levels increase the output of STATCOM becomes more efficient as the THD in its output reduce. But with the increase in the output voltage levels the number of components also increases and as a result the reliability of device reduces.

Hence, in order to maintain reliable operation of STATCOM fast fault detection has to be done. If fault is not detected in time then the devices can get severely damaged. If a leg gets short circuited and the circuit is not opened within time then there is a possibility that the module can explode [2]. Therefore, it is extremely important to identify fault and its location quickly.

For this various techniques have been proposed over past decade. A neutral point clamped three level PWM inverter was proposed which had inherent voltage vector redundancy which synthesized output AC voltage. The scheme was appropriate for high power, safety-critical applications but it could be used for single device short circuit fault conditions only [3]. In another method a fault detection technique was proposed which detected faults based on increase in harmonics level in the faulty module [2]. In an IGBT based multicell inverter if commutation failure occurs the intrinsic fault tolerant capability of converter prevents the failure of device and avoids risk of explosion. But this method was used for flying capacitor and was not extended to cascaded H-bridge topology [4]. Another technique based on sensing IGBT current using sensors was proposed to detect fault in the module [5]. In [6], an AI based technique was used to detect fault and neural network classification was applied for fault diagnosis. In [7], a modified neutral point clamped topology was proposed. In this modified converter a fourth leg was added, based on flying capacitor converter structure. This made the converter fault tolerant and low frequency voltage oscillations were eliminated. In asymmetric multilevel converters, the inability to interchange the H-bridge under faulty condition is a major problem. In [8], a reconfiguration technique based on bidirectional electronic valves was proposed for three phase cascaded H-bridge inverters. [9] presented optimum angles and modulation indexes that can be used to obtain maximum balanced load voltage. A fault detection technique is proposed in [1], which calculates faults based on output voltage magnitude of each cell. The technique does not employ any sensor but only uses a bypass switch to bypass faulty module and maintain the operation of STATCOM uninterrupted. Another fault detection and reconfiguration technique was proposed in [10]. It detects fault in cascaded H-bridge converters and on occurrence of fault uses a redundant H-bridge to maintain normal operation of inverter.

In this paper a method for detecting open circuit faults in a eleven level cascaded H-bridge converter STATCOM is proposed. In this method the output voltage of each cell is measured and if fault occurs then it is detected and the faulty module can be removed by applying various devices like circuit breakers, isolators or power electronic switch. The main advantage of this technique is that no extra sensors are needed as the output voltage is measured for controlling purposes. Also, due to the modular structure of cascaded H-bridge converters, the reconfiguration of circuit is easier and hence the operation of STATCOM remains uninterrupted.

II. MULTILEVEL STATCOM

The static synchronous compensator (STATCOM) is a switching converter type VAR generator which operates as voltage or current source to produce reactive power without using any reactive power storage component, like, capacitors or inductors. It is usually composed of a voltage source converter which is connected to a DC source. The voltage source converter can be a two level converter or multilevel converter. The multilevel converters are more preferred over two level converters due to following reasons [11]:

1) It is better for high power and high voltage applications as voltage and current across each module is small.
2) The efficiency of multilevel converters is high because switching can be done at minimum frequency. Also with increase in number of levels THD in output reduces.
3) The common mode voltage or EMI problems are not present.
4) It has better voltage balancing as each module has its own DC source.

The multilevel inverters produce a staircase wave whose steps increases with the increase in the number of levels of inverter. As the number of steps in output increases, the harmonic distortion in output reduces. In this type of inverters higher voltage levels can be generated easily because voltage produced at each level is added to get final output voltage. Since, each level produces low voltage the stress on switching devices of each level is small. In order to further reduce THD without any filtering devices, switching is done at fundamental frequency [11]. The output waveform of an eleven level cascaded inverter is shown in Fig 2 [11].

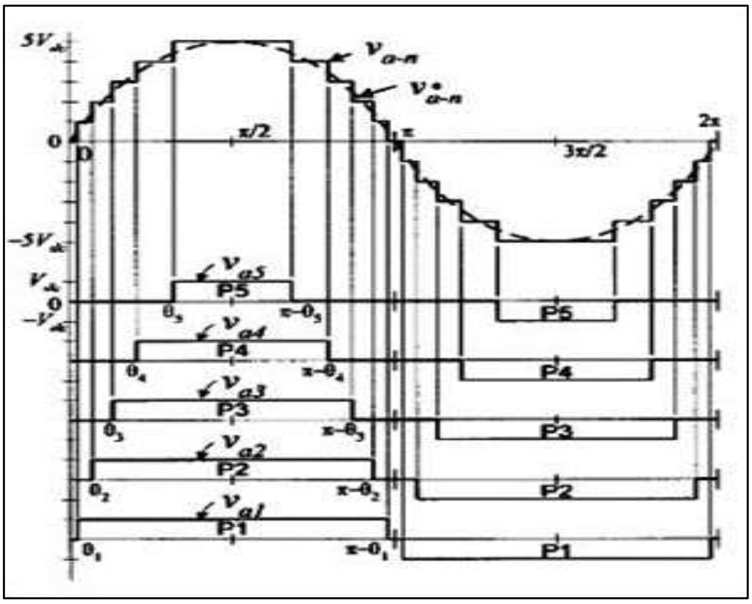

Fig. 2: Output waveform of an eleven level cascaded inverter

This quasi-square wave is generated by phase shifting the switching timings of positive and negative leg. In order to equalize current stress each switching device conducts for 180o. The conducting angles are chosen in such a way so as to eliminate lower order harmonics [11]. The carrier frequency for PWM is kept in range of 1-10 kHz. For making circuit modular all the switching devices must be identical.

III. FAULT DETECTION METHODOLOGY

Some techniques are used for fault detection in multilevel converter STATCOM:
1) Voltage Frequency Analysis [12]: In this method SPWM is used to produce output voltage of the converter. Using SPWM the voltage with different phase angle will be produced whose sum under normal condition is zero. If this sum is not zero then it indicates occurrence of fault. This method is able to differentiate between transients and real faults. The detection is accurate and fast. But the main drawback is that it involves complex frequency analysis.
2) AI based Fault Detection [6]: This method is based on neural network classification of fault. The fault diagnostic scheme has three stages: 1) feature extraction, 2) Neural Network classification and fault diagnosis. A binary corresponding to the system condition is generated. The technique detects faults efficiently but it is very slow. Also training has to be provided to neural network.

IV. METHODOLOGY USED

The proposed fault detection methodology is based on detection of faulty cell by measuring output voltage and finding its RMS value. The RMS value of output voltage during open circuit fault is higher than the RMS voltage during normal conditions. This variation is sensed to locate fault and generate a signal indicating occurrence of open circuit fault. This signal can be used to turn on a bypass switch to reconfigure STATCOM and mitigate the fault.

Fig 3 shows the proposed fault detection system. In this the RMS value of output voltage is sensed. This value, if increases from a threshold value (here 85V) indicates occurrence of fault. A delay is used in the circuit to avoid transients. The output gives a pulse indicating fault.

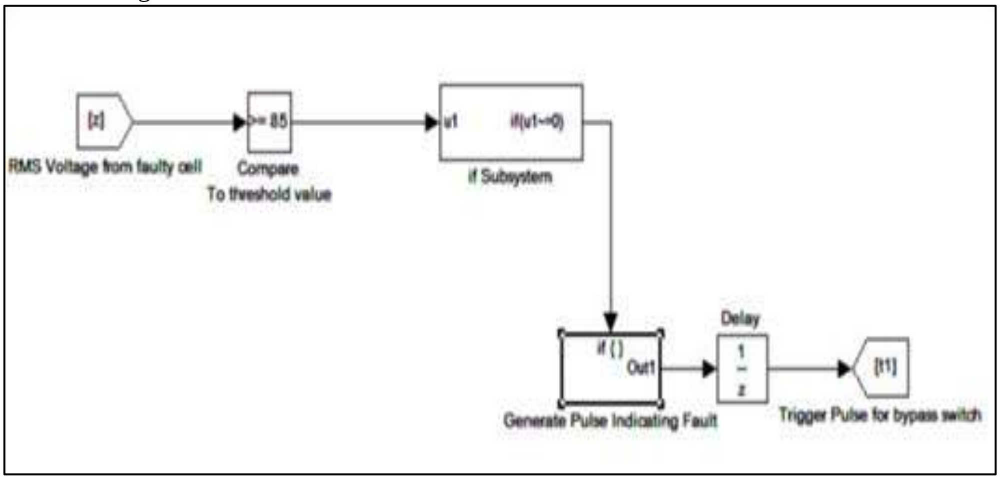

Fig. 3: Fault detection circuit

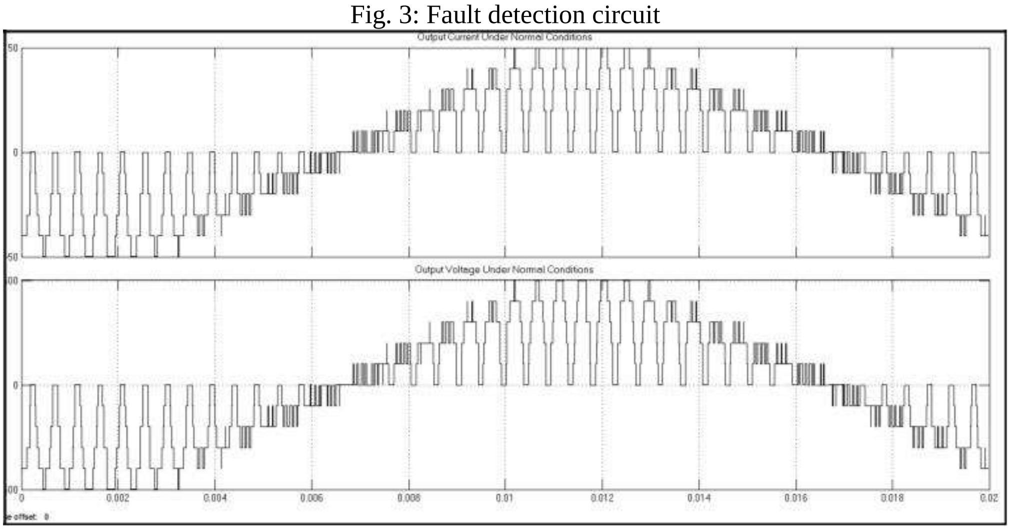

Fig. 4: Output current and voltage under normal conditions

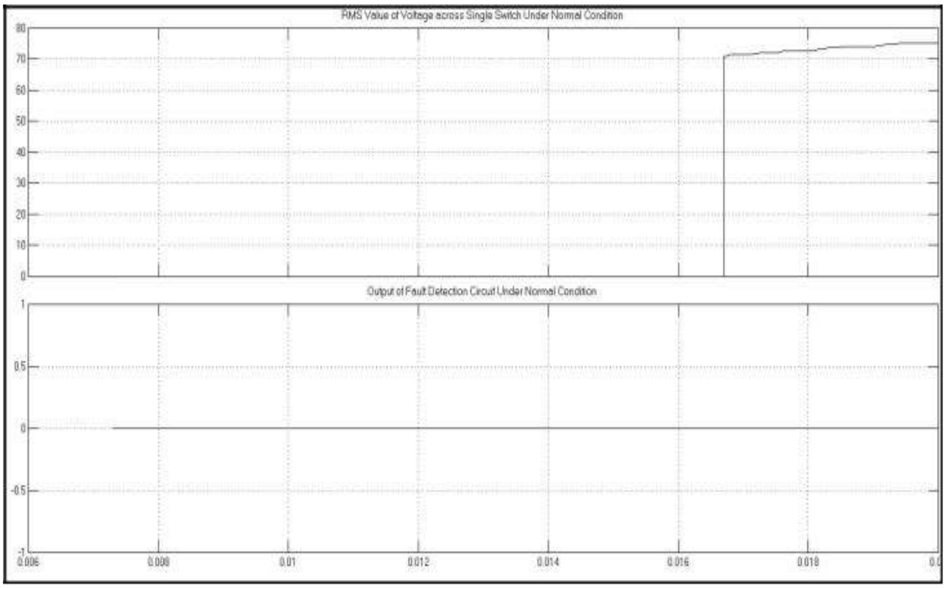

Fig. 5: RMS voltage across a switch and output of fault detector circuit under normal conditions

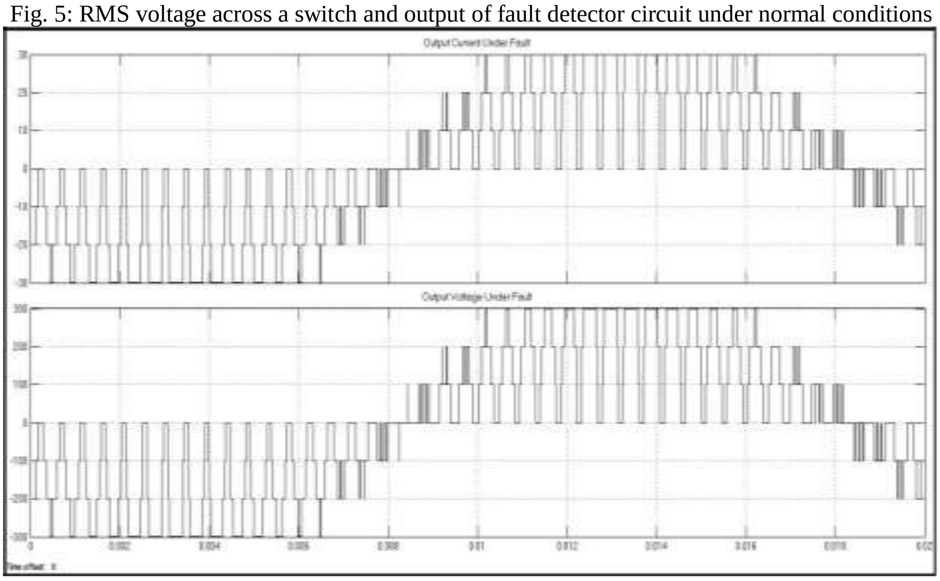

Fig. 6: Output current and voltage under fault voltage

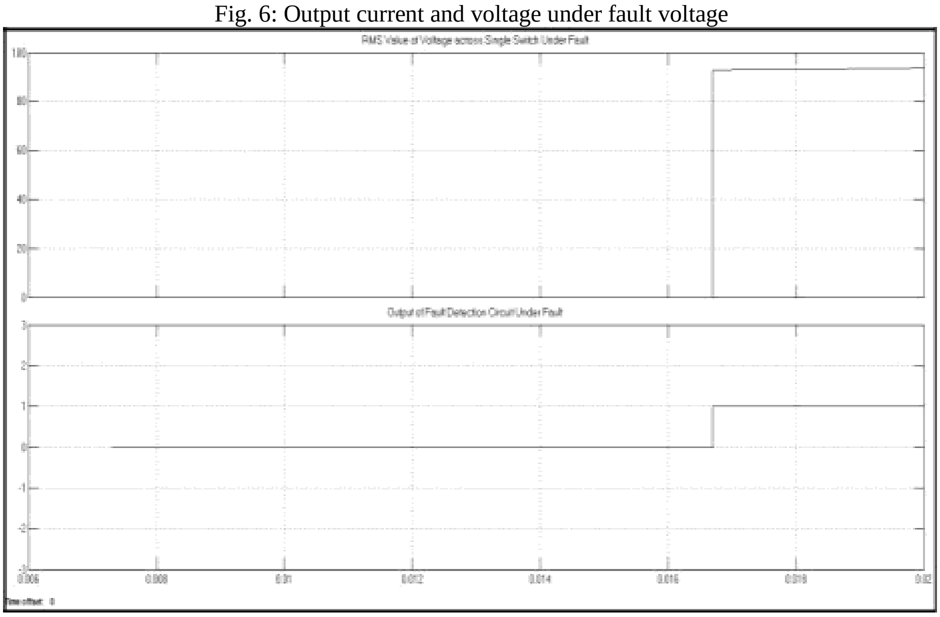

Fig. 7: RMS voltage across a switch and output of fault detector circuit under fault

V. CONCLUSION

In this paper a fault detection strategy for a multilevel cascaded inverter was proposed. In the proposed strategy no extra sensors were needed rather the output voltage is used for detection of fault. This output voltage also measured for controlling circuit. Therefore, no additional devices are needed. The methodology was verified using an eleven-level cascade H-bridge converter STATCOM. electronic file, IJSTE TEMPLATE, from the IJSTE Web site. so you can use it to prepare your manuscript.

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